EARTH SCIENCES
RESEARCH JOURNAL
Earth Sci. Res. J. Vol. 27, No. 4 (December 2023): 415 - 424

UNIVERSIDAD NACIONAL DE COLOMBIA

SOILS

Assessment of the extent of soil degradation over different land uses in the Kebbi area, northwestern Nigeria

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ABSTRACT

This paper assessed soil degradation over different land uses in the Kebbi area, Northwestern Nigeria. The specific objectives entailed identifying major forms of soil loss in the study area, estimating soil loss and examining the responses of soil physico-chemical properties over dominant land use types. Slope angles were determined using a GPS, a handheld Abney level, ranging poles and a 30 m measuring tape while gully depths, widths and lengths were taken at 5 m-30 m intervals. Key soil physico-chemical parameters were determined using standard procedures. Descriptive statistics such as mean, standard deviation and coefficient of variation were used to summarize the data generated from the study. The analysis of variance and the student's t-test was used to test for significant association between and within pairs of land uses. The results show that slopes range from 4^0 - 16^0, while the magnitude of soil loss ranged between 3580.32 m^3 in K1 (Kalgo 1), 3550.89 m^3 in G2 (Goru 2) and 161.01 m^3 in A1 (Angwar Daji 1). Results show significance at $p \leq 0.05$ in bulk density values over the different land uses with the highest bulk density value of 1.78 g/cm^3 in badland and lowest value of 1.35 g/cm^3 in plantation land use. Total nitrogen range between 0.01 - 0.38% with the least values in badland and scrubland, while soil base saturation is highest over plantation (76.3%) and lowest in badland (50.4%). The study concludes that the dominant geomorphic responses identified in the study area are gully initiation and development and a varying magnitude of soil degradation over the different land uses. The findings should facilitate policy initiation to rehabilitate degraded lands, adopt sustainable soil management practices such as tree planting while linking geomorphological information to infrastructural planning and development.

Keywords:
Keywords: Estimates, gully characteristics, soil degradation, land uses.

Evaluación de la extensión de la degradación en suelos de diferentes usos en el área de Kebbi, al noroeste de Nigeria

RESUMEN

Este trabajo evalúa la degradación del suelo debido a su uso en el área de Kebbi, al noroeste de Nigeria. Los objetivos específicos implican la identificación de las razones principales de la pérdida de suelo en el área de estudio, la estimación de esta pérdida, y la evaluación de las respuestas de las propiedades físicoquímicas del suelo en los tipos de uso del suelo dominantes. Los ángulos de la pendiente se determinaron con un GPS, un nivelador Abney de mano, balizas, y una cinta métrica de 30 metros mientras que la profundidad de las cárcavas, el ancho y el largo se tomaron en intervalos de entre 5 y 30 metros. Los parámetros fisicoquímicos clave del suelo se determinaron con procedimientos estandarizados. Estadísticas descriptivas como la media, desviación estándar y variación de coeficiente se utilizaron para sintetizar la información generada durante el estudio. El análisis de la diferencia y la prueba t de estudiante se utilizaron para evaluar las asociaciones significantes entre y dentro de pares de usos del suelo. Los resultados muestran que la inclinación varía entre 4^0 y 16^0, mientras que la magnitud de perdida de suelo se estima en 3580.32 m^3 en K1 (Kalgo 1), 3550.89 m^3 en G2 (Goru 2) y 161.01 m^3 en A1 (Angwar Daji 1). Los resultados muestran importancia en los valores de densidad aparente $p \leq 0.05$ sobre los diferentes usos del suelo, con el mayor valor de densidad aparente de 1.78 g/cm^3 en tierras baldías y el menor valor, de 1.35 g/cm^3, en suelos usados para plantaciones. El nitrógeno total varía entre 0.01 – 0.38%, con los menores valores en tierras baldías y matorrales, mientras que la saturación base del suelo es mayor en los suelos plantados (76,3 %) y el menor en tierras baldías (50,4 %). El estudio concluye que las respuestas geomórficas identificadas en el área de estudio son la iniciación y desarrollo de hondonadas y varían la cantidad de degradación del suelo sobre los diferentes usos del suelo. Los hallazgos debería facilitar la iniciación de políticas para rehabilitar suelos degradados y adoptar prácticas sostenibles de manejo de suelos como la plantación de árboles, además vincular la información geomorfológica a la planificación y desarrollo de infraestructura.

Keywords estimaciones; características de hondonadas; degradación del suelo; usos del suelo:

Record
Manuscript received: 14/04/2022
Accepted for publication: 30/01/2024

How to cite this item:
Aminu, Z., Ishiaku, I., Aminu, H. G., Garba, Y. S. (2023). Assessment of the extent of soil degradation over different land uses in the Kebbi area, northwestern Nigeria. *Earth Sciences Research Journal, 27*(4), 415-424. https://doi.org/10.15446/esrj.v27n4.102140

ISSN 1794-6190 e-ISSN 2339-3459
https://doi.org/10.15446/esrj.v27n4.102140

1. Introduction

Soil is an important natural resource that either directly or indirectly supports most of the planet’s life (ILO, 2007). A major function of soil is that it supports food supply, food security and provides the primary source of livelihood for 36% of the world’s total workforce (ILO, 2007). Soil degradation encompasses physical, chemical and biological deterioration and manifests in loss of organic matter, decline in soil fertility and structural condition, erosion and excessive flooding (Doran and Parkin, 1994; Stocking and Murnaghan, 2000). Soil degradation occurs globally but its negative impacts are most felt in regions which depend solely on agriculture for incomes (Swift and Shepherd, 2007). Previous studies (Stocking and Murnaghan, 2000; Aminu and Jaiyeoba, 2015; Bashir *et al*., 2020; Yousaf *et al*., 2021) have documented major causes of soil degradation relating to environmental factors. These relate to rainfall, soil, topography and vegetation characteristics. Rainfall provides energy for sediment detachment from soil surfaces and transportation down slope, causing varying degrees of erosion (Bashir *et al*., 2020). This is because bare or poorly vegetated surfaces when accompanied by substantial variation in elevation and precipitation are highly vulnerable to erosion (Bashir *et al*., 2020).

One of the ways in which soil degradation manifests is through soil erosion. Soil erosion systematically transforms soil into sediments, causing loss of soil and soil fertility (Tekwa and Usman, 2006). Gullying is a serious form of soil degradation with severe consequences for agriculture and environmental sustainability (Tekwa and Usman, 2006). The degradation of forest lands, the development of agricultural land and the conversion of rangelands into rain fed farming is leading to an increase sediment yield (Mohammadi *et al*., 2021).

Land use change has been recognized as one of the main influencing factors of soil erosion and sediment production processes (Mohammadi *et al*., 2021). Although soil degradation processes can occur without human interference, studies have shown that accelerated rates of degradation are often influenced by man’s intervention in natural processes (Aramolaran *et al.,* 2001; Yousaf *et al*., 2021). Inappropriate land use practices have been found to be a major cause of soil degradation, manifesting in land use and land cover changes and increasing the vulnerability of land surfaces to erosion processes (Bashir *et al*., 2020; Yousaf *et al*., 2021). Land use practices which result in land cover changes represent a major source of global environmental degradation (Yousaf *et al*., 2021). Increased pressure on land as a result of increasing world population has led to increased degradation of world soils (Doran and Parkin, 1994; Stocking and Murnaghan, 2000). It is estimated that 33% of global soils are degraded, with over 500 million hectares of tropical soils battered by accelerated erosion and other forms of degradation (Yousaf *et al*., 2021). Rapid urban expansion triggered by population growth has increased the demand for more built-up spaces and agricultural lands. For example, agriculture was found to contribute 82 percent of natural vegetation transformation (Aramolaran *et al.,* 2001). The transformation of natural vegetation has been found to accelerate the soil degradation process by increasing the tendency to bring more marginal lands under cultivation (Aramolaran *et al.,* 2001; Aminu and Jaiyeoba, 2015). In the developing countries, such as Nigeria, human-induced soil degradation has intensified, due mainly to the expansion of agricultural lands into marginal areas, occupied by poor rural households characterized by low incomes and diminishing land productivity (Aramolaran *et al.,* 2001; Aminu and Jaiyeoba, 2015). Soil degradation is a symptom of under-development and results from a combination of factors such as poverty, inequitable distribution of land resources and inappropriate land use systems (Scherr and Yadav, 1996; Bridges and Van Baren, 1997).

Emerging from the soil degradation researches in the last few decades, is an attempt to develop different methods and techniques for effective assessments and monitoring of soil degradation occurrences globally (Wischmeier and Smith, 1978; Stocking and Murnaghan, 2000; Stringer and Reed, 2006; Hamisu *et al*., 2018; Yousaf *et al*., 2021). For example, Mohammadi *et al*. (2021) in an assessment of the impact of land use changes on soil erosion intensity and sediment yield in the Talar watershed of Iran, found that the IntErO model has proven to be a suitable tool for assessing watershed responses to land use changes in terms of peak flow, erosion, and sediment yield, especially in countries with data limitation.

In assessing land degradation in South Africa, Stringer and Reed (2006) observed that scientific methods such as remote sensing and GIS in measurements of soil properties have limitations. They observed that satellite imageries may guide the sampling of fields but are often not as effective as on-field erosion assessment. Similarly, Bashir *et al*., (2020) observed that using evidence-based models for degradation assessments still tend to possess uncertainties such as the potential of bias induced weight and the absence of a spatial scope of the area of interest. However, these uncertainties have the potential of significantly limiting their application. Adopting the land user approach in studying soil degradation provides more practical views of the types of interventions or solutions that are more acceptable to land users (Stocking and Murnaghan, 2000), but apart from being subjective, participatory surveys are slow, expensive and primarily based on contextual analysis often embedded in socio-cultural beliefs which may lead to inaccurate accounts of the extent and magnitude of any environmental change (Stringer and Reed, 2006). Soil loss assessments have been assessed using the Universal Soil Loss Equation (Wischmeier and Smith, 1978) and the Revised Universal Soil Loss Equation (Renard *et al*., 1997). The Universal Soil Loss Equation predicts the long-term annual rate of erosion on field slopes based on the rainfall pattern, soil types, topography, crop system and management practices (Renard *et al*., 1997). Though these equations provide detailed understanding of erosion processes, they have limitations because of the difficulty of generalizing the results due to varying environmental conditions (Mohammadi *et al*., 2021).

Various studies have been carried out in Northwestern Nigeria to assess soil degradation and soil management practices. For example, Mailumo *et al*. (2011) assessed soil degradation using the land user perception and observed that bush burning and excessive cropping were major causes of soil degradation in the region. Usman (2016) used an Integrated Soil Surface Approach (ISSA) which combined a Visual Soil Analysis (VSA) and Digital Soil Analysis (DSA). The study laid emphasis on soil forming factors and surface soil characteristics as major determinants of soil quality. Similarly, Aleiro *et al*., (2018) evaluated soil physical properties and their impact on vegetation status in Kebbi State, using geo-spatial techniques. Although literature exists, there is very limited data on the processes and impact of soil degradation in the study area where many lives and livelihoods depend on agriculture. Thus, while several studies on soil degradation have been carried out in the study area the dynamics and extent of soil degradation are changing with time and there is need for studies which integrate land use change assessments and actual field quantifications to provide a holistic and up to date picture of the problem. Tackling the menace of soil degradation requires an understanding of the rates of the degradation processes as well as identifying major controlling factors which enhance degradation processes. It is against this background that the study aims at an assessment of soil degradation over different land uses in the Kebbi Area, Northwestern Nigeria. The objectives include identifying major forms of soil loss, estimating soil loss and examining the responses of soil physicochemical properties over dominant land uses, with a view to establishing a soil degradation pattern in the study area.

2. Materials and methods

2.1 Study Area

Kebbi State is located on latitude 12° 10’.90”N to 12°40'.00"N and longitude 4°10'.00"E and 4°40'00"E (Fig.1). The climate is dominated by two air masses, Tropical Maritime and Tropical Continental which determine the two dominant seasons of wet and dry. The wet season lasts from April to October in the south and May to September in the north; while the dry season lasts for the remaining period of the year (Aleiro *et al.*, 2018). Rainfall is highly seasonal and varies from over 1000 mm in the southern parts to less than 500 mm in the northern part (Aleiro *et al.*, 2018). Average temperatures range from 21°C to 40 °C between April and June. Relative humidity is generally low (40 percent) for most of the year except during the wet season when it reaches an average of eighty percent.

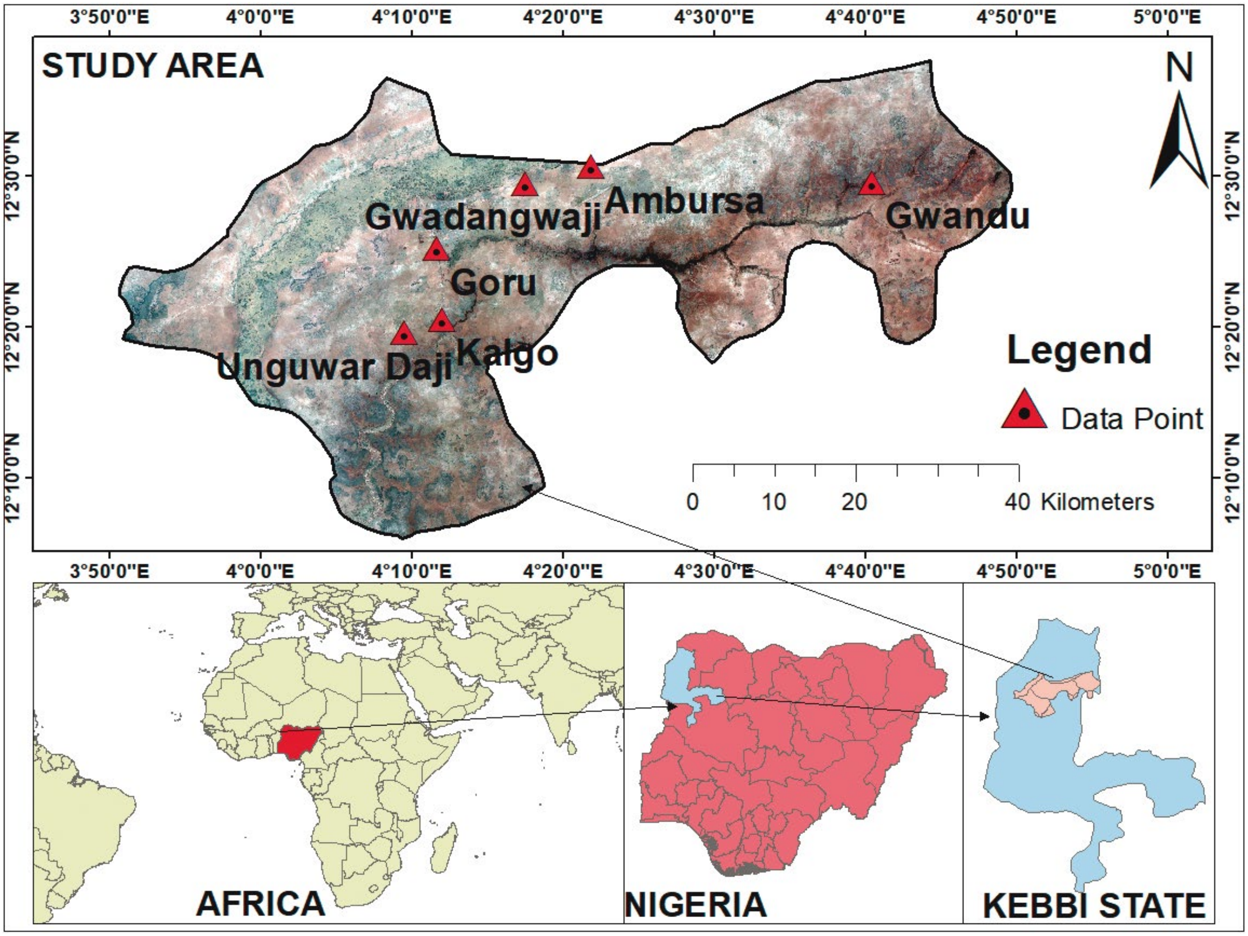

Figure 1. Geographical Location of the Study Area

Source: GIS Laboratory, Department of Geography, Federal University Birnin Kebbi.

The river Rima flows through the sedimentary area into the river Niger in the south west, creating extensive flood plains (Online Nigeria, 2003). Kebbi State can be divided into three relief regions, namely the high plains in the south and southeast, the plain landscape in the north and the riverine lowland of the Niger and lower Rima valleys (Mailumo *et al.*, 2011). The high plains are characterized by dissected crystalline rocks with hill ranges and domical rises (inselbergs). The plain landscape, where the study area is situated, is monotonous lowland and forms part of the vast Sokoto plains. It is sedimentary in origin, with an average height of about 300 m above sea level. The plain surface is interrupted by isolated flat topped lateritic capped hills and ridges. The riverine lowlands are mainly the flood plains of the major rivers (Aleiro *et al.*, 2018). The natural vegetation of the study area is the Sudan Savannah and consists mainly of shrubs and bushes with few trees of economic value such as a*cacia aibida* (gawo) and drum palms (goriba). Dominant soil types are the upland and fadama soils. These two soil groups are generally characteristic of the entire Sokoto Rima Basin. While the upland soils are sandy and well drained, the fadama soils are generally clayey and hydromorphic. Rain-fed agriculture is the dominant economic activity in the study area. However, irrigation farming along wetlands (*fadamas)* also exists and is practiced throughout the dry season with rice as the major crop produced (Usman, 2016; Aleiro *et al.*, 2018). The dominance of agricultural production as the primary socio-economic activity in the study area predisposes the inhabitants to the negative impact of soil degradation.

2.2 *Methodology*

2.2.1 Data collection

Based on the result of a reconnaissance survey, 3 study locations were selected for the study. These are Goru, Kalgo and Ungwar Daji, all located within the Kalgo area and characterized by the same climate, geology and land use types. The study comprised of 2 experimental plots (100 m× 25 m) per land use (plantation, fadama, cultivated, scrubland and badland land uses), giving a total of 30 experimental plots. An inventory of soil loss indicators taken during the reconnaissance survey of the study area indicated that the dominant visual indicators of soil degradation in the study area include rills, gullies, sediment deposition, compaction, tree root exposure and loose soils. However, soil loss estimates were taken over gullies only.

The gully sites were marked with plot sizes 100 m length and 25 m width, respectively. These dimensions were chosen to enable measurements be carried out accurately. Measuring stations were also established at every marked point where successive measurements of slopes, gully length, width, depth and volume of soil loss amongst others were recorded.

2.2.2 Determination of gully morphometry

Field assessments were carried out to determine gully characteristics in the study area. In assessing the contribution of gully occurrence to erosion in a tropical environment, the depth and width characteristics of gullies are critical parameters that determine the dynamics of soil degradation (Bashir *et al*., 2020). Therefore, gully depths, widths and lengths were taken at 5 m-30 m intervals (after Stocking and Murnaghan, 2000; Tekwa and Usman, 2006). Altitudes were taken at the head of each gully using a GPS. Slope profiles along measured gullies were determined using a handheld Abney level, ranging poles, and a 30 m measuring tape. Slope and land use characteristics were described based on field observations.

2.2.3 Soil physicochemical assessments

Soil samples used to determine soil physicochemical properties were drawn from five land use categories identified in the study locations (plantation, fadama, cultivated, scrubland and badland land uses) in June, 2021, corresponding with the start of the wet season. Surface soil samples, at 0-30 cm depth were taken over quadrants established during transect walks. Samples were taken 20 cm apart at four equidistant points for each land use and bulked to form composite samples. Each sample was packed into translucent polythene bags and labelled appropriately. Thus, on the whole, 30 composite samples were drawn and used for the study. Each soil sample was air- dried, crushed and sieved through a 2 mm sieve and used for the assessment of selected soil physicochemical properties using standard procedures. Core samples were analyzed for water content and bulk density gravimetrically, while porosity values were determined from bulk density values, using an assumed particle density value of 2.65 g/cm^3. Particle size distribution was determined using Bouyoucos hydrometer method. Soil pH was determined potentiometrically in 0.1M $CaCl_2$ solution using a soil to solution ratio of 1:2.5. The Walkley-Black digestion method was used to determine the soil organic carbon. Total Nitrogen was determined using macro Kjedahl method, while Available Phosphorous was determined using Bray No.1 method. The cation exchange capacity (CEC) was determined using the ammonium acetate saturation method. The leachate preserved during the CEC determination was used to determine the exchangeable bases (Ca, Mg, K and Na). The percentage base saturation was derived by dividing the sum of the values of the exchangeable bases by the CEC value and expressed as percentage. Similarly, the exchange acidity was determined by extraction with KCl (Agbenin, 1995).

2.3 Data Analysis

Descriptive statistics such as mean, standard deviation and coefficient of variation were used to summarize the data generated from the study. Gully cross-sectional area was computed (after Stocking and Murnagham, 2000) using the formular;

$$A = \frac{1}{2}(W_1 + W_2)d \quad (1)$$

Where; A= gully cross-sectional area, W_1 = average gully width at lip 1, W_2 = average gully width at lip 2, d= gully depth (m)

From eq. (1), the volume of soil loss from the gullies is estimated as:

$$V_L = A \times L \quad (2)$$

Where; V_L= volume of soil loss (m^3), A= gully cross-sectional area, L= gully channel length

The analysis of variance (F-ratio) was used to test for variations in the selected soil properties over the different land uses while the student's t-test was used to test for significant association between pairs of land uses.

3. Results and discussion

3.1 Gully characteristics of the study area

The characteristics of the gully system in the study area are presented in Table 1. A total of ten gully units were identified in the study area and numbered as K1 (1, 2), K2, K3 (1, 2), A1, A2, G1 and G2 (1, 2).

Table 1. Gully characteristics

Gully site	Altitude (m)	Average Width (m)	Average Depth (m)	Cross-sectional area (m^2)	Gully length (m)	Order
K1(1)	191	13.6	5.6	76.2	42.7	2
(2)	203	3.2	4.6	14.7	22.3	1
K2	193	7.4	7.23	54.0	47.3	1
K3 (1)	202	7.72	1.69	13.0	43.0	2
(2)	204	4.6	1.25	5.69	56.8	1
A1	200	3.7	0.98	3.61	44.6	1
A2	209	4.54	2.13	9.66	30.0	1
G1	225	3.81	2.78	10.6	35.8	1
G2 (1)	194	13.6	5.8	78.9	38.9	2
(2)	226	3.5	3.11	10.9	44.2	1

*K= Kalgo; A= Angwar Daji; G= Goru

The gully network labelled as K1 has an elevation of 191 m above sea level and is located on the fringes of the built-up area in Kalgo town. It has a length of 42.7 m and terminates in an artificial drain, 1.3 m away from the highway. K1 is a matured gully characterized by broadly lobed heads, located on a steep slope of 16º. It has an average width of 13.6 m and an average depth of 5.6 m. The gully side walls are dissected by numerous rills which are micro-morphological features with average width and depth of about 0.5 m and 1 m respectively. The presence of several tree-root exposures indicates undercutting by runoff, while loose soils on gully beds indicate soil loss from upslope terrain. The gully is meandering and serves as an ephemeral stream in the rainy season as it receives substantial surface runoff from the built-up upslope terrain. However, it dries out during the dry season and becomes a useful source of sand mining for construction purposes. It is a second order gully which receives runoff water and sediment from a first order gully which has a width, depth and length of 3.2 m, 4.6 m and 22.3 m respectively.

K2 is a discontinuous gully characterized by vegetation such as short grasses and shrubs. It is 193 m above sea level on a steep slope of 16º. The gully unit is fed with runoff and sediment from upslope by small rills which cascade downwards and are enlarged through the process of micro piracy. It covers a distance of 47.3 m with an average width and depth of 7.4 m and 7.23 m respectively. K3 is found on an elevation of 202 m above sea level. It has a length of 43 m, a width of 7.72 m and depth of 1.69 m. It is a network of two gully heads on a strongly sloping profile with sediment deposited on the gully bed to an average depth of 1 m. The A1 gully unit is found on an elevation of 200 m above sea level with a moderately steep angle of 13º, extending to a distance of 44.6 m. It has an average width of 3.7 m and is shallow at 0.98 m. The dominant land use type is a mix of badland, shrubs and stony surfaces. A2 is found on elevation of 209 m above sea level on a moderately sloping terrain of 4º, covering a distance of 30 m. It is a discontinuous gully with an average width and a shallow depth of 4.54 m and 2.13 m respectively. The G1 gully network is located on an elevation of 194 m above sea level. It is developed on strongly sloping terrain of 7º. It is characteristically U-shaped and covers a distance of 38.9 m, with an average width and depth of 13.6 m and 5.8 m respectively. The G2 is on an elevation of 226 m above sea level. It is a second order gully developed on a steep slope of 15º and derives runoff and sediments from the first order gully and a series of micro channels which coalesce to form gullies. Generally, the gullies in the study area are ephemeral and are characterized by micro-piracy, meandering, linear undercutting and formation of grooves in the base and sidewalls (Figure 1).

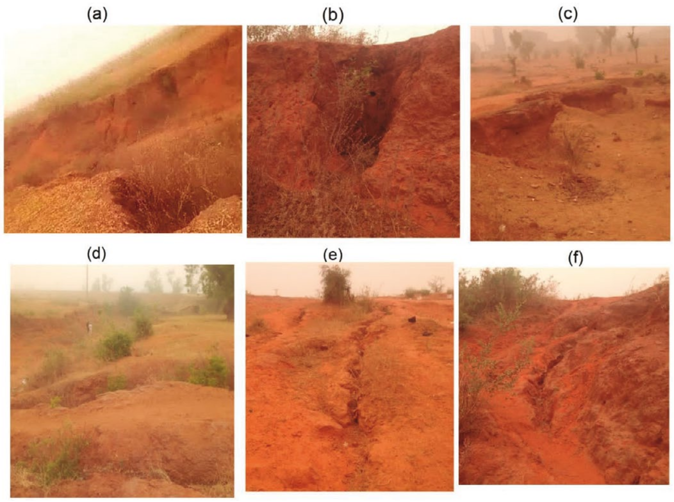

Figure 2. Gully Channel Characteristics in the study Area Meandering within the gully channel **(b)** Groove formation in the gully channel **(c)** Linear undercutting along footpath **(d)** Deeply incised soil surfaces **(e)** Eroded surfaces characterized by micro-piracy **(f)** Movement and deposition of sediment down slope

3.1.1 Slope characteristics

The slope description and characteristics recorded for the study area are presented in Table 2a and Table 2b.

Table 2a. Slope Description

Slope (percentage)	Slope (degrees)	Slope class	Description
0-2	0–1.15	A	Nearly level
3–6	1.72–3.43	B	Gently sloping
7–12	4.00–6.84	C	Moderately sloping
13–18	7.41–10.20	D	Strongly sloping
19–25	10.76–14.04	E	Moderately Steep
26–35	14.57–19.29	F	Steep
>35	>19.29	G	Very steep

(After Fashae *et al*., 2022)

Table 2b. Slope characteristics

Gully site	Slope (Degrees)	Slope Class	Description
K 1	16	F	Steep
	7.0	D	Strongly sloping
K2	16	F	Steep
K3	10	D	Strongly sloping
	11.5	E	Moderately steep
A1	13	E	Moderately steep
A2	4	C	Moderately sloping
G1	7	D	Strongly sloping
G2	15	F	Steep
	7.5	D	Strongly sloping

The results from Table 2a indicate that the study area is characterized by slopes ranging from 4° - 16°. The slope description in Table 2b show that slope classes are moderately sloping, strongly sloping, moderately steep and steep. The slope characteristics have implications for soil degradation as they influence the direction and volume of runoff and soil loss (Tekwa and Usman, 2006; Aminu, 2015). The slope characteristics of the study area explain the depth of sediment deposition on the gully beds in the study area, movement of soil down slope (Figure 2f) and accretion along gully beds. Results from Table 2b indicate that larger gully depths and widths correspond with areas characterized by steeper slopes. Studies by Tekwa and Usman (2006); Aminu *et al.,* (2017) have shown that rill and gully initiation and development are exacerbated by steep slopes as slopes greatly influence the direction of flow of runoff, sediment transport and deposition. Similarly, slope profile characteristics influence soil depth, bulk density (Tekwa and Usman, 2006; Aminu *et al.,* 2017) infiltration and soil moisture retention (Mohammadi *et al*., 2021).

3.1.2 Soil loss

The capacities of the gullies were determined to estimate the volume of soil loss from the gullies and are presented in Figure 3.

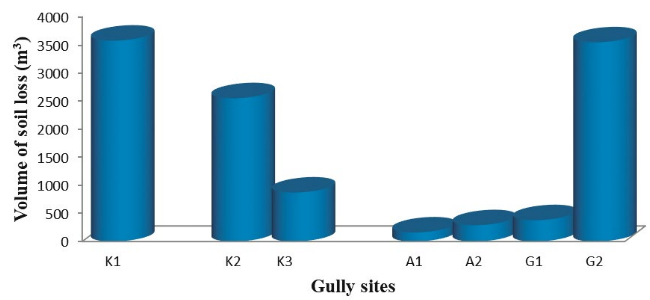

Figure 3. Volume of soil loss across the study area

The gully system with the highest soil loss is K1 with an estimated soil loss of 3580.32 m^3. It is followed by G2 with 3550.89 m^3 and K2 with 2554.2 m^3. K3 has an estimated soil loss of 872.6 m^3, followed by G1, A2 and A1with 379.5 m^3, 289.8 m^3 and 161.01 m^3 soil loss estimates respectively. The results indicate that soil loss estimates were higher in gullies with the highest widths and depths. The higher mean length of the second order gullies studied (Table 1) correspond with greater channel capacities and larger volumes of soil loss as indicated in the three catchments studied. The results also indicated that larger gully channels correspond with steeper slopes and higher volumes of soil loss. Tekwa and Usman (2006) reported similar results while estimating soil loss in Mubi, Northeastern Nigeria as their study found that large soil losses observed in this study area corresponded closely with gully channel sizes. However, Renard *et al*., (1997) observed that though erosion increases with increase in slope length, soil loss occurrences were more rapid with slope steepness than with length. The estimated gully volumes across the respective sites indicate the volume of soil that has been eroded and deposited elsewhere within the basin. The implications of sediment detachment and deposition down-slope include increased accretion (Fashae *et al*., 2022), siltation and pollution of water bodies (Mohammadi *et al*., 2021).

3.2 Physicochemical characteristics of soils under different land uses in the study area

The mean values, standard deviation, coefficient of variation and Analysis of Variance (ANOVA) performed to test for significant differences amongst the various land uses are summarized in Table 3, while Table 4 summarizes results of t-test performed to detect variations in soil physicochemical properties between pairs of land uses. The results show that the mean values of sand over badland is highest (88%) and lowest over plantation (76%) and fadama (62%). Similarly, variation in silt fractions is statistically significant ($p< 0.05$). The mean value of silt is highest over fadama landuse (14%) and least over cultivated land (4.0%). Analysis of variance shows a statistically significant difference ($p< 0.05$) in the silt fraction of soils over the different landuses. The mean values of clay are higher in the fadama landuse and lowest over badland at $p< 0.05$. Soil texture is a fundamental soil property that influences a soil's susceptibility to erosion, its infiltration capacity, moisture and nutrient retention

(Afolabi *et al*., 2014). The dominance of sand fractions predisposes the soil to erosion due to the macro pores, resulting in low moisture retention by the soils and nutrient loss through translocation by soil wash and leaching (Afolabi *et al*., 2014). Yousaf *et al*., (2021) also reported clay fraction loss due to migration down the soil profile and erosion in areas with sparse or no vegetation cover.

The result from the table show statistical significance in bulk density values in soils over the different landuses with the highest bulk density value in badland (1.78 g/cm^3). The lower bulk density value of 1.35 g/cm^3 in the plantation land use could be attributed to higher organic matter content due to litter addition from the vegetal cover (Yousaf *et al*., 2021). Results show soil porosity mean values over the different land uses are generally low as the variation analysis shows a significant difference at p<0.05. Porosity values are also lower than the critical limits of >50% in top 30 cm for normal mineral soils (Malgwi, 2007). Compaction by cultivation, trampling by humans and cattle may also be responsible for the high bulk density and low porosity, particularly over cultivated and badlands. These have implications for infiltration and plant rooting depths (Aminu and Jaiyeoba, 2015).

Moisture content over the respective land uses is generally low and range between 0.003-0.08 g/g. The analysis of variance indicates a significant difference at p< 0.05. Results of t-test analysis show significant difference between plantation/cultivated, plantation/fadama and cultivated/fadama pairs of land uses. The high soil moisture over the plantation land use may be attributed to soil protection from excessive solar radiation by the vegetal cover and the higher organic matter content of the soils. On the other hand, lower soil moisture in the cultivated and badland topography could be due to the low organic matter content, high evaporation rates over exposed soil surfaces and low porosity of the soils (Aminu and Jaiyeoba, 2015). The higher moisture content in the fadama and plantation land uses could be attributed to the higher silt and clay content of the soils. Similarly, the proximity of the fadama landuse to water bodies and the high fraction of soil fines may be responsible for its high moisture content (Aminu and Jaiyeoba, 2015).

The mean value of soil pH is highest over plantation and fadama (6.20) and least over the badland topography (6.00) and cultivated (5.50). The slight acidity of the badland soils may be due to leaching of soil cations which have been found to increase soil acidity (Afolabi *et al.,* 2014; Aminu and Jaiyeoba, 2015; Yousaf *et al*., 2021). Soil organic matter is highest over the plantation landuse (1.68%) and lowest over badland (1.30%) and scrubland (1.25%). Analysis of variance shows a significant difference in soil organic matter at p< 0.05 over the different landuses. The result of t-test analysis shows no significant difference between pairs of plantation/scrubland, scrubland/cultivated, scrubland/fadama and scrubland/badland land uses. The critical limit of organic matter content for soils under natural conditions in the Savannah is ≥ 2% (Esu, 1991; Landon, 1991; Malgwi, 2007; Aminu and Jaiyeoba, 2015). This indicates that all soils over the different land uses are low in organic matter. High organic matter has been found to increase cohesion of soil particles thereby protecting soils from wash processes (Aminu and Jaiyeoba, 2015). The generally low levels of soil organic matter across all land uses is confirmed by similar studies (Afolabi *et al*., 2014) which attributed low organic matter of the study area soils to rapid mineralization of organic matter. Similarly, Yousaf *et al*., (2021) found that erosion and higher oxidative rates were responsible for low soil organic matter in tropical soils. However, the higher organic matter content over plantation land use could be attributed to continuous litter deposition and minimum disturbance (Malgwi, 2007; Aminu and Jaiyeoba, 2015).

Results show that mean values of total nitrogen (TN) range between 0.01 - 0.38%. The highest mean value was in the plantation and (0.38%) while the least values were over badland and scrubland (0.20% and 0.01%) respectively. The higher TN in the plantation land use may be attributed to higher organic matter and higher nitrogen fixation within the land use, while the generally low levels of TN in the badland and scrubland topography may be due to loss of nitrogen through mineralization as a result of high diurnal temperatures, as reported by Madaki (2011) in his study in Gwagwalada area, Nigeria. The result of t-test analysis shows that only the pairs of plantation/ fadama and scrubland/badland showed a significant difference in their total nitrogen content.

For available phosphorous, the highest mean values are in the cultivated (15.3 mg/ kg-^{1}) and fadama (7.85 mg/ kg-^{1}) land uses while the least mean values are in scrubland (3.08 mg/kg-^{1}) and badland (2.10 mg/ kg-^{1}). The coefficient of variation is generally low at less than 50% across all land use categories. Analysis of variance shows statistical differences at p< 0.05 in available phosphorous in all land use types. The higher mean values over the fadama and cultivated land uses may be attributed to the addition of nitrogen and phosphorous bearing fertilizers (Aminu and Jaiyeoba, 2015).

The analysis of variance for Ca shows significant differences exist (p< 0.05) in the respective land uses. The mean value is highest over plantation (3.20 cmol/kg^{-1}) and least over cultivated land use (2.16 cmol/kg^{-1}). The results also show significant differences of exchangeable Mg over respective landuses with the highest concentration over fadama (1.24 cmol/kg^{-1}) and lowest over badland (0.15 cmol/kg^{-1}). The values of exchangeable Na over various land uses showed significant differences (p< 0.05) among land uses. The mean values are highest over plantation and cultivated (0.22 cmol/kg^{-1}), while scrubland and fadama land uses have 0.06 cmol/kg^{-1}. The mean value of exchangeable K shows statistically significant differences (p< 0.05) amongst the land use types. The lower concentration of exchangeable K is in the badland and scrubland has been attributed to leaching (Yousaf *et al*., 2021). The mean values for CEC are homogenous over the different landuses with the highest mean values over plantation (6.71 cmol/kg^{-1}) and least over cultivated land (5.0 cmol/kg^{-1}). Analysis of variability for CEC shows significantly different amounts amongst the land use types. Result of t-test shows significant difference only between the pairs of scrubland/cultivated and fadama/badland land uses. The CEC values across different land use categories are generally low.

However, the higher CEC values over plantation land use may be attributed to organic residues which have been found to increase the CEC content of soils (Oluwadare *et al*., 2013). Mean values of soil exchangeable acidity (H±Al^{3+}) is highest over the badland (0.31 cmol/kg^{-1}) and scrubland (0.29 cmol/ kg^{-1}) while the values over the remaining land uses are homogeneous (between 0.04 and 0.08 cmol/kg^{-1}).). Analysis of variance reveals significantly different values of exchange acidity amongst the various land uses. Result of t-test show no significant difference between most pairs of land uses. Soil base saturation is highest over plantation (76.3%) and lowest over badland (50.4%). The analysis of variance reveals significant differences in base saturation amongst the various landuses, while the t-test result shows significant differences (p< 0.05) between pairs of plantation/scrubland, plantation/cultivated, scrubland/ cultivated and fadama/badland land uses. The lower base saturation over cultivated and badland uses has been attributed to absorption of ions by plants and leaching (Madaki, 2011).

Table 3. Variations of Soil Physical and Chemical Properties Over Different Land Uses

Land uses	Sand %	Silt %	Clay %	Bulk density (g/cm^3)	Porosity %	GMC (g/g)	pH (1:2.5) (soil:H_2O)	Organic matter (%)	TN(g/ kg^{-1})	AP (mg/ kg^{-1})	Ca	Mg	K	Na	CEC	H+AL	BS %
											($cmol/kg^{-1}$)						
Plantation																	
$\overline{x}$	76.0	12.0	12.0	1.35	49.0	0.07	6.20	1.68	0.38	6.42	3.20	1.24	0.46	0.22	6.71	0.06	76.3
SD	52.3	7.8	7.6	0.53	28.7	0.03	3.12	6.65	0.12	2.87	1.88	0.59	0.31	0.18	2.22	0.04	33.1
CV%	68	65	63	39	58	49	50	61	32	45	59	48	67	81	33	67	43
Scrubland																	
$\overline{x}$	86.0	6.0	8.0	1.75	34.0	0.003	5.90	1.25	0.20	3.08	3.00	0.60	0.11	0.06	6.50	0.29	58.0
SD	45.4	3.5	3.36	0.53	20.2	0.022	2.32	0.54	0.16	1.01	1.9	0.27	0.07	0.02	4.4	0.12	28.7
CV %	52	58	42	30	59	67	39	43	80	33	63	45	63	33	67	41	48
Cultivated																	
$\overline{x}$	80.0	4.0	16.0	1.53	42.3	0.041	5.50	1.32	0.31	15.3	2.16	0.72	0.34	0.22	5.00	0.08	69.0
SD	55.2	2.56	9.3	0.66	23.3	0.025	2.22	2.34	0.16	6.77	1.13	0.51	0.15	0.14	3.43	0.05	28.2
CV%	69	64	58	43	55	60	40	60	51	44	52	70	44	63	68	63	41
Fadama																	
$\overline{x}$	62.0	14.0	24.0	1.45	45.3	0.079	6.20	1.40	0.28	7.85	3.11	0.82	0.19	0.06	6.00	0.07	70.0
SD	43.1	8.5	19.3	0.88	29.1	0.048	2.81	5.33	0.10	2.88	1.91	0.56	0.08	0.04	2.94	0.03	41.1
CV%	69	61	80	60	64	60	45	68	35	37	61	68	42	66	49	43	58
Badland																	
$\overline{x}$	88.0	6.0	6.0	1.78	33.0	0.003	6.00	1.30	0.01	2.10	2.34	0.15	0.10	0.08	5.30	0.31	50.4
SD	47.7	2.2	2.8	1.52	13.5	0.001	4.9	1.01	0.01	1.01	1.52	0.08	0.05	0.03	2.22	0.2	30.1
CV%	54	36	46	85	41	33	81	77	81	48	64	53	50	37	42	64	59
ANOVA	4.61	3.85	6.17	3.51	5.73	3.47	3.66	7.19	4.03	3.92	3.15	3.33	4.20	5.02	3.77	3.45	3.08
Level of sig	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

$\overline{x}$ = mean, SD= standard deviation, CV%= coefficient of variation, Level of significance: **=0.05
Source: Laboratory Analysis (2021)

Table 4. Result of Student's t-test Analysis Between Pairs of Land Uses

Land uses	Soil Properties																
	Sand %	Silt %	Clay %	Bulk density (g/cm^3)	Porosity %	GMC (g/g)	pH (1:2.5) (soil:H_2O)	Organic matter (g/kg-^{1})	TN (g/kg-^{1})	AP (mg/kg-^{1})	Ca	Mg	K	Na	CEC	H+AL	BS%
											← (cmol/kg^{-1}) →						
PL/SCR	-1.78 **	-0.80 **	-3.28	-3.25	-0.04 **	7.9	-2.30	-2.92	7.84	-3.30	0.59 **	-0.38 **	-0.37 **	-7.39	6.57	-3.34	1.18 **
PL/CU	0.02 **	-0.11 **	-0.59 **	-3.25	-0.44 **	1.67 **	-2.17 **	-0.27**	4.6	-0.02 **	-0.89 **	3.05	-3.27	-1.49 **	6.64	0.06**	-0.59 **
PL/FA	0.1 **	-0.45 **	1.31 **	4.35	0.62 **	1.32 **	-0.90 **	0.65**	2.03 **	-2.00 **	0.41	2.55	-3.87	-1.59 **	4.26	-3.34	2.49
PL/BA	-1.57 **	-4.96	-2.43	6.35	-3.05	-6.5	5.01	1.46 **	7.87	0.70 **	0.76	0.96 **	-2.17 **	-6.00	2.66	0.26 **	2.61
SCR/CU	1.8 **	0.69 **	2.69	4.94	-0.40 **	-6.23	0.13 **	2.65	-2.89	3.28	-1.48	3.43	-2.90	5.90	0.07**	3.4	-1.77 **
SCR/FA	1.88 **	0.35 **	4.59	7.60	0.66 **	-6.58	1.40 **	3.57	-6.44	1.30 **	-0.18 **	2.93	-3.50	5.80	-2.31	0.01 **	1.31 **
SCR/BA	0.21 **	-4.16	0.85 **	9.6	-3.82	-14.4	7.31	4.28	0.03 **	4.00	0.17 **	1.37 **	-1.80 **	1.39 **	-3.91	0.01 **	1.43 **
CU/FA	0.08 **	-0.34 **	1.90 **	2.66	1.06 **	-0.35 **	1.27 **	0.92 **	-3.55	-1.98 **	1.30 **	-0.50 **	-0.60 **	-0.10 **	-2.38	-3.40	3.08
CU/BA	-1.59 **	-4.85	-1.84 **	4.66	-2.61	-8.17	7.18	1.64 **	2.92	0.72 **	1.65 **	-2.09 **	1.10 **	-4.51	-3.98	0.20 **	3.20
FA/BA	-1.67 **	-4.51	-3.74	2.00 **	-3.67	-7.82	5.91	0.7**	6.47	2.70	0.32 **	-1.59 **	1.70 **	-4.41	-1.6 **	3.60	0.12 **

PL= plantation, CU= cultivated land, SCR= scrubland, FA= fadama, BA= badland
Level of significance: *=0.05
Source: Laboratory Analysis (2021)

4. Conclusion

This study assessed soil degradation over different land uses in the Kebbi Area, Northwestern Nigeria. Major land use types are cultivated, fadama, plantation, scrublands and badlands. Findings from the study show a varying magnitude of soil degradation over different land uses in the study area. The dominant geomorphic response identified in the study area is gully initiation and development on bare or sparsely vegetated areas and cultivated lands. The study observed the presence of several discontinuous and second order gullies in the study area; these are ephemeral and evacuate storm runoff in the study area. The high gully frequency in the study area has implications for drainage density as it has the potential to exacerbate storm runoff and soil loss. Although drainage density was not considered in this study, it indicates how dissected a basin is by channels and affects runoff and sediment transport (Ofomata, 2009). Similarly, slope angles significantly influenced runoff and soil loss as estimates of soil loss were significantly higher over steeper slopes. The soils in the study area are characterized by low organic matter and high bulk densities while the dominance of sand fractions predisposes the soil to low moisture retention and nutrient loss by soil wash and leaching.

Soil characteristics, land use and steep slopes combine to make many areas erosion-prone as supported by studies (Aminu *et al*., 2017; Bashir *et al*., 2020) which have found that cultivation on slopes and loose soils exacerbate erosion and makes soils vulnerable to degradation. This vulnerability is affected not only by factors such as topography and soil properties but also by human influence (Stocking and Murnaghan, 2000). The destruction of soil structure and texture associated with deforestation, grazing and poor agricultural practices help create conducive conditions for the development of gullies which often begin in the form of sheet or rill erosion and eventually capture the available drainage channels (Aminu *et al*., 2017; Bashir *et al*., 2020). The study found that topography, soil properties and land use/vegetation cover mutually re-enforce fluvial and geomorphological processes which lead to soil degradation.

In a developing country such as Nigeria, soil degradation assessment is crucial for food security, environmental management and sustainable development. Soil degradation assessment through combined soil loss estimation and soil physicochemical assessments is useful as it provides site specific results for effective management and remediation. Although this study has provided baseline data on the extent of soil degradation in the study area, only one wet and dry season was considered. Future studies may consider a temporal and spatial expansion of the study, while taking into consideration the history of the dominant geomorphic processes in the study area. The study recommends linking geomorphological information to infrastructural planning and development, reclamation and rehabilitation of degraded lands, adoption of sustainable soil management practices such as tree planting, structural barriers, cross-slope farming and other cropping systems that will provide maximum protection for soils to prevent soil degradation.

Acknowledgement

The authors acknowledge the funding from the Tertiary Education Trust Fund (TETFund, Federal Government of Nigeria) through the award of the TETFund Institution- Based Research Grant (IBR) 2020.

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