Interactive Evaluation of Soil Erosion using Soil Loss Equation and Interviews in the Desertification Prone Katsina State of Nigeria

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Abstract- The paucity of knowledge by the majority of the rural farmers has made information on soil erosion difficult to perceive. The problem, however, can be overcome by using predictive models for planning, assessment and extension purposes. The objective of this paper was to predict soil loss by the methods of USLE and interview the farming families. The study showed that the factors that determined the rate of soil loss in the study area were the Topographical Factor and the Soil Erodibility of the different textural classes. There was agreement between the conclusions of the USLE and the responses of the farming families and the community leaders. This Sahel Savannah Agro-ecological zone has the highest rate of soil loss with the three observation sites recording 68.5 t/ha/year, 69.9 t/ha/year and 69.6 t/ha/year, respectively. Thus the total average of 69.3t/ha/year. The Northern Guinea Savannah followed at the rates of 53.5t/ha/year, 59.2t/ha/year and 56.1t/ha/year respectively for the three observation sites with a total average of 56.3t/ha/year. The Sudan Savannah sites revealed a soil loss rate of 46.7t/ha/year, 59.2t/ha/year and 53.5t/ha/year respectively at a total average of 53.1t/ha/year. The study concluded that there was a significant soil loss in the desertification prone State of Katsina, hence bringing knowledge on the extent of the soil loss in the area. This data is instrumental in informing future interventions.

Index Terms- Land Degradation, Soil Erosion, Tolerance Value, Rural Farmers, Agriculture.

I. Introduction

Soil erosion is one of the critical processes which signifies a reduction in the nutrient status of the affected zones – in contrast to the depositional sites [1, 2,3] and provides a means of characterizing desertification in time and space. Exploitative cropping is perceived to cause soil degradation. The agents could be water, wind or both. The soil degradation impact, is its major constraint for production, for both crops and natural vegetation [4].

In water erosion, the rain drops falling on bare soil breaks the structure of the surface soil, detaching and dispersing the particles. If the land is sloping and water cannot be immediately absorbed by the soil or detained by microtography, the water moves off down the slope in the form of run-off carrying dislodged particles with it [3].

The USLE is a convenient way to predict the long-term average annual rate of erosion on field slopes, based on the rainfall pattern, soil type, topography, crop system and management practices [5]. USLE only predicts the amount of soil loss that results from sheet or rill erosion and does not account for additional soil losses that might occur from gully or tillage erosion. Some case studies in the continent that employed USLE method, include [6] to determine soil loss due to sheet and rill erosion in Morocco; and [7] in their study of the Condo eroded area in Tanzania. USLE is popular because it (i) combines acceptable accuracy with relative simplicity (ii) can use quite basic data, and (iii) the model relies on a global (i.e. Worldwide distributed) dataset [8,9,10,11].

The K Factor of the USLE is the most important measure of erodibility and can be estimated from simple soil properties by a nomograph [2].

The study objectives addressed gaps in knowledge for Katsina State. Hence the objectives were to: i) to determine soil losses in three agro-ecological areas of the Sahel, ii) to document land degradation process in the study area, hence providing knowledge on the extent of the problem; and iii) to compare results of the USLE with farmers' perceptions for validity and contrasting the traditional and modern scientific knowledge systems. Thus the study's contribution is to contribute precise data on the land degradation process. Hence, this will add to documented knowledge on effects of soil erosion in terms of soil loss for Katsina State in Nigeria.

II. MATERIALS AND METHODS

Description of the Study area

Katsina State lies in the semi-arid region of Nigeria[13], and it is predominantly an agricultural state with over 75% of the population involved in agriculture [14]. The state covers an area of 24,192 km^2. Physically, the State is made up of undulating plains that generally rise gently from 360m in the northeast around Daura, to 600m around Funtua in the southwest. The two main geological regions are - . the southern and central parts which are underlain by crystalline rocks of the basement complex, but in the northern parts cretaceous sediments overlap the crystalline rock. The Katsina –Daura plains are at a lower base level than other parts of the state. Southwards of the Katsina-Daura plains is a flat and gently undulating surface which manifests long periods of surface erosion.

In the southern parts of the State, the soil cover is largely clay of about 5 meters in depth. The soil exhibits smectitic properties - becoming waterlogged with heavy rains, dries/cracks down during the dry season. Subsistence rain-fed farming is the common economic activity in the area and fragmented farmland forms the dominant land use pattern[15]. In the north, the drift deposits are coarser, resulting in light sandy soils of buff or reddish color with medium fertility, and suited for millet and guinea corn. The State falls into two climatic zones: the tropical continental and the semi –arid continental. The southern part of the state belongs to the former with annual rainfall ranging from 1000mm around Funtua to over 800mm around Dutsinma (Figure 1). The north of Katsina has total rainfall figures ranging from 600mm-700mm annually.

Field observation sites – their choice, field analysis and results

Following a reconnaissance survey, three (3) selected observation sites were randomly selected in Mai'adua, Charanchi and Funtua Local Governments representing the three agro-ecological zones (of Katsina State. The field observation sites are fairly representative of the larger part of each of the agro-ecological zones. The following steps were taken to select a representative site for observation (1) conducted a investigation of the intended study areas using available maps and remote sensing images and previous studies and reports that elucidated any major erosion features, their place in the landscape and their association with recognizable land uses in the area.(2) The representative sites in the various land use types (LUT) in the area (e.g. Cropping land, forest) was sought for, and (3) led by locals who live or work in the area (i.e. Farmers) to those areas that they believed were most degraded, or on which they are most dependent (e.g. For food production, forest replanting etc.) Additionally/alternatively, the previously eroded areas that have been effectively restored through effective management measures. A representative site was then selected.

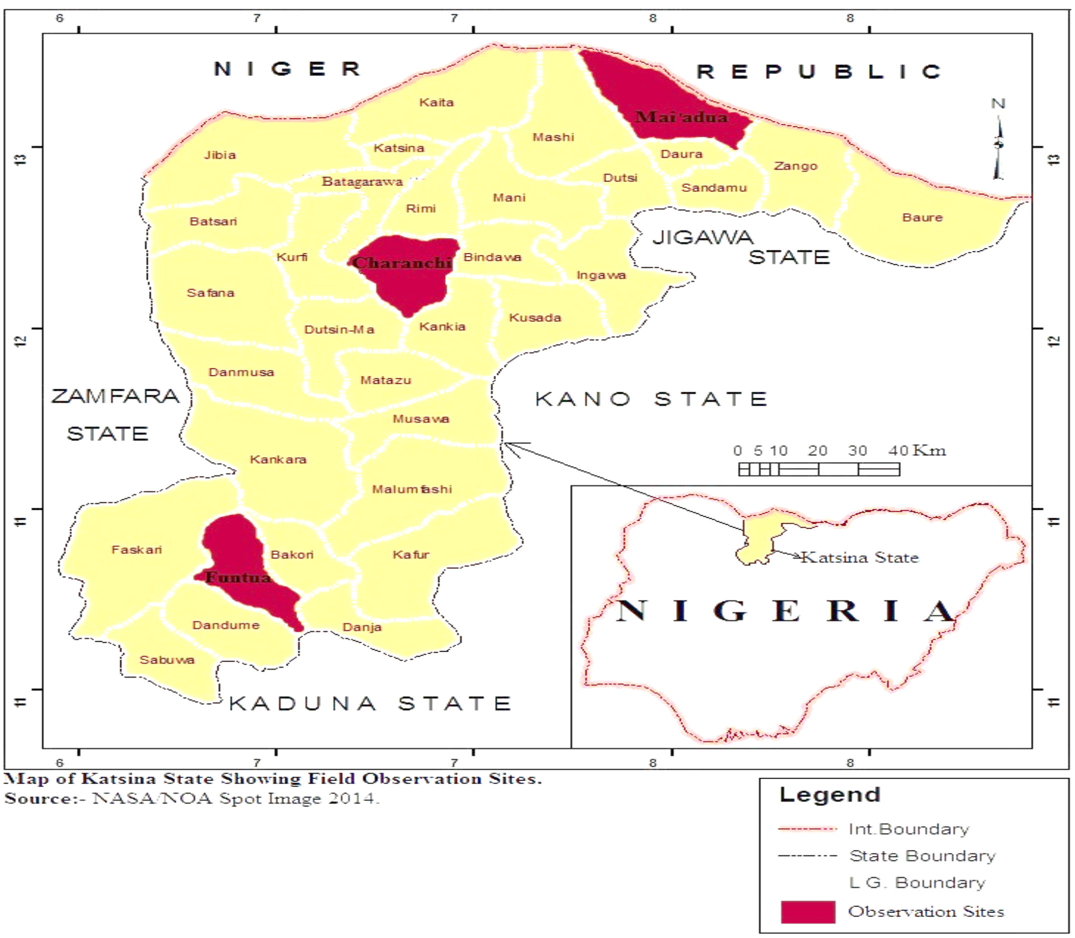


Figure 1 Map of Katsina State showing Field Observation Site

Source: NASA/NOA Spot image (2014)

The Rate of soil loss was determined using the Universal Soil Loss Equation (USLE) following the formula: A=KR (LS)

Values for different soil textures			
			Organic
matter content (%)			
Textural Class	0.5	2.0	4.0
Fine Sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand loam	0.12	0.10	0.08
Very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Very fine sand loam silt	0.47	0.41	0.33
Clay loam	0.48	0.42	0.33
Silty clay loam	0.28	0.25	0.21
Clay	0.37	0.32	0.26
	0.25	0.23	0.19

CP where A=estimate of soil loss rate in ton/hectare/year

K= soil erodibility factor
R=rainfall factor
LS= slope factor
C=crop management factor
P=conservation practice factor

The potential soil loss was then categorized into a soil erosion class of Low, Moderate and High.

R-Factor

The rainfall pattern of the study area is such that rainfall increases southward with the northern parts receiving an average of 600mm annually, while the southern parts experience an average of 1000mm (Nigeria Meteorological Agency (NIMET)). Although the annual R Index is not directly linked to annual rainfall, in West Africa, [16] has shown that the mean annual R over 10 years= Mean annual rainfall × a

a=. 05 in most cases ±0. 05
= 0.6 near the sea (<40km)
=0.03 to 0.02 in tropical mountain area
=0.1 in Mediterranean mountain.

Thus, following [16] the calculated R-Factor values, with a =0.45 [17] for the study area for each of the three agro-ecological zones, are shown in table 1.

Table 1 computed R Factor values

Average Annual Rainfall	**R Factor**
600mm	270
800mm	360
1000mm	450

Source: Field Survey (2015)

K Factor (Soil erodibility)

A descriptive soil map of the study area obtained from a previous FAO survey in Nigeria was used. The description in the attribute table, allowed for computing K Factor for each soil textural class using values in the table 2.

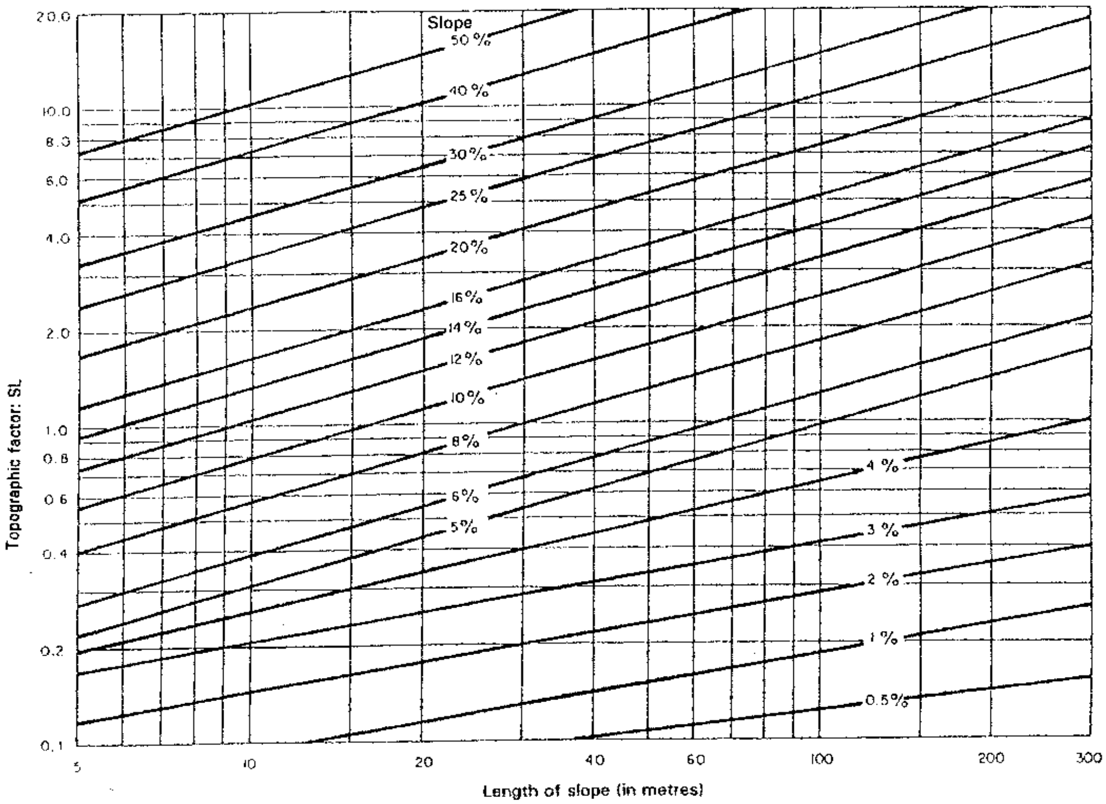
Table 2 K Factor values determination

Adapted from [17].

SL Factor

Derivation of the slope factor (LS) was from the use of the Topographical factor nomograph [18]. In Nigeria[19] observed that run-off stabilizes above a certain gradient depending on the way crop residues were used and on soil type. The ratio between erosion and length of slope varies from year to year than from one site to another [20]. The slope length was measured using a measuring tape from the point where the rain drops to the point of the deposition (Figure 2). In particular, the slope steepness and slope length (LS) factor represents the erosive potential of a particular combination of slope length and slope steepness. Slope length is not the distance from the uppermost point in the field to the lowest point. To determine slope length, the researcher walked the field and determined where the water will flow. Contour farming channels on natural flow patterns were disregarded. Once the natural flow patterns were identified, the determination of the point on the slope where the flow began, was made. The slope length was then the distance from this point to the point where (1) the slope gradient decreases enough that sediment deposition generally occurred, or (2) the runoff water becomes a concentrated flow, or (3) the runoff enters a well-defined channel, for example, part of a natural drainage network or a constructed grass waterway or terrace channel. Once the slope length and steepness were determined, use can be made of tables and nomograph presented by FAO to substitute for other values [21].

Figure 2



Topographical factor (cf. Wischmier and Smith 1978)

C-Factor

The land cover and vegetation parameter and cultural technique values produced by [22] were used to arrive at the corresponding C-factor for the different cultural techniques as provided in Table 3.

Table 3 Vegetal Cover Factor and Cultural Practices (C Factor) in West Africa

Cultural Techniques	Annual Average C Factor
Bare continuously fallowed	1
Forest or dense shrub, high mulch crops	0.001
Savannah, prairie in good condition	0.01
Overgrazed savannah or prairie	0.1
Crop cover of slow development or late planting-first year	0.3 to 0.8
Crop cover of rapid development or early planting-first year	0.01 to 0
Crop cover of slow development or late planting-second year	0.01 to 0
Corn, sorghum, millet (as a function of yield)	0.4 to 0.9
Rice (intensive fertilization)	0.1 to 0.2
Cotton, tobacco (second cycle)	0.5 to 0.7
Peanuts (as a function of yield and the date of planting)	0.4 to 0.8
1st year cassava and yam (as a function of the date of planting)	0.2 to 0.8
Palm tree, coffee, cocoa with crop cover	0.1 to 0.3
Pineapple on contour (as a function of slope) burned residue	0.2 to 0.5
Buried residue	0.1 to 0.3
Surface residue	0.01

Adapted from Roose (1976)

P-Factor

The P-Factor values were derived, according to the land use type as guided by Federal Department of Agriculture Land Resources [23]. The P-Parameter was set as 1 since it was not possible to distinguish differences in cultivation practices between adjacent smaller areas. The T Value which is the soil loss tolerance for shallow tropical soils with a limited rooting depth is extremely low. This is because the loss of nutrient-rich surface soil cannot be compensated by the addition of fertilizers alone. Tolerance values for tropical soils ranges between 0.2-2t/ha/year [24].

The Interview

The interview was conducted in each of the agroecological zone. Purposive sampling was employed for the selection of 10 heads of farming families and 3 community leaders in each of the agroecological zone. The questions raised were principally on the state of the farmlands, the perceived causes and problems of soil loss in the study area, including the likely control measures of the morphodynamic process. The choice of the farming families was informed by the fact that Katsina is predominantly an agricultural State with over 750% of the population involved in agriculture [14]. In addition, according to [25] 67% of the land in Katsina state is devoted to cultivation. The community leaders were selected because as observed by [26], key informant participants by their expertise and mandates are expected to hold rich information or experiences related to the phenomenon under investigation**.**

III. RESULTS AND DISCUSSION

The computed soil loss table (Table 4) represent the data collected on each of the key factors of the USLE Model from the 3 observation sites in each of the agroecological zone. The factors were then computed and an annual soil loss per hectare arrived at. The results of the 3 observation sites provided an average soil loss in tonnes per hectare per year of each agroecological zone. The results obtained showed the intensity of the soil loss and brought about a renewed interest among the farming families and the community leaders.

Table 4 Computed Soil Loss
A= RK(SL)CP

SiteNo.	Observation site	Agro-ecological zone	R	K	SL	C	P	A (t/ha/year)	Average A t/ha/year
1	Mai'adua 1 2 3	Sahel savannah	270 270 270	0.47 0.48 0.47	0.6 0.6 0.61	0.9 0.9 0.9	1 1 1	68.5 69.9 69.6	69.3
2	Charanchi 1 2 3	Sudan Savannah	360 360 360	0.24 0.30 0.28	0.6 0.61 0.59	0.9 0.9 0.9	1 1 1	46.7 59.2 53.5	53.1
3	Funtua 1 2 3	Northern Guinea savannah	450 450 450	0.33 0.34 0.33	0.4 0.43 0.42	0.9 0.9 0.9	1 1 1	53.5 59.2 56.1	56.3

Source: Field Survey (2015)

The T Value, the soil loss tolerance for shallow tropical soils with a limited rooting depth is extremely low. The results obtained above have shown A values to be higher than the T values, indicating significant soil loss in all the agro-ecological zones in the study area. It could be deduced that the major factors that define the rate of soil loss in the study area were the topographical factor and the soil erodibility of the different soil textural classes. The findings mirror the study of [17] which recorded a similar significant soil loss in the Katsina area.

The area with the highest soil loss Mai'adua in the Sahel Savannah agro-ecological zone, had an average of 69.3 t/ha /year. The Northern Guinea Savannah represented by Funtua has a soil loss of 53.1 t/ha/year on average. The Sudan Savannah however recorded lesser soil loss in comparison to the two earlier agro-ecological zones. The USLE record showed 56.3 t/ha/year as the soil loss.

All of the key informants were unanimous in appreciating the general problem of soil erosion as a result of water and wind erosion and provided the causes of the soil loss in the study area. There was also an understanding of the need for more interventions from the Government because some of the control measures were far beyond the capacity of a farming family to adopt.

A key informant observed with trepidation that:

"The problem of soil erosion in this part of the area seems to be exacerbated by the farming families for their refusal to provide drainage in their farmlands, and they are aware that where vegetation is scant; run-off will be serious.''

While another key informant who was concerned in a different perspective observed that:

"The problem of soil erosion goes beyond the sheet erosion we see but rather we are always faced with an economic loss by repeating application of fertilizer whenever there is a heavy downpour. This is because the applied fertilizer is washed away to low lying areas or adjacent farmlands thus necessitating another fertilizer application and you could see most of the farmlands do not have the preventive thick bushes to prevent the run-off."

Another key informant who has been in the study area for over sixty years shared his experience on soil erosion where he identified sheet erosion to be devastating process in the following order:

"Our major problem here is not only the increase of rainfall we receive, but the wind speed is high…so you find deposition of sand being made at short and long distances even though it is not a rainy season. Over time, many farmlands have visibly become a mixture of sand and gravel because of the weathering effect of the winds."

A key informant who has watched the happenings in the Bun-Bum Village of the Mai'adua Local Government elucidated that:

"This area Unguwar Jummai has been noted by the Government and in fact, some programs have been set in motion to arrest the visible sand movement that is threatening both farmland and settlements. We are going to engage the rural people in identifying local adaptive strategies that could be cost effective."

When asked whether they have been experiencing soil erosion, the majority of the farming families (93.5%) were of the view that they have experienced soil erosion over time in the study area.

IV. CONCLUSION

The northern part of the study area comprising of the Sahel Savannah and some part of the Sudan Savannah has shown a high degree of soil loss as it was the same area identified to have a significant decline in vegetation. Hence, it could be inferred that the significant soil loss experienced in the Sahel Savannah has a direct correlation with the vegetation cover of the study area as noted by [27] who emphasized that vegetation controls soil erosion rates significantly. At the same time high rate of the soil loss recorded in the wetter Northern Guinea Savannah may not be unconnected with the terrain and run-off. Overall, study findings showed that the factors that determined the rate of soil loss in the study area were the Topographical Factor and the Soil Erodibility of the different textural classes. The study area is predisposed to soil loss owing to a number of factors; making it one of the most degraded areas in Nigeria, hence the need for urgent attention. There farming families observed the phenomenon with great concern and were disposed to evolve traditional techniques to reduce the soil loss as a result of water and wind. There was a strategic alliance between the families and the government in order to introduce technical control measures and extended drainages system, which were beyond the financial capacity of individuals.

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