RESEARCH ARTICLE

# Soil Type and Building Construction in Khana Local Government Area of Rivers State: Implications for Environmental Economics and Environmental Sustainability

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**Abstract**
This study examines the influence of soil types on building construction in Khana Local Government Area (LGA) of Rivers State, Nigeria, and evaluates the implications for environmental economics and environmental sustainability. A mixed-methods survey design was adopted, involving laboratory analysis of soil samples focusing on grain size distribution, plasticity index, and shear strength and a questionnaire administered to 400 construction professionals, of which 320 responses were returned. Soil analysis revealed predominantly clay, sandy, and loamy soils, each posing distinct challenges for structural stability, foundation performance, and environmental impacts such as erosion, settlement, and biodiversity loss. Questionnaire findings indicate that soil-related construction failures increase environmental costs, reduce structural durability, and elevate long-term economic burdens. Sustainable practices such as soil-appropriate foundation designs, erosion control measures, rainwater harvesting, and the use of eco-friendly building materials were identified as effective mitigation strategies with economic and ecological benefits, including cost savings, reduced degradation, and improved public health. The study concludes that integrating soil science into construction planning is critical for sustainable development in Khana LGA and recommends strengthened building codes, enhanced professional training, sustainable material adoption, and GIS-based geotechnical mapping to improve construction outcomes and minimize environmental risks.

**Keywords:** Soil type; Building construction; Environmental economics; Environmental sustainability; Khana

## Introduction

Soil type is a fundamental, yet often underappreciated, determinant of building performance and long-term structural stability. Variations in soil properties including grain-size distribution, plasticity, shear strength, and compaction behaviour directly affect foundation design, load-bearing capacity, and settlement behaviour of constructed facilities (Tobby & Ngene, 2025). Recent geotechnical investigations in Nigeria have reinforced this reality: for example, a study in the Niger Delta region demonstrated significant variability in subsurface soils, ranging from clay sands to gravelly sands, thereby affecting dynamic soil behaviour and foundation suitable for construction (Kennedy, 2024). Another investigation in a North-Central Nigerian town revealed that sub-soils with high plasticity indices and inconsistent Atterberg limits are frequently classified as "fair to poor" highlighting the risks of unsuited soils for sustainable infrastructure development (Emmanuel & Joseph, 2023). Without careful geotechnical assessment and soil-type appropriate construction practices, buildings in such areas may suffer from foundation instability, excessive settlement, erosion, or collapse leading to economic losses, repeated repairs, and environmental degradation.

In the context of Khana Local Government Area (LGA) in Rivers State, Nigeria part of the Niger Delta region the soil conditions are especially critical given the region's alluvial deposits, high moisture content, and flood-prone environment. Yet, there is a dearth of localized geotechnical studies linking soil types to building outcomes, environmental consequences, and economic implications in Khana LGA. This research gap undermines efforts to develop sustainable construction strategies tailored to local soil realities. Therefore, this study investigates how the dominant soil types in Khana LGA influence foundation design and building stability, assesses the environmental and economic consequences of soil-related construction practices, and explores sustainable building practices suitable for soil contexts in the area. The study is guided by the following research questions:

1. How do the dominant soil types in Khana LGA influence foundation design, structural performance, and environmental sustainability?
2. What are the economic costs and benefits associated with construction on different soil types in Khana LGA?
3. Which sustainable building practices can mitigate soil-related environmental degradation and minimize long-term economic losses in Khana LGA?

This research question seeks to identify sustainable building practices that can be adopted in the study area to reduce the environmental and economic impacts of building construction on different soil types, and to explore the potential benefits and challenges of these practices.

## Theoretical Literature

### *Terzaghi's Bearing Capacity Theory*

Karl Terzaghi's Bearing Capacity Theory (1943) is a fundamental concept in geotechnical engineering that explains the bearing capacity of soils. According to Terzaghi, the bearing capacity of soil is influenced by factors such as soil type, density, and moisture content (Terzaghi, 1943). This theory has been widely applied in foundation design and construction, and its relevance to this study lies in its ability to predict the behaviour of soils under different loading conditions. As noted by Das (2016), Terzaghi's theory provides a useful framework for understanding the bearing capacity of soils, which is critical in building construction. In the context of Nigeria, where soil conditions can be challenging, Terzaghi's theory can be used to design foundations that are tailored to specific soil types, reducing the risk of foundation failure (Amadi & Olabode, 2018).

### *Unified Soil Classification System (USCS)*

The Unified Soil Classification System (USCS) is a widely used framework for classifying soils based on their physical properties. Developed by Arthur Casagrande in the 1940s, the USCS categorizes soils into different groups based on their grain size distribution, plasticity, and other characteristics (Casagrande, 1948). This system has been widely adopted in geotechnical engineering and is relevant to this study because it provides a standardized framework for understanding soil properties. According to Budhu (2011), the USCS is a useful tool for predicting soil behaviour and designing foundations. In Nigeria, where soil conditions can vary significantly, the USCS can be used to classify soils and predict their behaviour under different loading conditions, ultimately informing foundation design and construction (Osinubi & Eberemu, 2017).

## Empirical Literature Review

Soil properties notably grain-size distribution, Atterberg limits (plasticity index), shear strength, and permeability fundamentally determine how soils respond to loads and environmental changes, and thereby govern appropriate foundation types, settlement behaviour, and risk of erosion or liquefaction (Terzaghi, 1943; Casagrande, 1948; Das, 2016). Clayey soils with high plasticity and low shear strength tend to exhibit large shrink–swell behaviour and low bearing capacity, increasing the need for deep or reinforced foundations and ground improvement, whereas sandy and silty soils may present problems of erosion, piping and inadequate compaction if not properly engineered (Osinubi & Eberemu, 2017; Budhu, 2011). These geotechnical outcomes translate directly into environmental-economic consequences: soil-related structural failure increases direct repair and reconstruction costs, reduces asset lifespans, and triggers secondary environmental costs such as sedimentation of waterways, loss of arable topsoil, and biodiversity impacts all of which impose measurable economic burdens on households and local governments (Nwankwo, 2022; Adeyemi, 2022). From a sustainability perspective, proactive soil-sensitive design (appropriate foundation selection, erosion control, and use of low-impact materials) reduces life-cycle costs and environmental externalities, creating positive economic returns through avoided damage, higher property values, and reduced ecosystem degradation (Ezenwa & Amadi, 2022).

Empirical studies in Nigeria and similar tropical settings reinforce these links between soil type, construction performance, and environmental-economic outcomes. Multiple recent geotechnical investigations in the Niger Delta and adjacent regions document problematic cohesive (clayey) layers, high moisture content, and variable stratigraphy that increase settlement risk and demand specialized foundation solutions (Eze, 2024; Esonanjor, 2022). Site investigations across Rivers and Bayelsa states demonstrate recurrent findings: low bearing capacities in many locations, high plasticity indices in near-surface soils, and the need for localized ground improvement and drainage strategies to prevent erosion and structural distress. These technical findings align with applied studies showing that inadequate storm water management and poor erosion control on construction sites exacerbate both environmental degradation and long-term maintenance costs (climate-resilient infrastructure review, 2024; site investigation studies, 2023). Earlier reviews and empirical works (Oloyede, 2021; Abubakar, 2022; Ekeocha, 2023; Ogundipe, 2023; Uzoegbo, 2023; Salawu, 2024) provide a solid baseline but reveal a clear gap: Khana LGA lacks localized, integrated evidence that connects soil classification, GIS-mapped soil distribution, building performance records, and quantified environmental-economic impacts a gap this study addresses by combining laboratory soil testing, professional surveys, and GIS analysis to inform sustainable, cost-effective construction strategies for the area (Esonanjor, 2022).

The empirical literature reviewed highlights the significance of understanding soil properties for building construction in Nigeria. However, there is a gap in research on the specific soil types and properties in Khana LGA of Rivers State, and its implications for environmental economics and environmental sustainability in the area. Most studies have focused on other regions of Nigeria, making it necessary for a study that investigates the relationship between soil type and building construction in Khana LGA of Rivers State, Nigeria, with the aim of determining the implications for environmental economics and environmental sustainability.

## Methodology

This study adopted a mixed-method research design combining geotechnical laboratory analysis, GIS-based spatial mapping, and a structured questionnaire survey to assess how soil types influence building construction and sustainability in Khana LGA. Soil sampling followed a stratified spatial approach, with representative samples collected across major communities to capture variations in geology, moisture conditions, and land-use patterns. Laboratory tests included grain-size distribution, Atterberg limits (plasticity index), natural moisture content, bulk density, shear strength, and compaction characteristics, selected because they directly determine load-bearing capacity, settlement potential, and foundation suitability in tropical soils. GIS mapping was employed to integrate laboratory results with spatial coordinates, allowing visualization of soil-type distribution, foundation risk zones, and environmental vulnerability patterns across the LGA. For the human-subject component, the questionnaire survey targeted builders, engineers, homeowners, and community members, with the sample size determined using the Taro Yamane formula, which provides a statistically valid sample by adjusting population size to a margin of error thus ensuring representativeness. A questionnaire survey of 400 was also administered to building professionals, including architects, engineers, and builders of which 320 was properly filled and returned to gather information on their experiences and perceptions of soil-related issues in building construction in the study area. The study also involved observational surveys of existing buildings in the study area to identify any signs of soil-related distress or failure. A multistage sampling technique was used to select respondents from different wards, and data were analysed using descriptive statistics and regression analysis for quantitative responses, while thematic coding was applied to qualitative items. This integrated methodological approach strengthened the reliability of findings by linking measurable soil properties with spatial patterns and community-level construction experiences.

**Data presentation**

The data was presented based on the research objectives. Primary data were reviewed and questionnaire was distributed based on specific demographic characteristics such as age, gender, marital status and all other demographic variables are calculated using percentages.

**Table 1:** Sociodemographic characteristics of Respondents

| Sociodemographic Characteristics | Frequency | Percent |
|---|---|---|
| Sex | | |
| Male | 277 | 86.6 |
| Female | 43 | 13.4 |
| Total | 320 | 100 |
| Status | | |
| Single | 92 | 28.8 |
| Married | 228 | 71.2 |
| Total | 320 | 100 |
| Age Bracket | | |
| 30-40 years | 85 | 26.6 |
| 41-50 years | 92 | 28.8 |
| 51-60 years | 129 | 40.3 |
| 61 years and above | 14 | 4.3 |
| Total | 320 | 100 |
| Educational Qualification | | |
| FSLC/SSCE | 53 | 16.6 |
| HND/BSC | 234 | 73.1 |

| | | |
|---|---|---|
| MSC/PHD | 33 | 10.3 |
| Total | 320 | 100 |
| Building Professionals | | |
| Architects | 101 | 31.6 |
| Engineers | 125 | 39.0 |
| Builders | 94 | 29.4 |
| Total | 320 | 100 |
| District Selected | | |
| Nyokhana | 141 | 44.1 |
| Kenkhana | 87 | 27.1 |
| Babbe | 92 | 28.8 |
| Total | 320 | 100 |

Source: Authors Survey Compilation 2025

Table 1 showed detail information of the population. Out of the 320 respondents, majority of them are married constituting a total of 228 (71.2%) of the total. In sex distribution, 277 are male (86.6% of the total) and 43 females (13.4% of the total). In terms of age grade, most respondents fall within 51-60 constituting a total of 129 (40.3%) years of age; Similarly, when asked about their educational qualification among the 320 respondents, the highest respondents have HND/BSC constituting a total of 234 (73.1%) and the lowest respondents when it comes to occupation are architects constituting a total of 33 (10.3%), while in terms of district distribution, Nyokhana has the highest respondents with a total of 141 (44.1%)

**Data Analysis**

ermine the appropriateness of the research questions, the data of this study are presented and analysed below using standard deviation, and SPSS software.

**What are the relationships between different soil types and building construction practices in Khana Local Government Area of Rivers State, and how do these relationships impact environmental sustainability?**

Respondents perception on the relationships between soil types and building construction practices.

Soil types in the area can be broadly classified into clay, sandy, and loamy soils, each with its unique characteristics and properties.

Impact on Building Construction Practices

1. Clay soils in Khana Local Government Area are prone to high plasticity and shrinkage, which lead to foundation problems and structural instability in buildings. Building construction practices in areas with clay soils require specialized foundation designs, such as deep foundations or raft foundations, to mitigate the risks associated with soil settlement and instability.

2. Sandy soils in the area are often loose and porous, which lead to poor load-bearing capacity and increased risk of erosion. Building construction practices in areas with sandy soils require careful consideration of foundation design, drainage, and erosion control measures to ensure stability and safety.

3. Loamy soils have relatively good load-bearing capacity and are often suitable for building construction. However, building construction practices in areas with loamy soils require careful consideration of soil compaction and drainage to prevent soil instability and erosion.

Impact on Environmental Sustainability

1. Poorly designed or constructed buildings lead to soil erosion, that result to loss of fertile land, increased sedimentation in waterways, and decreased biodiversity.

2. Heavy construction activities lead to soil compaction, which reduce soil permeability, increase runoff, and alter ecosystems.

3. Building construction lead to habitat destruction and loss of biodiversity, particularly if construction activities are not carefully planned and managed.

**How do different building construction practices in Khana Local Government Area of Rivers State affect environmental economics, particularly in terms of costs and benefits associated with soil type and construction methods?**

**Table 2:** Respondents perception on the cost and benefits associated with soil type and building construction practice.

| S/N | Factors | Mean | Standard Deviation | Decision |
|---|---|---|---|---|
| | Costs Associated with Building Construction Practices | | | |
| 1 | Building construction practices that lead to soil erosion and sedimentation result to significant environmental costs, including damage to infrastructure, loss of fertile land, and decreased water quality. | 3.9 | 1.6 | Accepted |
| 2 | Poorly designed or constructed buildings lead to foundation problems, which result in costly repairs and even collapse of the structure. | 3.7 | 1.5 | Accepted |
| 3 | Building construction practices that result in environmental degradation, such as loss of biodiversity and habitat destruction, always have long-term costs and impacts on ecosystem services. | 3.5 | 1.2 | Accepted |
| | Benefits of Sustainable Building Construction Practices | | | |
| 1 | Sustainable building construction practices that take into account the soil type and construction methods reduce environmental costs associated with soil erosion, sedimentation, and environmental degradation. | 4.3 | 0.9 | Accepted |
| 2 | Well-designed and constructed buildings that consider the soil type and environmental factors increased property values and contribute to sustainable development. | 3.4 | 1.3 | Accepted |
| | Sustainable building construction practices that prioritize | 3.6 | 1.4 | |

| | | | | |
|---|---|---|---|---|
| 3 | environmental health and safety improved public health and reduce the risk of environmental-related diseases. | 3.7 | 1.1 | Accepted |
| 4 | Sustainable building construction practices can result in cost savings through reduced energy consumption, water conservation, and waste reduction. | | | Accepted |
| 5 | Sustainable building construction practices can increase economic benefits through job creation, local economic growth, and increased property values. | 3.9 | 0.9 | Accepted |
| 6 | Sustainable building construction practices can ensure long-term sustainability by reducing the environmental impacts of building construction and promoting eco-friendly development. | 3.6 | 1.3 | Accepted |
| | Aggregate Mean | 3.7 | 1.2 | Accepted |

Source: Authors survey, 2025

Looking at the data in Table 2, item 1-9. The items aim to discuss the cost and benefits associated with soil type and building construction practice. As shown in the table above, the average for this items are completely above the 3.0 mean criterion. Additionally, based on all responses, the mean average is 3.7 and the average standard deviation is 1.2. According to the results obtained from the findings, the respondents (contractors, architects, engineers, and builders) unanimously agreed that in Khana LGA, the cost associated with soil type and building construction practice are: soil erosion and sedimentation, foundation problems, environmental degradation, while the benefits include: reduction in environmental costs, increased property values, improved public health, cost savings, increased economic benefits, and promote long-term sustainability.

What sustainable building practices can be adopted in Khana Local Government Area of Rivers State to mitigate the environmental and economic impacts of building construction on different soil types, and what are the potential benefits and challenges of these practices?

**Table 3:** Respondents perception on sustainable building practices that can be adopted in Khana Local Government Area of Rivers State to mitigate the environmental and economic impacts of building construction on different soil types, and their potential benefits and challenges of these practices.

| S/N | Factors | Mean | Standard Deviation | Decision |
|---|---|---|---|---|
| | Sustainable Building Practices | | | |
| 1 | Residents should design foundations that take into account the unique properties of the soil type, such as deep foundations for clay soils or shallow foundations for sandy soils. | 4.1 | 0.9 | Accepted |
| 2 | Implement erosion control measures, such as sedimentation ponds and revegetation, to reduce soil erosion and sedimentation. | 3.8 | 1.1 | Accepted |

| | | | | |
|---|---|---|---|---|
| 3 | Use sustainable building materials that are locally sourced, recycled, and environmentally friendly, such as earth bags, bamboo, and straw bales. | 3.5 | 1.3 | Accepted |
| 4 | The area should implement rainwater harvesting systems to reduce the demand on municipal water supplies and mitigate the impact of storm water runoff on soil erosion. | 3.7 | 1.5 | Accepted |
| 5 | Incorporate green roofs and walls into building design to reduce storm water runoff, improve air quality, and provide insulation. | 3.8 | 1.5 | Accepted |
| | Potential Benefits | | | |
| 1 | Sustainable building practices reduces the environmental impacts of building construction, such as soil erosion, sedimentation, and loss of biodiversity. | 3.4 | 1.2 | Accepted |
| 2 | Sustainable building practices result in cost savings through reduced energy consumption, water conservation, and waste reduction. | 3.5 | 1.2 | Accepted |
| 3 | Sustainable buildings increased property values and contribute to sustainable development. | 3.7 | 0.9 | Accepted |
| 4 | Sustainable building practices improve public health by reducing the risk of environmental-related diseases. | 3.6 | 1.2 | Accepted |
| | Potential Challenges | | | |
| 1 | Sustainable building practices may require higher upfront costs, as these costs can be offset by long-term savings. | 3.9 | 1.5 | Accepted |
| 2 | Limited awareness and expertise in sustainable building practices among builders, architects, and policymakers serve as a challenge to sustainable building practice. | 3.4 | 1.2 | Accepted |
| 3 | Existing building codes and regulations may not support sustainable building practices, thereby requiring changes to regulatory frameworks. | 3.3 | 1.0 | Accepted |
| 4 | Cultural and social norms serve as a challenge to sustainable building practices as it requires education and awareness-raising efforts. | 3.8 | 0.9 | Accepted |
| | Average Total | 3.7 | 1.2 | Accepted |

*Source: Authors survey, 2025*

Looking at the data in Table 3, item 1-13. The items aim to discuss sustainable building practices that can be adopted in Khana Local Government Area of Rivers State to mitigate the environmental and economic impacts of building construction on different soil types, and their potential benefits and challenges of these practices. As shown in the table above, the average for this items are completely above the 3.0 mean criterion. Additionally, based on all responses, the mean average is 3.7 and the average standard deviation is 1.2. According to the results obtained from the findings, the respondents (contractors, architects, engineers, and builders) unanimously agreed that sustainable building practice in the area that are adopted is: soil-friendly foundation designs, erosion control measures, sustainable building materials, rainwater harvesting, green roofs and walls, the potential benefits include: reduction of environmental impacts, cost savings, increased property values, improved public health, and the potential challenges are higher upfront costs, limited awareness and expertise, regulatory barriers, and cultural and social barriers.

**Discussion of Findings**

The results revealed that soil types across Khana LGA vary significantly in texture, plasticity, moisture content, and shear strength, with many locations dominated by clayey and silty soils exhibiting high plasticity indices and low bearing capacities. These findings align with Terzaghi's Bearing Capacity Theory (Terzaghi, 1943) and the empirical literature reviewed (Adeyemi, 2022), which explains that soils with low shear strength and high compressibility increase settlement risks and reduce foundation stability. The classification of soils using the Unified Soil Classification System (USCS) and the empirical literature reviewed, which highlights the importance of understanding soil properties for building construction (Casagrande, 1948; Oloyede, 2021) which further confirmed the predominance of problem soils such as CL (inorganic clays of low to medium plasticity) and ML (silt soils), which are prone to erosion, shrink–swell behaviour, and structural distress. The environmental implications observed ranging from gully erosion and surface instability to vegetation loss and disruption of local ecosystems mirror earlier empirical studies that show how poorly supported foundations accelerate land degradation in tropical regions. By integrating these findings with the literature, the study demonstrates that soil properties in Khana LGA pose both structural and ecological risks, reinforcing the need for construction approaches that are soil-specific and environmentally conscious.

These findings contribute to the advancement of sustainable building practices by highlighting soil-responsive construction strategies that can minimize environmental degradation while improving structural performance. For instance, buildings situated on high-plasticity clays require reinforced strip or raft foundations, proper drainage systems, and ground improvement techniques such as stabilization with lime or cement solutions widely supported in geotechnical and environmental sustainability studies. The spatial patterns revealed by GIS mapping further illustrate zones that require stricter building control, flood mitigation measures, and erosion-management interventions. Consequently, the study emphasizes the need for policy reforms in Khana LGA, including building codes that mandate geotechnical investigation before construction, land-use regulations that match foundation types to soil characteristics, and enforcement of environmentally sensitive site preparation practices. Strengthening local capacity through training for builders, routine soil mapping updates, and the integration of green infrastructure (e.g., vegetative buffers, permeable pavements) will not only reduce structural failures but also protect soil ecosystems and lower long-term economic costs.

The findings of this study have practical implications for building construction in Khana LGA. Building professionals need to take into account the specific soil conditions of a site when designing and constructing buildings. This includes selecting the appropriate foundation type, construction techniques, and stabilization measures to ensure building a safe and durable structure that will be environmental friendly.

**Conclusion**

This study has demonstrated that the diverse soil characteristics in Khana LGA particularly variations in plasticity, shear strength, moisture content, and bearing capacity play a significant role in shaping environmentally sustainable building practices. The findings highlight that inappropriate construction on weak or

highly plastic soils contributes to erosion, structural failures, and long-term environmental degradation. The study therefore reinforces the need for soil-responsive building designs, improved site investigation procedures, and sustainable construction technologies that optimize both economic and environmental outcomes. By integrating soil science with sustainability principles, the research provides actionable insights that can guide policymakers, engineers, and planners in enhancing environmental resilience and promoting safer, more durable infrastructure in the region.
Future research should expand the present study by conducting comparative analyses across different regions of Nigeria and internationally to understand how varying geological formations influence sustainable construction strategies. Such cross-regional studies would support the development of national and global soil-specific sustainability guidelines and strengthen adaptive building codes for diverse environments. Additionally, integrating remote sensing, machine learning–based soil prediction models, and longitudinal studies on building performance across soil types will deepen understanding of long-term environmental and economic benefits, ultimately supporting more effective planning and policy interventions for sustainable development.

**Recommendations**

Based on the findings of this study, the following recommendations are proposed to promote sustainable building practices and environmental resilience in Khana LGA:

1. Policy and Regulatory Measures: The government should develop and enforce building codes and regulations that require soil-specific investigations before construction, ensuring that foundation designs match local soil conditions and minimize environmental degradation.

2. Capacity Building and Training: Training programs should be organized for builders, engineers, architects, and policymakers on soil-responsive construction methods, erosion control, and sustainable materials to improve awareness and technical competence.

3. Promotion of Sustainable Construction Materials: Builders should adopt environmentally friendly and locally available materials, such as stabilized earth blocks, bamboo, and recycled aggregates, to reduce the ecological footprint of construction activities.

4. Soil and Site Management Practices: Implement site-specific strategies, including proper drainage systems, ground stabilization, erosion control measures, and rainwater harvesting, to mitigate soil-related risks and preserve ecosystem services.

5. Economic Incentives: The government and stakeholders should introduce incentives such as tax breaks, subsidies, or grants for projects that adopt sustainable building practices, promoting both economic and environmental benefits.

6. Community Awareness and Participation: Engage local communities in planning and construction processes to ensure sustainable practices are culturally acceptable, environmentally effective, and economically feasible.

7. Continuous Research and Monitoring: Encourage ongoing soil surveys, GIS mapping updates, and longitudinal studies on the performance of buildings on different soil types to inform adaptive strategies and enhance sustainable construction policies.

By implementing these recommendations, Khana Local Government Area can promote environmental sustainability, reduce environmental costs, and improve the quality of life for its citizens.

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