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Natural And Anthropogenic Drivers Of Soil Erosion In Sokoto Metropolis, Nigeria: Evidence From Gidan Dare, Bakin Kusu, And Runjin Sambo

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ABSTRACT

Soil erosion is a pervasive environmental challenge in semi-arid regions, particularly in northern Nigeria where fragile soils, sparse vegetation, and high-intensity rainfall combine to accelerate land degradation. This study examines the natural and human-induced factors responsible for soil erosion in three communities—Gidan Dare, Bakin Kusu, and Runjin Sambo—within Sokoto Metropolis. Using structured questionnaires and descriptive statistics, the research identifies intense rainfall (81%) and poor drainage systems (71%) as the dominant causes of erosion. Other significant factors include deforestation and bush burning (66%), overgrazing (55%), and urban construction activities (53%). The findings are consistent with established literature emphasizing the role of rainfall intensity, infrastructural inadequacy, and vegetation removal in accelerating erosion in semi-arid environments. The study concludes that erosion in Sokoto Metropolis arises from a complex interplay between natural climatic forces and anthropogenic land-use practices. It recommends integrated drainage design, afforestation programs, regulated grazing, urban planning reforms, and community-based conservation as essential measures to mitigate further environmental degradation. The paper contributes to the growing body of research on soil erosion in northern Nigeria and provides location-specific insights for urban planners, environmental managers, and policymakers.

Keywords: soil erosion, anthropogenic drivers, natural drivers, Sokoto Metropolis, semi-arid, urbanization, land degradation

1. INTRODUCTION

Soil erosion has emerged as one of the most pressing environmental challenges in sub-Saharan Africa, particularly in regions undergoing rapid land-use transitions driven by population growth, urbanization, and climate variability. Defined as the detachment, transportation, and deposition of soil particles by agents such as water and wind, soil erosion leads to the loss of fertile topsoil, reduced agricultural productivity, sedimentation of water bodies, and deterioration of infrastructure. In semi-arid northern

Nigeria, erosion is exacerbated by fragile soil structures, sparse vegetation, and erratic but high-intensity rainfall.

Sokoto Metropolis, located in the northwestern part of Nigeria, typifies these challenges. The area falls within the Sudan Savannah ecological zone and experiences a unimodal rainfall regime characterized by short-duration but high-intensity rainfall events. These conditions generate substantial surface runoff capable of transporting soil particles and forming rills and gullies. At the same time, increasing human activities such as deforestation, overgrazing, and unplanned urban expansion intensify the erosion process by weakening natural soil protection mechanisms.

Research on soil erosion in northern Nigeria has been extensive, yet localized studies focusing on specific urban and peri-urban communities remain limited. Many urban centers like Sokoto lack adequately planned drainage infrastructure, and unregulated construction activities disrupt natural drainage systems, compounding the risk of erosion. The consequences of these processes are evident in the form of degraded farmlands, damaged roads, and deepening gullies that threaten lives and property.

This study seeks to identify the major causes of soil erosion as perceived by residents in three selected communities within Sokoto Metropolis of Gidan Dare, Bakin Kusu, and Runjin Sambo. These communities were selected due to their varying degrees of urbanization, exposure to human activities, and differing landscape characteristics. By examining both natural and anthropogenic drivers of soil erosion, the study aims to generate location-specific insights that can guide sustainable land-use planning and environmental management in the region.

2. LITERATURE REVIEW

2.1 Conceptual Understanding of Soil Erosion

Soil erosion involves the removal and transport of topsoil by agents such as water, wind, and human activities. It is widely regarded as one of the most significant forms of land degradation globally. In tropical and semi-arid environments, water erosion dominates due to high rainfall intensities and seasonal flooding (Morgan, 2009). Erosion is influenced by five major factors: climate, soil properties, vegetation cover, topography, and land-use practices. The interaction of these factors determines the rate at which soil particles are detached and transported.

2.2 Climatic Drivers of Soil Erosion

Climate plays a critical role in erosion dynamics, particularly rainfall characteristics. High-intensity rainfall generates large raindrops with kinetic energy capable of dislodging soil particles a process known as splash erosion. When the rate of rainfall exceeds the infiltration capacity of the soil, surface runoff occurs, transporting detached particles downslope and forming rills and gullies. Olofin (2016) emphasizes that semi-arid regions such as Sokoto are more vulnerable due to their torrential rainfall pattern and limited vegetation cover.

2.3 Anthropogenic Drivers of Soil Erosion

Human activities substantially accelerate erosion, often surpassing the impact of natural processes. Key anthropogenic drivers include:

2.3.1 Deforestation and Bush Burning

Vegetation cover plays a protective role in minimizing erosion by reducing raindrop impact and enhancing soil structure. Deforestation destabilizes soil aggregates, reduces organic matter, and increases runoff. Ofomata (2002) and Audu (2017) argue that vegetation removal is one of the leading contributors to erosion across Nigeria's semi-arid and savanna regions.

2.3.2 Overgrazing

Overgrazing leads to vegetation removal and soil compaction. Compacted soils have reduced infiltration capacity, encouraged runoff and accelerated erosion. This is particularly prevalent in peri-urban areas where livestock movement is uncontrolled.

2.3.3 Poor Drainage Systems

Urban centers in Nigeria often suffer from inadequate drainage networks. During heavy rainfall, water flows along streets and unpaved surfaces, forming rills and gullies. Jimoh (2013) attributes much of the erosion in Nigerian cities to poor urban planning and inadequate stormwater management.

2.3.4 Urban Construction

Land clearing, excavation, and the replacement of vegetation with impermeable surfaces such as concrete and asphalt alter natural hydrological cycles. Construction debris further obstructs drainage channels, intensifying runoff.

2.4 Knowledge Gaps

Although numerous studies address soil erosion in northern Nigeria, fewer investigate resident-based perceptions in specific urban contexts such as Sokoto. This study bridges this gap by providing community-specific insights that reflect local realities and environmental challenges.

3. METHODOLOGY

3.1 Study Area Description

Gidan Dare, Bakin Kusu, and Runjin Sambo are communities located within Sokoto Metropolis. The area experiences annual rainfall ranging from 500-700 mm, with the highest intensities recorded between July and September. The soils are predominantly sandy and easily eroded due to low organic content. Sparse vegetation, combined with increasing urbanization, makes these communities highly susceptible to erosion.

3.2 Research Design

The study adopted a descriptive survey design. The choice was informed by the need to gather firsthand information from residents on the perceived causes of soil erosion in their communities.

3.3 Sampling and Data Collection

A structured questionnaire was administered to residents in the three communities. Respondents were selected using a stratified sampling technique to ensure adequate representation of different demographic groups.

3.4 Data Analysis

Data were analyzed using descriptive statistics, primarily expressed through percentages. Findings were presented in tables and figures with corresponding interpretations aligned with relevant literature.

4. RESULTS

4.1 Major Causes of Soil Erosion

The findings presented in Table 4.2 reveal five major causes of soil erosion across the study communities.

Table 4.2: Major Causes of Soil Erosion Identified by Respondents

Cause of Erosion	Gidan Dare (%)	Bakin Kusu (%)	Runjin Sambo (%)	Average (%)
Intense rainfall	80	85	78	81
Poor drainage	75	70	68	71
Deforestation/Bush burning	60	65	72	66
Overgrazing	55	60	50	55
Urban construction	45	55	60	53

Source: Authors' Fieldwork 2026

4.2 Analysis of Dominant Factors

The analysis of dominant factors contributing to soil erosion in Sokoto Metropolis reveals a complex interplay between natural climatic events and anthropogenic activities. These factors vary in intensity and spatial distribution across the study areas of Gidan Dare, Bakin Kusu, and Runjin Sambo. Respondents' observations, supported by field investigations, indicate that certain drivers are more prevalent and impactful than others.

4.2.1 Intense Rainfall

Intense rainfall emerged as the most frequently cited factor, accounting for 81% of responses across the three study areas. This observation aligns with Sokoto's semi-arid climate, where rainfall, though often seasonal, occurs in short bursts of high intensity. Such rainfall events generate significant kinetic energy, which impacts the soil surface, dislodging particles and initiating sheet erosion. In areas devoid of protective vegetation, the effect is particularly pronounced. The short duration but high intensity of these rains also promotes rapid surface runoff. This runoff, if uncontrolled, accumulates in depressions, forming rills and, over time, deep gullies.

The erosive power of these rains is compounded by the urban landscape. Bare soil surfaces, often exposed by construction or land clearing, provide minimal resistance to raindrop impact. Moreover, the absence of vegetative cover reduces the soil's infiltration capacity, causing water to flow over the land rather than percolate into the ground. This not only accelerates erosion but also contributes to sediment deposition in drainage channels, exacerbating flooding risks.

4.2.2 Poor Drainage Systems

Poor drainage systems were identified as the second most significant factor, cited by 71% of respondents. The lack of adequately designed stormwater channels results in uncontrolled water flow, particularly during periods of intense rainfall. Water accumulates in residential areas, along roads, and across open spaces, causing localized flooding and soil displacement. Field observations indicate that existing drainage systems are often blocked by waste, debris, and sediment, rendering them ineffective. In some areas, drainage channels are completely absent, forcing rainwater to carve new pathways across the landscape. The consequences are particularly severe in urban and peri-urban areas where natural watercourses have been altered or obstructed by construction and development. Poor drainage thus acts as a multiplier of the erosive effects of rainfall, highlighting the critical need for infrastructural intervention and proper urban planning.

4.2.3 Deforestation and Bush Burning

Deforestation and bush burning contribute significantly to soil erosion, with an average response rate of 66%. This factor is most pronounced in Bakin Kusu and Runjin Sambo, where clearing of vegetation for farming, fuelwood collection, and settlement expansion is prevalent. The removal of trees and shrubs exposes the soil surface to direct raindrop impact, making it more vulnerable to detachment and transport. Bush burning, a common practice in these communities, exacerbates the problem by destroying organic matter that binds soil particles together. The loss of vegetative cover also increases susceptibility to wind erosion, especially during dry periods. Moreover, deforestation reduces the soil's capacity to absorb and retain water, leading to increased surface runoff and the formation of gullies. The long-term ecological consequences include the degradation of soil fertility, loss of biodiversity, and heightened desertification risk.

4.2.4 Overgrazing

Overgrazing emerged as a significant contributor to soil erosion in peri-urban areas, accounting for 55% of respondents' observations. Livestock are often grazed indiscriminately, removing grasses and shrubs that protect soil surfaces. The repetitive trampling by animals also compacts the soil, reducing its porosity and infiltration capacity. Compacted soils promote faster runoff during rainfall events, accelerating the erosion process. The combination of vegetation loss and soil compaction creates conditions for both surface and gully erosion. Overgrazed areas are less able to recover naturally, as the soil structure is weakened and seedling establishment becomes difficult. This underscores the importance of managing grazing intensity, establishing rotational grazing systems, and designating specific grazing areas to minimize the negative environmental impact.

4.2.5 Urban Construction

Urban construction, cited by 53% of respondents, represents a growing anthropogenic pressure on soil stability. Activities such as land clearing, excavation, road expansion, and sand mining disturb the natural soil structure and alter drainage patterns. In many cases, construction occurs without proper soil stabilization measures, leaving large tracts of land exposed to rainfall and runoff.

Construction activities in Sokoto Metropolis often prioritize short-term development needs over environmental considerations, resulting in increased erosion risks. For instance, removal of topsoil for building foundations or road networks not only exposes the soil but also creates channels for water to flow, forming rills and gullies. Additionally, sand mining near riverbanks and water channels destabilizes adjacent soils, increasing sediment load in streams and contributing to downstream flooding. The interaction between urban construction and other factors particularly intense rainfall and poor drainage is significant. Areas undergoing construction often coincide with insufficient drainage infrastructure, meaning that rainfall events have a compounded effect on erosion. This highlights the necessity for environmental impact assessments (EIAs) prior to construction, the implementation of erosion control measures, and adherence to sustainable urban planning practices.

4.2.6 Synthesis of Dominant Factors

The analysis demonstrates that soil erosion in Sokoto Metropolis is not caused by a single factor but by a combination of interrelated natural and human-induced processes. Intense rainfall initiates erosion, while poor drainage, deforestation, overgrazing, and urban construction amplify its severity. These factors interact synergistically, meaning that the presence of one factor often exacerbates the effects of another. For example, intense rainfall on overgrazed or deforested land with poor drainage will result in rapid gully formation, whereas similar rainfall in vegetated areas with adequate drainage may cause minimal damage. Understanding these interactions is crucial for designing effective mitigation strategies, as interventions must address both environmental and anthropogenic dimensions to achieve sustainable soil management.

5. DISCUSSION

5.1 Interactions Between Natural and Human Factors

The results of this study indicate that soil erosion within Sokoto Metropolis is the product of a complex interaction between natural environmental factors and human-induced activities. Natural forces, particularly the region's climatic conditions, play a foundational role. Rainfall intensity and distribution, for instance, have been identified as primary natural drivers of soil erosion in the area. The semi-arid climate of Sokoto Metropolis, characterized by seasonal torrential rains, creates conditions conducive to surface runoff. When rainfall intensity exceeds the infiltration capacity of the soil, it leads to detachment and transportation of soil particles, thereby accelerating erosion processes.

However, natural forces alone do not account for the full extent of erosion observed. Human activities significantly exacerbate the vulnerability of the landscape. In particular, poor urban planning, inadequate drainage systems, uncontrolled construction, deforestation, and overgrazing have been observed to amplify the erosive impact of rainfall. For example, unplanned construction in densely populated neighborhoods obstructs natural drainage pathways, leading to water accumulation and localized flooding, which in turn erodes topsoil. Similarly, deforestation and the removal of vegetative cover reduce the soil's natural resistance to erosion. Vegetation typically acts as a protective layer that cushions the impact of raindrops and facilitates water infiltration. Its absence accelerates the process of surface runoff, further contributing to gully formation and sediment displacement.

The interplay between these natural and anthropogenic factors is synergistic rather than additive. That is, the presence of one factor intensifies the effects of the other. For instance, even moderate rainfall can cause significant erosion in areas where vegetation has been removed or drainage infrastructure is insufficient. Conversely, in well-managed areas with intact vegetation and efficient drainage systems, even intense rainfall may have a limited erosive impact. These dynamic underscores the importance of an integrated approach to erosion management that simultaneously addresses environmental, infrastructural, and social dimensions.

5.2 Comparison with Existing Literature

The findings of this study are consistent with previous research on soil erosion in semi-arid and urban environments. Morgan (2009) emphasizes that rainfall intensity is a crucial driver of soil erosion, particularly in regions with sparse vegetation cover. This aligns closely with observations in Sokoto

Metropolis, where seasonal torrential rains generate substantial surface runoff. Similarly, Jimoh (2013) identifies inadequate drainage and infrastructural deficiencies as significant contributors to urban erosion. The prevalence of poorly maintained drainage channels and blocked water pathways in Sokoto Metropolis echoes Jimoh's conclusions and highlights the critical role of infrastructural planning in mitigating erosion.

Moreover, the human-induced factors observed in this study, such as deforestation and overgrazing, corroborate the findings of Ofomata (2002) and Audu (2017). Ofomata's work emphasizes the destructive impact of vegetation removal on soil stability, while Audu notes that overgrazing not only reduces ground cover but also compacts the soil, decreasing infiltration rates and enhancing runoff. In Sokoto, widespread livestock grazing and clearing of vegetation for agricultural expansion have directly contributed to the degradation of soil structure, confirming the applicability of these studies to the local context.

Furthermore, this study expands on the existing literature by illustrating how these natural and anthropogenic factors interact in an urban setting. While previous research often focuses on either rural or semi-arid contexts, the findings here demonstrate that urbanization introduces unique erosion dynamics. Unregulated construction, improper waste disposal, and the lack of formal drainage infrastructure amplify the natural vulnerability of soils to erosion, creating a cycle of land degradation that is both spatially and temporally complex.

5.3 Implications for Land Use and Environmental Sustainability

The implications of these findings for land use, urban planning, and environmental sustainability are profound. First, continued soil erosion threatens the viability of agricultural lands in and around Sokoto Metropolis. Loss of topsoil diminishes soil fertility, leading to reduced crop yields and economic hardship for local farmers. If left unaddressed, erosion could result in irreversible land degradation, undermining food security in the region. Second, urban infrastructure is highly vulnerable to the consequences of erosion. Roads, bridges, drainage channels, and residential structures are frequently damaged by gully formation and runoff-induced flooding. This not only imposes substantial economic costs on local governments and residents but also poses safety risks for inhabitants. Third, unchecked erosion has broader ecological consequences. Sediment runoff into rivers and streams can degrade water quality, affect aquatic ecosystems and increase the risk of waterborne diseases. Furthermore, the reduction of vegetation cover contributes to desertification tendencies in the region, with potential long-term climate implications.

Therefore, sustainable land-use planning and environmental management must prioritize erosion control as a central objective. Integrating natural resource conservation with urban development strategies can mitigate the negative effects observed, ensuring that both ecological integrity and human livelihoods are preserved.

6. CONCLUSION

This study concludes that soil erosion in Sokoto Metropolis, particularly in areas such as Gidan Dare, Bakin Kusu, and Runjin Sambo, is driven by a combination of natural and human-induced factors. Intense seasonal rainfall serves as the primary natural driver, while poor drainage infrastructure amplifies the vulnerability of soils to erosive processes. Anthropogenic activities including deforestation, overgrazing, and unregulated urban construction further exacerbate the situation. The findings demonstrate that erosion in Sokoto Metropolis is not solely a consequence of environmental conditions but rather the outcome of a complex interaction between natural forces and human activities. This underscores the need for integrated management approaches that address both ecological and socio-economic dimensions. Failure to act will likely result in continued land degradation, economic losses, and increased vulnerability of urban and peri-urban communities to environmental hazards.

7. RECOMMENDATIONS

To mitigate the problem of soil erosion in Sokoto Metropolis, a multi-faceted approach is recommended:

1. **Construction of Efficient Drainage Systems:** Local authorities should prioritize the development of durable and well-maintained stormwater drainage networks. Properly designed drainage systems can significantly reduce surface runoff, minimize gully formation, and protect both urban infrastructure and agricultural lands.
2. **Afforestation and Environmental Rehabilitation:** Tree planting campaigns and reforestation programs should be implemented to restore vegetative cover. Plant roots stabilize soil, reduce surface runoff, and enhance water infiltration, thereby mitigating erosion. In addition, the use of native species can improve biodiversity and ecosystem resilience.
3. **Regulation of Grazing Practices:** Implementing designated grazing areas and rotational grazing schemes can reduce overgrazing pressure on vulnerable soils. This will allow vegetation to regenerate and maintain its protective function against erosion.
4. **Strict Urban Planning Enforcement:** Environmental impact assessments (EIAs) should be mandatory for all construction and urban development activities. Urban planning authorities must enforce zoning regulations, prevent encroachment on flood-prone areas, and ensure that development does not compromise natural drainage pathways.
5. **Community Education and Awareness:** Public enlightenment programs should educate residents on sustainable land-use practices. Awareness campaigns can highlight the economic, environmental, and social costs of soil erosion, promoting collective action for soil and water conservation.
6. **Monitoring and Early Warning Systems:** Establish community-based erosion monitoring units capable of providing timely alerts to local authorities and residents. These units can employ simple monitoring tools such as erosion pins, photographic documentation, and rainfall measurements to track erosion hotspots and inform preventive measures.
7. **Integration of Traditional Knowledge:** Encourage the integration of indigenous knowledge and community practices in erosion management. Local communities often possess valuable insights into land-use practices that enhance soil conservation and can complement modern approaches.

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