Kontagora International Journal of Educational Research (KIJER) ISSN: 3027-0618
Volume 2, Issue 1, January 2025
https://fuekjournals.org/index.php/kijer

An assessment of the Rate of Soil Erosion in Kachia Local Government Area of Kaduna State

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DOI: https://doi.org/10.5281/zenodo.14775118

To cite:
Dayyabu, M., & Jibrin, A. (2025). An assessment of the rate of soil erosion in Kachia Local Government Area of Kaduna State. *Kontagora International Journal of Educational Research, 2*(1), 232-247.

Abstract

Soil erosion is a critical environmental issue affecting many regions worldwide. The study assessed the rate and extent of soil erosion in Kachia Local Government Area of Kaduna State. The methodology for this research involved a combination of field surveys, geospatial analysis, and data collection techniques to assess the rate of soil erosion, its causes, and impacts in Kachia Local Government Area. The study adopted a mixed-methods approach involving both quantitative and qualitative methods. Quantitative methods include measurements of erosion rates, analysis of rainfall data, and GIS mapping, while qualitative methods involved field observations. The results showed that the rate and extent of soil erosion keeps increasing from the study years from 1990 to 2022. Changes in land use and natural factors have been identified as significant factors of soil erosion in this area. These changes are often the result of human activities such as deforestation, agricultural expansion, overgrazing, and urbanization and rainfall intensity and variability, topography among others. In order to mitigate the rate of soil erosion in the study area, here are practical and sustainable recommendations for mitigating soil erosion in Kachia Local Government Area (LGA), Kaduna State: such as: Sustainable Agricultural Practices, Vegetation Restoration, Controlled Grazing, Soil Conservation Measures and Improved Land Use Practices among others. When all these are carefully adhered to, the rate of soil erosion will drastically be minimized.

***Key word**: soil, erosion, land degradation, land use, rainfall intensity*

Introduction

Soil erosion is another common type of land degradation in the world. It refers to the deterioration of soil structure by the physical movement of particles from one site to another. Wind, water, animals, and land use activities by man are the main causes of soil erosion. Soil erosion is a natural process but it usually becomes a problem when human induced factors accelerate its rate of occurrence in the environment (Hoffman and Todd, 2019). Soil erosion remains a critical environmental challenge globally, particularly in developing regions where livelihoods depend heavily on natural resources. In sub-Saharan Africa, including Nigeria, soil erosion is one of the most significant causes of land degradation, reducing agricultural productivity, threatening food security, and accelerating poverty levels (UNCCD, 2020). The Kachia Local Government Area (LGA) of Kaduna State, located in the Guinea savanna region and central southern part of the state, is experiencing increasing soil erosion, primarily driven by both natural and anthropogenic factors.

Kachia LGA is an agrarian region where agriculture serves as the backbone of the local economy. However, a combination of population pressure, unsustainable land-use practices, deforestation, and climate variability has intensified soil erosion in the area. Rainfall variability, especially heavy seasonal rains, accelerates the erosion process by washing away the fertile topsoil, thereby reducing soil fertility and agricultural yield. Farmlands that are prone to this type of degradation also experience nutrient depletion with poor soil fertility since the top fertile soils are carried away by the agents of erosion.

Recent studies suggest that in semi-arid and savannah regions of Nigeria, soil erosion is exacerbated by erratic rainfall, which has increased in both intensity and variability over the past two decades (Ayoade et al., 2020). Furthermore, land-use changes, such as vegetation clearing for farming and urban expansion, have left the soil vulnerable to erosion. According to Iyaka et al. (2020), deforestation and poor land management practices contribute significantly to the rise of rill and gully erosion in northern Nigeria, including parts of Kaduna State. Kachia LGA's undulating topography further exacerbates this problem, as slope gradients increase the speed of runoff and sediment transport, resulting in severe soil loss. The socio-economic impacts of soil erosion in Kachia LGA are profound, affecting agricultural productivity, water quality, and infrastructure. Loss of fertile topsoil directly threatens food security by reducing crop yield, while siltation of water bodies affects both

irrigation and domestic water supply. Additionally, erosion-related infrastructure damages such as collapsed roads and bridges impair transportation and economic activities.

Worldwide, farmers are losing an estimated 24 billion tone of topsoil each year. (UNEP 2014). In developing countries, erosion rates per acre are twice as high as the standard, partly because population pressure forces land to be more intensively farmed. Although soil erosion is a physical process, it also affects productivity and growth (IUSS, 2008). Poor vegetation cover in most dry lands of Africa contributes to wind erosion in these areas leaving the ground bare

Given the growing concerns, it becomes imperative to assess the rate of soil erosion in Kachia LGA. This study therefore, aims to quantify soil erosion rates, identify major drivers, and analyze affected areas. By integrating recent findings and field assessments, it will also provide practical recommendations for mitigation strategies, such as soil conservation practices and sustainable land management, to reduce soil erosion and its adverse effects.

Research Questions

This research seeks to ask the following questions

1 What is the rate and extent of soil erosion in Kachia Local Government Area?

2 What are the major factors contributing to soil erosion in Kachia LGA?

3 How does rainfall variability and intensity influence soil erosion in the study area?

4 What sustainable land management practices can be recommended to reduce the rate of soil erosion in Kachia LGA?

Materials and Methods

The Study Area

Kachia LGA is located between Latitude 7°32' and 10°10′N and Longitudes 7°00′E and 8°05′E. Kachia is one of the LGAs in the southern part of Kaduna State (see Figure 3.1). situated in the Guinea savanna and central-southern part of Kaduna State. Kachia LGA is bounded by Zangon Kataf

LGA to the east, Kajuru LGA to the northeast, Kagarko LGA to the south, Jaba LGA to the southeast, Chikun LGA to the northwest and Niger state to the west respectively (Figure 1) (Isaac, et al,, 2017).

Climate. The area has a tropical climate with wet and dry seasons, characterized by high rainfall intensity during the wet season. it is generally tropical continental (tropical wet and dry) represented by Aw based on W. Koppen's classification (Eltantawi, 2011). Temperature in this area could reach up to 30°C or more especially in the months of April and March. The general pattern of rain is mainly affected by two principal air masses, which are Tropical Continental (cT), and Tropical Maritime (mT) air masses (Ati and Sawa, 2018). The mT is warm, moist and originates from the sea and it therefore, brings the rainy season while the cT originates from the Sahara Desert so it is characterised by cool dry and dusty conditions, which is the major cause of the dry season in the area. The tropical continental air mass also brings harmattan between December and January to the area (Abaje et al., 2016). The total annual rainfall in this area is about 1500mm (Murtala and Abaje, 2018). The rainy season begins in March-April with little hurricane of wind and rain, which becomes frequent and less violent as the year advances. Toward the month of July rain falls almost every day and by the end of September, the rivers are in full flood and tracks of the country under water measuring 1524cm. In October the steady rain is succeeded once more by violent storm which finally ceased about the end of the month or early November and giving way to dry season (Abaje et al., 2016). Climatic elements especially, rainfall, temperature and wind could aggravate land degradation in an area. Climate could therefore, induce water and soil erosion in the study area.

Topography and Vegetation: The area has an undulating topography with savanna vegetation, making it susceptible to erosion.

Economic Activities: Predominantly agriculture (subsistence farming and livestock rearing), with notable deforestation and land-use changes. Human activities especially through over-cultivation, forest conversion, urbanization and deforestation in this area could lead to high soil erosion

.**Soils:** The factors of soil formation in this area are not different from those found elsewhere particularly in places within the northern guinea savanna. However, the role of parent material, climate and topography are very great in the area. Soils in this LGA, are majorly due to intensive weathering of rocks and active surface denudation processes. As a result of this, the soils of the study

area are basically ferruginous in nature (Emielu, 2010). The soils in the area are generally rich in mineral content and therefore support high agricultural productivity in the area (Emileu, 2010). However, human activities such as through lumbering, faming, grazing, quarrying and hunting have severely exposed the soils of the area to various agents of soil erosion over time.

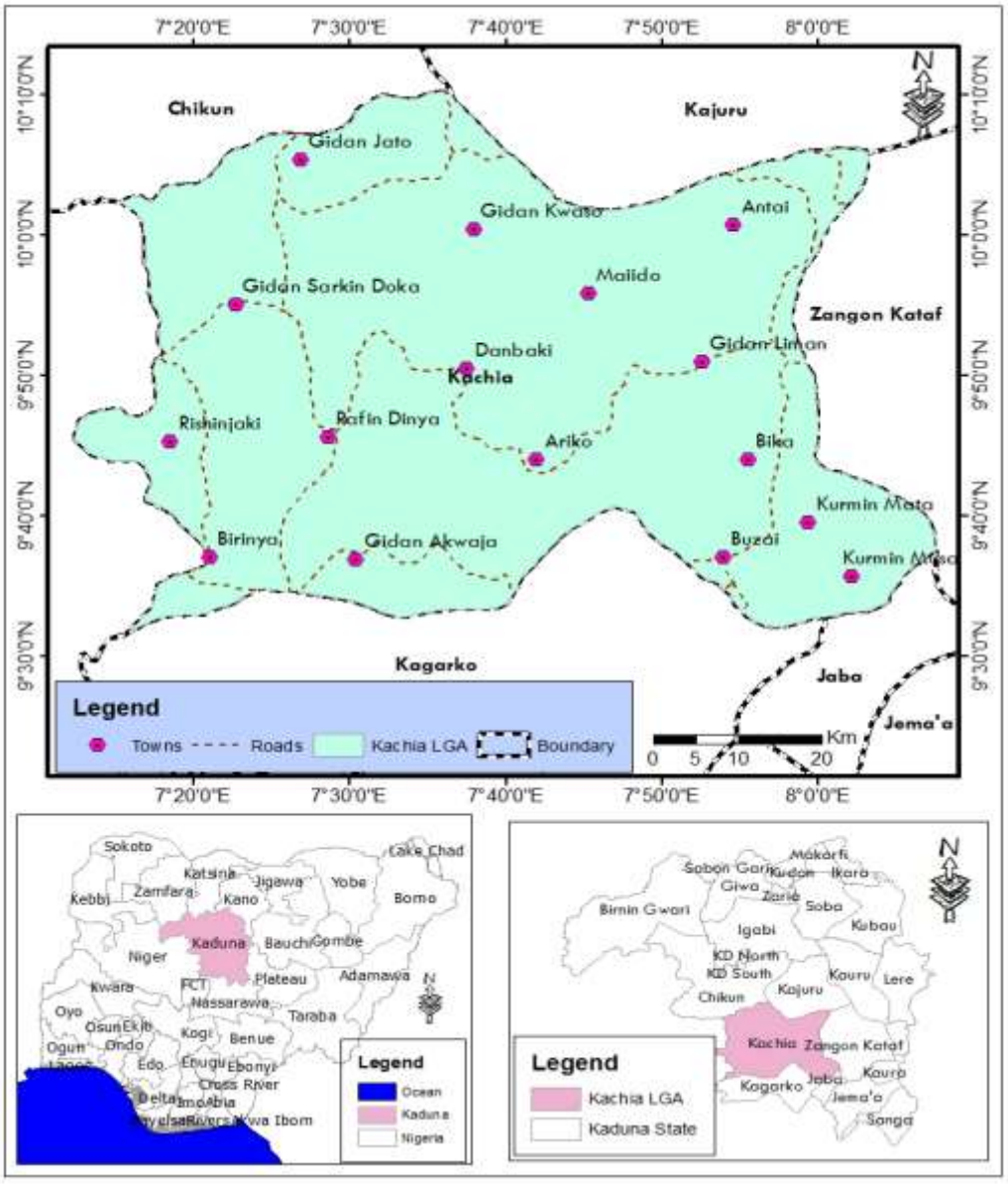

Figure 1: Kachia Local Government Area

Source: Adapted and Modified from Administrative Map of Nigeria (2022)

Methodology

The methodology for this research, involved a combination of field surveys**,** geospatial analysis, and data collection techniques to assess the rate of soil erosion, its causes, and impacts in Kachia Local Government Area. The study adopted a mixed-methods approach involving both quantitative and qualitative methods. Quantitative methods include measurements of erosion rates, analysis of rainfall data, and GIS mapping, while qualitative methods involved field observations.

Data Collection Methods

Field surveys was conducted to identify erosion-prone areas and measure erosion features such as rill, gully dimensions, and sediment deposits, GPS devices was used to record elevation, slope, and coordinates of erosion-prone areas and analyzed the influence of topography on soil erosion. Direct Observation was carried out t**o o**bserve erosion features like gullies, sheet erosion, and degraded farmlands during field visits. Anthropogenic activities contributing to soil erosion was also documented (e.g., deforestation, farming on slopes, and urbanization). Geographic Information Systems (GIS) and Remote Sensing were used to map erosion hotspots and analyze changes in vegetation cover over time. Soil Erosion estimation Models such as the Revised Universal Soil Loss Equation (RUSLE) was used to estimate soil loss rates. The model uses parameters such as rainfall erosivity, soil erodibility, slope length, land cover, and conservation practices.

The formula for RUSLE: $A=R\times K\times LS\times C\times PA = R \times K \times LS \times C \times PA=R\times K\times LS\times C\times P$ Where:

- *A*: Annual soil loss (tons/ha/year)
- *R*: Rainfall erosivity factor
- *K*: Soil erodibility factor
- *LS*: Topographic factor (slope length and steepness)
- *C*: Cover management factor
- *P*: Conservation practice factor

Results

The results of the rate and extent of soil erosion in the study area from 1991 to 2022 were presented in Table 1 and Figure 2 to 5

Table 1: Rate and extent of Soil Erosion in the Study Area from 1991 to 2022

Category	1991 Area km^2	%	2000 Areakm^2	%	2010 Areakm^2	%	2022 Areakm^2	%
Low	647.54	13.977	1201.41	25.933	949.32	20.49	724.60	15.64
Moderate	3971.16	85.71	3419.27	73.806	3665.17	79.114	2749.67	59.35
High	13.40	0.289	11.50	0.248	17.64	0.380	178.05	3.84
Very high	0.62	0.001	0.54	0.011	0.59	0.012	980.40	21.16
TOTAL	4632.72	100	4632.72	100	4632.72	100	4632.72	100

Source: (United State Geological Survey) Interpretation from Landsat T M 2022

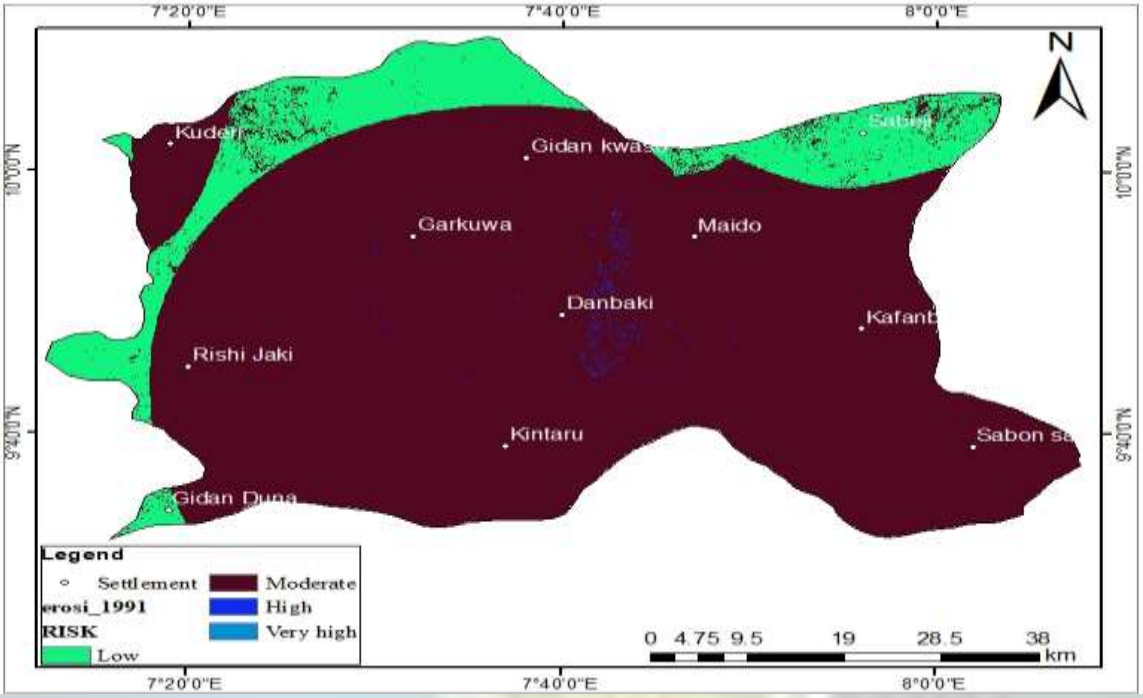

Figure 2: Rate of Soil Erosion in the Study Area as at 1991Source: United State Geological Survey LandSat TM 1991

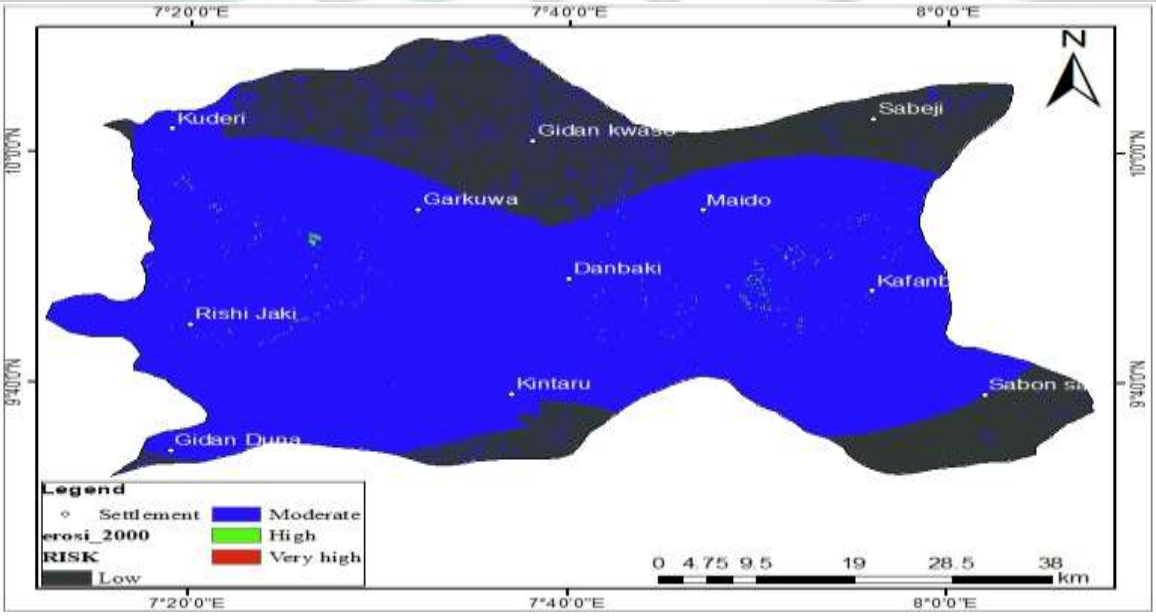

Figure 3: Rate of Soil Erosion in the Study Area as at 2000

Source: United State Geological Survey LandSat TM+ 2000

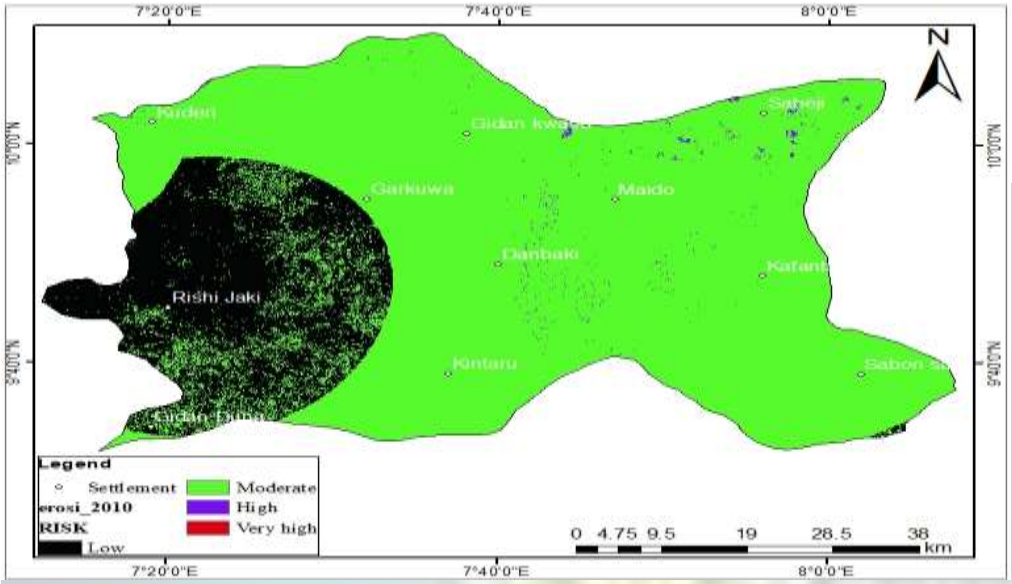

Figure 4: Rate of Soil Erosion in the Study Area as at 2010

Source: United State Geological Survey LandSat TM+ 2010

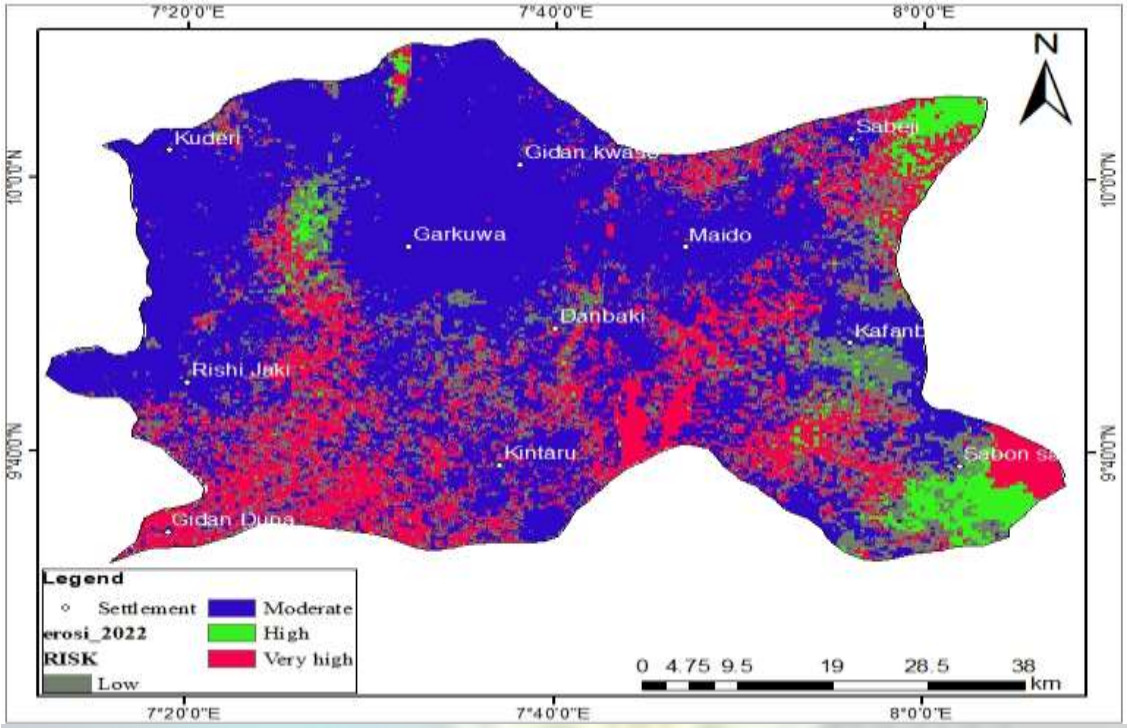

Figure 5: Rate of Soil Erosion in the Study Area as at 2022

Source: United State Geological Survey LandSat OLI 2022

The results showed the rate and extent of soil erosion areas were identified as shown on table 1 and on the above imageries. The major factors contributing to soil erosion were also identified both natural and anthropogenic (human-induced) factors. The intensity of rainfall in the area is also high. Socio economics that caused soil erosion were observed and identified

Discussion

The rate and extent of soil erosion

The results in Figure 2 show that in 1991 the highest percentage (85.71%) of the study area experience moderate rate of soil erosion, this was followed by areas with low rate with 13.9% while the smallest land mass with 0.001% recorded very high erosion rate.

Figure 3 presents the results of soil erosion rate during 2000, it indicated that highest percentage (73.8%) of the study area experience moderate soil erosion rate, this was followed by areas with low erosion rate with 25.9% while the lowest (0.011%) percentage goes to very high rate.

The result in Figure 4 shows that in the year 2010 the highest (79.1%) part of study area recorded moderate soil erosion rate; this was followed by area with the low rate of erosion which occupied about 20.49% while the lowest (0.012%) has experience very high rate of soil erosion.

Similarly, the findings in Figure 5 indicates that, major (59.35%) part of the study area in the year 2022 experience moderate soil erosion rate, this was followed by area with the very high soil erosion rate with 21.16% while areas with high erosion rate recorded the lowest percentage of 3.84%.

As a whole the findings in Table 1, revealed that the rate of soil erosion in the study area becomes highest recently, whereby the year 2022 recorded very high rate of about 21.16% covering a total land area of about 980.40km^2. The results further show that, area with low soil erosion rate in the year (2022) is small when compare with what is obtained in the previous year. However, in the base year which is 1991, the result shows that, even though areas with low soil erosion rate have been the lowest which is just about 13.9%, the year experience the highest moderate erosion rate covering a total land area of about 3971.16km^2. Despite the fact that many factors might be associated to these, yet, nature of vegetation cover in the area must be one of the factors. Going by what is obtain in Table 1 of this study, the results indicated that soil erosion in the study area were strongly influence by LULC pattern of the area. This could be seen clearly by how vegetation cover has been recently reduced when compare with what has been in the previous years, and consequently with how the rate of soil erosion have been increasing. The cultivated land has been drastically reduced, many land were left uncultivated, which renders it a bare surface, thereby exposing it to a high to a high rate of erosion. Also, the rate of land allocated to buildup increases, this also increases the percentage of land that are exposed to soil erosion.

The finding of this study in the previous years is similar with that of Maqsoom et al. (2020) in the Chitral district which revealed areas with moderate soil erosion to have been recording the highest percentage of 21% and those with the very high recording the lowest percentage of 8%. The result also conforms to that of Sidi-Almouctar et al. (2021) in Maradi, Niger Republic which indicated areas

with moderate erosion to has been recording the highest percentage of 85.2% and those with the low rate to has been recording 14.8%.

The Major Contributing Factors of Soil erosion in the Study Area

The findings indicate that factors such as deforestation, unsustainable agricultural practices, poor land management, overgrazing, urbanization and infrastructural development, as well as population pressure and poverty and natural factors such as rainfall intensity and variability, topography and vegetation cover among others are the major factors of soil erosion in Kachia Local Government Area (LGA) of Kaduna State These factors work together to accelerate the loss of soil, impacting agricultural productivity and the environment.

Deforestation: Tree felling for fuelwood, farming, or settlement expansion were found to be high in the area thereby, reducing forest cover, leaving the soil exposed to wind and water erosion. Loss of root systems decreases soil stability, leading to increased sediment displacement during rainfall.

Unsustainable Agricultural Practices: Over-cultivation, mono-cropping, and improper tillage methods were the common practices in the area which disturb the soil structure, making it susceptible to erosion. Farming on slopes without contour plowing or terracing aggravates runoff and soil loss.

Poor Land Management: The lack of sustainable land management practices, in the study area such as crop rotation, mulching, or cover cropping in the study area, leaves soil vulnerable. Limited adoption of soil conservation techniques further exacerbates erosion.

Overgrazing: The area is a grassland and therefore, support grazing in the area but unregulated grazing by livestock was found to be common which leads to the removal of protective grass cover, soil compaction, and the creation of paths that accelerate surface runoff. Trampling by animals disrupts soil structure and contributes to gully formation.

Urbanization and Infrastructure Development: Clearing of land for housing, roads, and other infrastructure were found to be increasing higher, thereby increasing bare surfaces, altering natural drainage patterns and accelerating erosion. Poorly designed drainage systems channel storm water, leading to gully erosion.

Population Pressure: Growing population in Kachia LGA according to (NPC, 2006) is increasing, this increase the demand for farmland and settlement areas, leading to deforestation and encroachment on erosion-prone areas.

Poverty: Most of the people in the area are local farmers and therefore, limited financial resources often force these local farmers to engage in unsustainable land use practices, prioritizing short-term yields over long-term soil conservation that leads to soil erosion.

Topography: The undulating terrain in Kachia LGA, with slopes and valleys, increases runoff velocity, making steep areas highly susceptible to rill and gully erosion. Slope length and gradient contribute to sediment transport, especially during heavy rains.

Vegetation Cover: Natural vegetation in Kachia, primarily savanna grassland, plays a critical role in stabilizing soil. Areas with sparse vegetation or degraded cover are more exposed to erosion as observed.

Influence of Rainfall Variability and Intensity on Soil Erosion in the Study Area

Rainfall variability and intensity significantly influence soil erosion in Kachia Local Government Area (LGA) as observed through the following:

Increased Surface Runoff: High-intensity rainfall in the area generates excessive surface runoff, especially when the soil cannot absorb water quickly enough. This leads to the detachment and transport of soil particles, resulting in sheet and rill erosion.

Erosion of Topsoil: Intense rainfall events directly impact the soil surface, breaking apart soil aggregates and dislodging particles. The topsoil, which is the most fertile layer, is often the first to be washed away.

Gully Formation: Concentrated runoff during heavy rains carve out deep channels, leading to gully erosion. This is particularly common in areas with steep slopes or poorly managed drainage systems, this is common in the area.

Seasonal Variability: Variability in the timing of rainfall affects vegetation cover. Delayed rains leave the soil exposed for longer periods, while excessive rains in a short duration may overwhelm the protective effect of vegetation..

Flooding: Prolonged or heavy rains lead to flooding, especially in low-lying areas. Floodwaters carry away large volumes of soil, exacerbating erosion.

Reduction in Vegetative Cover: Intense rainfall damage crops and vegetation, reducing their ability to protect the soil. Variability in rainfall patterns also hinder the growth of vegetation, leaving the soil vulnerable to erosion..

Conclusion

It is clear from this study that across the study area, various land use practices are exacerbating the problem of soil erosion. The results further revealed that the rate of soil erosion in the study years keep increasing drastically from 1991 to 2022. It is also clear that factors such as deforestation, unsustainable agricultural practices, poor land management, overgrazing, urbanization and infrastructural development, as well as population pressure and poverty and natural factors such as rainfall intensity and variability, topography and vegetation cover among others are the major factors of soil erosion in Kachia Local Government Area (LGA) of Kaduna State.

Recommendations

Mitigating soil erosion in Kachia LGA require measures such Adoption of soil conservation techniques such as contour farming, terracing, and cover cropping can reduce runoff and protect the soil. Reforestation and afforestation initiatives can help stabilize the soil and reduce erosion. Implementation of integrated watershed management practices ensures sustainable land and water use in the region. Measures also require a combination of local community engagement, technical solutions, and policy support. Implementing these measures can enhance soil productivity, protect natural resources, and improve the livelihoods of residents in the area.

Also there are some practical and sustainable recommendations for mitigating soil erosion in Kachia Local Government Area (LGA), Kaduna State: such as: Sustainable Agricultural Practices, Vegetation Restoration, Controlled Grazing, Soil Conservation Measures and Improved Land Use

Practices among others. When all these are carefully adhered to, the rate of soil erosion will drastically be minimized.

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