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An Overview on the Causes and Spatial Pattern of Erosion in Katsina State, Nigeria

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Abstract: This paper presents an overview of the major causes of erosion and the spatial pattern of erosion in the Katsina region. The factors that cause erosion are mostly climatic, environmental and anthropogenic. The factors operate together depending on the environmental circumstances and time. Climate, geology, soil character and vegetation or land cover characteristics are the important influences on erosion. The climatic factors that influence runoff and erosion in the Katsina region are precipitation, temperature and wind. Precipitation is obviously, by far, the most important. The entire Katsina region has generally very 'hard' rainfall associated with tropical thunderstorms but differences do exist between the northern and southern parts of the region. In the southern part, around Funtua, Temperature and Rainfall average 24.8 °C and 1024 mm respectively, while in the northern part around Daura, the Temperature and Rainfall average 28.8 °C and 578 mm per annum respectively. Vegetation cover also decreases from north (Sudan Savannah) to south (Guinea Savannah). These might have affected the soil characteristics and land-use to some extent as the situation has facilitated erosivity of the regional soils. Slope length and steepness also play some role in erosion event in the region. In terms of soil erodibility, the southern parts of the Katsina region stand an advantage due to the better conditions of soil. The study reveals that all the types of erosion identified in the region could be found in all locations regardless of the little differences in climatic and environmental conditions. The extent of erosion facilitated by high rainfall duration and slope angle in the southern parts of the region, around Dandume and Sabuwa, is equitable by the bare surfaces and loose soil conditions in the northern parts of the region. In spite of the fact that erosion is widespread in the region, there are areas identified as prominently more devastated by erosion menace, particularly gulley erosion. These erosion sites are found along major roads, in farmlands and even in settled areas as either extension of burrow pits or river expansion. Rills and gullies that flourish along the channels are largely responsible for the expansion of some depressions and elongation of stream channel networks.

Key Words: Erosion, Overview, Katsina State, Spatial pattern

INTRODUCTION

There are reports of accelerated erosion in sub-Saharan Africa between 1960's and 2000, and this is explained by the ongoing land use intensification. Land use intensification is recorded in form of the expansion of the cultivated land and the disappearance of the fallow system in many places (Junge and Stahr, 2006), as well as the degradation of the traditional agro forestry farmed parkland system of the unified management of scattered farm trees and crops. A transect survey from the derived Savanna to the northern Guinea Savanna of Nigeria showed land use intensification and accelerated erosion in the same years, 1960;s and 2000. In northern Nigeria, sheet erosion exposed iron-pan on lower slopes and destroyed farmland in some studied villages (Junge and Stahr, 2006).

Soil erosion is one of the major problems confronting agriculture worldwide. It is a major threat to the soil resource, soil fertility, productivity, and food and fibre production, mainly on farm and range lands. Although the problem is as old as settled agriculture, its extent and impact on human welfare and global environment are more now, than ever before. (Gujral, 1984). At present, it is the single most important environmental degradation problem in the developing world, especially the tropics (Ananda and Herath, 2003). United Nations (UN) Convention to Combat Land Degradation (CCD) opines that soil erosion automatically results in reduction or loss of the biological and economic productivity and complexity of terrestrial ecosystems, including soil nutrients, vegetation, other biota, and the ecological processes that operate therein (Claassen, 2004).

According to FAO 1978, many African countries have already lost a significant quantity of their soils to various forms of degradation. Many areas in the continent are said to be losing over 50 tonnes of soil per hectare per year. This is roughly equivalent to a loss of about 20 billion tones of Nitrogen, 2 billion tones of Phosphorus and 41 billion tones of potassium per year. Serious erosion areas in the continent can be found in Sierra Leone, Liberia, Guinea, Ghana and Nigeria among others.

Main Causative Agents of Erosion in the Katsina Region

In most incidences, it is concluded that agents of erosion are those mainly triggered by elements of climate. It has been mentioned in many studies that the agents are particularly water and wind, whereas all other contributing factors linger around the major agents and are regarded as influencing factors. The factors that cause erosion are well known to be originating from different prevailing conditions in an ecosystem. These factors are mostly climatic, environmental and anthropogenic. The factors operate together depending on the environmental circumstances and time. Climate, geology, soil character and vegetation or land cover characteristics are the important influences on erosion, but the relationships between the factors which influence erosion are very complex. Vegetation, for example, is dependent on climate and on soil. Vegetation in turn influences soil development and soil properties and protects soil from erosion. In the Katsina region, the factors are many and diverse in their nature.

Factors contributing to erosion in the Katsina Region

The climatic factors that influence runoff and erosion in the tropics and in the Katsina region are precipitation, temperature and wind. Precipitation is obviously, by far, the most important. Temperature has an effect on runoff by contributing to changes in soil moisture between rains. The wind effect, which is fairly common in the northern fringes of the region, provides the power to pick up and carry fine soil particles. It also affects the impact of raindrops on the soil.

As mentioned earlier, the factors contributing to erosion operates side by side with the major causative agents. For example, water erosion occurs when raindrops hit the ground and dislodge soil particles from the soil. These dislodged soil particles are washed away and in the process dislodge and remove further soil particles. The amount of erosion is thus a function of the following four factors: the rainfall energy, the vegetative cover, the length and steepness of the slope and the type of soil (Stocking, 1987).

The rainfall energy is the kinetic energy which falling raindrops have and is used for impacting the soil. This energy is a product of the mass (i.e., the size) of the drop as well as the speed at impact. The higher the origin of the rain drop, the more its impact speed. The bigger the drops, and thus the 'harder' the rainfall event, the more energy is released to the soil (Stocking, 1987). As an example, a normal raindrop of about 2 mm in diameter will fall with a terminal velocity of 6.4 m/sec (Smith & Wischmeier, 1962).

The entire Katsina region has generally very 'hard' rainfall associated with tropical thunderstorms compared to the southern part of the country, but differences do exist between the northern and southern parts of the state which form the region. This has been classified by Koppen as having two climate types which division has north-south orientation. In the southern part, in Funtua, Temperature and Rainfall average 24.8 °C and 1024 mm respectively, while in the northern part around Daura, the Temperature and Rainfall average 28.8 °C and 578 mm per annum respectively. This little variation in the climatic condition also offers a kind of differences in the power of raindrops which increases from north to south in the region and thereby influences the tendency of initial erosion incidence. In other word, the northern part is marked with higher rainfall intensity and lower duration "favourable for faster erosion" whereas the southern part is marked with lower intensity and higher duration, "condition for slower erosion".

The rainfall characteristics described impact on erosion proportional to erosive and/or erodible nature of the soil across the region. For example, using the regression formula of Bisal (1960), it can be calculated that a raindrop will dislodge approximately 2.35g of soil on a sandy loam (typical for Katsina and the central parts of the region). A bigger drop of 3 mm diameter will fall with a terminal velocity of 7.8 m/sec and will dislodge 4.7 g of soil on the same soil type. During heavy rains, with an average drop size of 4 mm in diameter, each drop will fall with a terminal velocity of 8.6 m/sec and will dislodge as much as 7.2 g of soil!

In another scenario typical of the northern parts of the Katsina region, on the same soils, devoid of vegetation and on fairly flat slopes, some 1.10 t/ha of soil will be washed away in a season with only 250 mm of rainfall. In a season with say 500 mm rainfall, an estimated 12.72 t/ha of soil will be washed away from the same site. This is based on using the estimations in the work of Stocking, (1987).

The above description hints on the environmental factors, in relation with the climate that can be considered as very convenient basis for erosion studies in the Katsina region. This is because all the climatic and environmental variables are displayed in the region in conformity with its stretch from south ($11^0$00'N) to north ($13^0$25'N). Apart from rainfall amount and intensity described above, vegetation cover also decreases from north (Sudan Savannah) to south (Guinea Savannah). These might have affected the soil characteristics and land-use to some extent as the situation has facilitated erosivity of the regional soils.

Erosivity is the potential ability of a process to cause erosion. For specified soil and vegetation conditions, one storm can be compared with another and a quantitative scale of values of erosivity created.

The relief of Katsina region is generally described as relatively plain, yet, slight differences can be marked. The relief of the region ranges from an average height of 450m to about 650m above mean sea level on the typical plains and it rises to as much as 750m at the rare isolated hills and rock outcrops found in some locations.

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The inclination of the relief of Katsina can be depicted by the stretch of the region from north to south. The southern fringe of the region rises up to as high as 700 metres above mean sea level and with an average of 550 metres in the low laying areas. The area slants towards the north and northwest across Bakori and Kankara to the central areas of Safana, Dutsin-ma and Kankia. The relief of this part of the region ranges from 450m to 560m above mean sea level. From the central part, the topography continues descending across Katsina Local Government Area to Jibia and Kaita areas. At this point, the altitude falls to as low as 450m above mean sea level on the average (Ibrahim, 2013).

Slope length and steepness also play some role in erosion event in the region to a certain extent. Gravity is the driving force: The steeper the slope, the faster the water can move. The faster water moves, the more soil particles it can take along, and the more additional soil particles that can be dislodged. The steeper the slope angle, the more erosion that will take place.

Erodibility is the vulnerability of a soil to erosion. For a given rainfall conditions, one soil can be compared quantitatively with another and a scale of erodibility created. Erodibility is usually thought of in two parts which include the characteristics of the soil and the effect of treatment of the soil beneath land use**.**

Coarse sand particles present enough pore spaces for water to infiltrate. Finer sand and silt particles provide less inter-particle spaces and by way of compaction reduce their ability to take up water. This makes fine sandy and loamy soils more erodible than coarse sands. This is typical of the soils of northern and central parts of the Katsina region because sandy soils have little or no structure; this is an indication that no binding forces exist between the soil particles. Such soils are thus inherently very erodible.

In terms of soil erodibility, the southern parts of the Katsina region stand an advantage due to the better conditions of soil formation. The soils in the south have more of clay and clay-loam particles. The clay particles are the smallest particles of all and are strongly bound together by colloidal forces, making dislodging of particles extremely difficult. The southern of the region is, therefore, likely to have less erosion in comparison with the north, though slope is on their disadvantage.

The discussion so far on factors of erosion in the Katsina Region can also be expressed in a summarized descriptive equation as:

E = f(C, T, R, V, S,...[H],...)

Where C= climate, T = topography, R = rock type, V = vegetation, S = soil character, to which further factors such as human interference (H) may be added. The human factor dominates through modifying other factors, as when land use is changed. Topography is modified by land forming, landscaping, conservation, and infrastructure development and soils are changed by the chosen husbandry. Human disturbance has disrupted the balance between soil formation and soil erosion in many parts of the Katsina region, where soil development hitherto has taken place under natural vegetation at a rate greater than the rate of erosion. In some areas it is plain that because of an impenetrable layer below the soil, there have been no significant net erosion over many thousands of years or the soil would have disappeared by now.

Spatial Distribution of Gullies and Erosion Sites

From what has been learnt so far on causative agents and factors facilitating erosion in Katsina region, it is not surprising to have found erosion sites evenly spread across the region. The physical survey reveals that all the types of erosion identified in the region could be found in all locations regardless of the little differences in climatic and environmental conditions. The extent of erosion facilitated by high rainfall duration and slope angle in the southern parts of the region, around Dandume and Sabuwa, is equitable by the bare surfaces and loose soil conditions in the northern parts of the region, around Daura and Baure. Such conditions in the central parts of the region, for example, around Dutsin-ma and Safana, plays a significant role in making erosion incidents more common and wide spread in that part of the region. In other word, this is due to the fact that most of the conditions found active in the extreme south and extreme north of the region are moderately found active in the central part. For example, the impact of slope on erosion is seen in areas around Matazu and Musawa. Soil erodibility is perceived in areas of Charanchi and Bindawa. High rainfall intensity is perceived in areas of Kankara and Dutsin-ma while the impact of bare surface is common in areas around Kankia across Kusada and Ingawa.

In spite of the fact that erosion is widespread in the region, there are areas identified as prominently more devastated by erosion menace, particularly gulley erosion. These erosion sites are found along major roads, in farmlands and even in settled areas as either extension of burrow pits or river expansion. Rills and gullies that flourish along the channels are largely responsible for the expansion of some depressions and elongation of stream channel networks.

In the course of field survey for this work, a number of spectacular erosion/gully sites were identified and studied across the study area. The spatial distribution of this gullies studied is shown in a map of the study region presented here as figure I.

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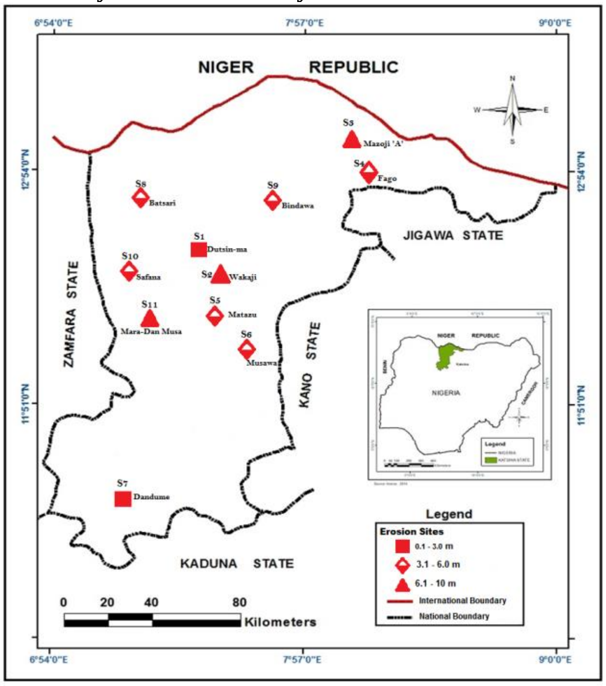
The basic geometric variables of the gullies were obtained using appropriate techniques in the field alongside their absolute and relative locations. Table I presents the results of the measured erosional features and the relative locations of the selected gully sites studied and are also displayed in the figure I.

Table I: Location and Geometric Characteristics of Selected Gullies in the Study Area

S/N	Site	Relative Location	Lat. Location	Long. Location	Elevation (m)	Mean Width (m)	Mean Depth (m)	Cross Section (m^2)	Gully Shape
1	S1	Dutsin-ma	12º26'27"	7º30'21"	522	04.5	02.2	09.9	V-Shape
2	S2	Wakaji	12º25'12"	7º31'20"	504	14.6	06.1	87.6	U-Shape
3	S3	Mazoji A.	12º98'75"	8º24'90"	528	04.8	08.6	41.28	V-Shape
4	S4	Fago	12º18'19"	7º43'46"	513	03.6	03.2	11.5	V-Shape
5	S5	Matazu	12º13'41"	7º40'41"	532	13.0	05.5	71.5	U-Shape
6	S6	Musawa	12º08'09"	7º39'15"	573	05.0	03.7	18.5	V-Shape
7	S7	Dandume	11º47'16"	7º12'69"	635	08.8	02.8	24.6	U-Shape
8	S8	Batsari	12º08'13"	7º33'57"	486	11.0	04.5	49.5	V-Shape
9	S9	Bindawa	12º20'41"	7º29'47"	507	08.0	04.4	36.0	V-Shape
10	S10	Safana	12º41'08"	7º41'56"	546	13.2	05.2	68.6	U-Shape
11	S11	Mara - Danmusa	12º25'37'	7º29'29"	567	06.4	07.6	48.64	U-Shape

Source: Author's field work 2018

FigureI: Map showing some Gully sites in the Study Area



Source:Administretive Map of Nigeria NASRDA. 2014

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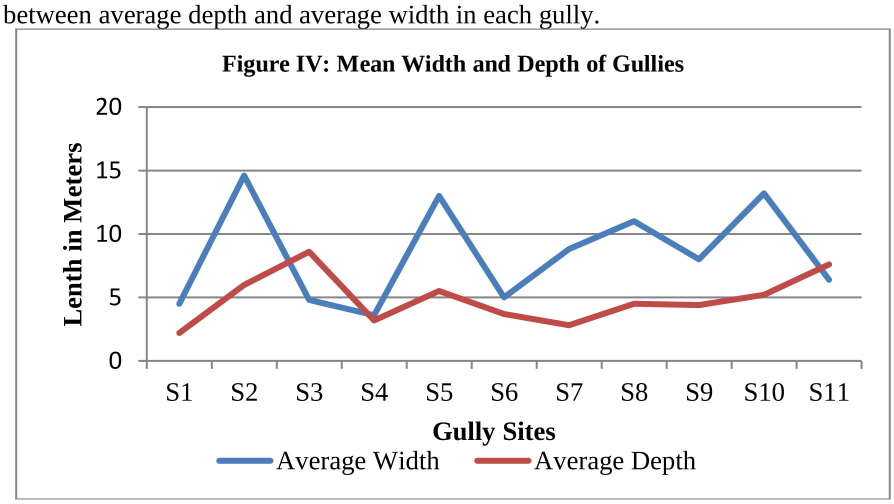
Figure II: (S1) Sample of Gulley Erosion at Dutsin-ma

Figure III: (S2) Gulley Erosion along at Wakaji along D/ma-Wakaji Road

Table I shows that among the gullies studied in the field, site S_2 at Wakaji is the largest in size as well as in mean depth and width. It appears to be a spectacular u-shaped gully with sides more or less like a cliff with a depth of up to 6 metres. This is followed by site S_{10} which has 68.6 meters cross section and yet is the widest but very narrow in proportion to the width. The smallest gully in cross sectional area is S_3 with only 4.7 meters square. These characteristics of the gullies are also depicted in figure IV below with a clear inter-relationship between gullies and intra-relationship between average depth and average width in each gully.



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From the general results in the table it is observed that gullies are distributed in the study area regardless of location, climate or with physical features. It is therefore, possible to believe that local conditions and anthropogenic factors dam are the important determinant factors for the differences in the magnitude of erosion across the study area.

CONCLUSIONS

The climatic factors that influence runoff and erosion in the Katsina region are precipitation, temperature and wind. Precipitation is obviously, by far, the most important. The entire Katsina region has generally very 'hard' rainfall associated with tropical thunderstorms but differences do exist between the northern and southern parts of the region. Vegetation cover also decreases from north (Sudan Savannah) to south (Guinea Savannah). These might have affected the soil characteristics and land-use to some extent as the situation has facilitated erosivity of the regional soils. Slope length and steepness also play some role in erosion event in the region. In spite of the fact that erosion is widespread in the region, there are areas identified as prominently more devastated by erosion menace, particularly gulley erosion. These erosion sites are found along major roads, in farmlands and even in settled areas as either extension of burrow pits or river expansion. Rills and gullies that flourish along the channels are largely responsible for the expansion of some depressions and elongation of stream channel networks.

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