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Effect of soil and land characteristics on the arable land of Breweries and Agricultural Research Company (BARC) farms, Zalaki, Bassa Local Government Area of Plateau State, North Central Nigeria

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Abstract: Soil Erosion and nutrient depletion are major threats to food security and the sustainability of agricultural production in sub-Sahara Africa. The problem of soil erosion, especially in the rocky terrain of Jos-Plateau is enormous due to high altitude. Estimating soil loss and identifying hotspot areas support combating soil degradation. Soil loss parameters for the study area were computed using USLE model in the Breweries and Agricultural Research Company, (BARC) farms in Central Nigeria. The annual rainfall was used to calculate the rainfall erosivity factor, soil data was used to calculate the erodibility factor, remote sensing topographic data was used to generate the slope length and gradient factors, and cover crop and conservation practice factors were obtained from available soil details nomographs. Finally, the parameters were integrated with tools to estimate soil loss rate of the study area. Mean annual soil loss rates were estimated to be between 4.2 to 5.09 t ha-1 yr-1 on the three catchments which were separated based on slopes steepness. The total annual soil loss was determined to be 16603.58 tons from the watershed and the annual soil loss rate of the study area was 5.09 t ha-1 yr-1. Although this could be said to be below tolerable soil loss rate of 11 t ha-1 yr-1, the scenario and the circumstances around the study area indicates the figures are dangerous to the food production if conservation practice is not improved. Desert encroachment, climate change, overgrazing and other vices shoed the severity of erosion which required immediate action of soil and water conservation.

Keywords: BARC farms, Soil loss, erosivity, erodibility, crop factor

1. Introduction

The amount of erosion at any site depends on the erosivity of rainfall and erodibiliy of the soil, the characteristics of the land, its use and management (Wild, 1996). Soil is an essential component of agricultural production, and in Nigeria, where food production is critical to development, more than 80 million people work as farmers at various levels. Agricultural land use in Nigeria frequently degrades soil fertility and reduces agricultural output (Sejonbi and Ogunkunle, 2011). Soil degradation caused by agriculture can result in soil erosion, sedimentation, and leaching.

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Soil erosion is the removal of part of the soil, or the whole soil, by the action of wind or water (Lal, 2000, Wild, 1996; Hudson, 1993. When there is too much water on the surface of the soil, it fills surface depressions and begins to flow, according to Ref (2001). With sufficient velocity, this surface runoff transports away the loosened soil. Wild (1975) also stated that as long as there is farmer, there is tendencies that serious erosion would occur.

The BARC farms is the major agricultural land in Jos-Plateau that have the national and international interests but characterized by sub-humid tropical climate and other vices ranging from land degradation, Climate change impact and desertification. The soil of Jos-Plateau is primarily composed of basaltic rocks, which can be found at altitudes ranging from 1600 to 3000 metres above sea level (Olowolafe, 2002).

The productivity of the soil of this area appears to have declined drastically following intensive grazing, poor management and impact of climate change. This situation necessitated an investigation that would provide a proper evaluation and lead to the formation of better management practices in order to increase yields, particularly of grains like maize and sorghum, which are the predominant crops in the region.

The objective of the study is to investigate the effects of rainfall erosivity and soil erodibility indices of BARC farms so ascertain the level of susceptibility to soil erosion.

According to Nyakatawa et al. (2001), soil erosion is a major environmental concern on a global scale. Erosion transports nutrients, pesticides, and other noxious chemicals into rivers, streams, and groundwater. Crops such as Maize and sorghum are shallow root crops which required nutrients from the surface (0-30cm) of the soil for its growth and yield and mostly affected by this erosion phenomenon due to its shallow rooting systems. Destruction of farmlands, reduction in crop yields per hectare of land as a result of soil erosion create problems for the smallholder farmers as they often move from one particular field to the other due to degradation of soil. Tunebo et al (2021) Extreme fragmentation on remaining farm land may follow, this may result in extensive use of the available land, hence, reducing output except soil management strategies are applied.

Salako (2003) defines erosivity as the potential or capacity of precipitation to cause soil erosion. As the only form of precipitation contributing to the hydrologic cycle or as the source of water, rainfall is the true agent of soil erosion by water in tropical regions. It is the source of water for the majority of crop productions in tropical Africa, as neither irrigation agriculture nor the utilization of available facilities where they are required have been developed.

There are three popular indices for assessing the erosivity of precipitation:

- EI30 index (Wischmeier and Smith, 1978; Renard et al., 1997)
- KE ≥ 25 (Hudson, 1995)
- AI¬m index (Lal, 1976)

Because they evaluate multiple rainfall characteristics, these indices are known as compound erosivity indices. The EI30 index is a product of rainfall kinetic energy and maximum short-term intensity, I30; KE 25 index is a sum of rainfall kinetic energy exceeding 35 mm h-1, based on the assumption that such rainfall events are the primary cause of soil erosion; and aim index is a product of daily rainfall amount and maximum short-term intensity, I30 (Im).

2. Materials and Methods

The study was based on a survey conducted between May and September 2021 at Breweries Agricultural Research Company (BARC) farms. The farm is located about 25 kilometers northwest of Jos, the state capital. The Jos Plateau covers an area of 8,600km^2 in central part of Nigeria. It lies between latitudes 8^0 30’ and 10^0 10’N and Longitude 8^0 20’ and 9^0 30’ E with an average elevation of about 1330 asl (Olowolafe, 2002). The climate is dry and wet seasons classified as Tropical rainy climate by Kowa and Kassam (1976). It receives a mean annual rainfall of 1250 mm and has a mean annual temperature of about 25^{0}C. Eswaran, (1999) reported that the soil moisture regime is ustic while soil temperature regime is isohyperthermic. The farm was purposely selected because of the levels of degradation occasioned by long neglect, poor management and for soil and water conservation awareness that will boost food security within and around the study area.

2.1. Data collection

The objective of this study involves estimating the rate of soil loss in the farm. The primary data which include soil samples for analysis were collected randomly at the farm, rainfall and climatic data were collected at the Meteorology Center, Geography Department University of Jos, while secondary data such as climatic, demographic and other related information was collected at the National Remote Sensing Center, Jos.

2.2. Estimation of Soil Loss

The Universal Soil Loss Equation has the advantage of being less data demanding than several other models and it continue to be a widely accepted method of estimating sediment loss despite its simplification of the many variables involves (Schwab, et al., 1993). Available models for predicting soil loss vary in their data requirements for taking into account model calibration, application, complexity, and processes (Merritt, et al., 2003). To quantify Physically-based, spatially-distributed soil erosion models can be used to calculate the amount of soil loss from watersheds and to identify critical soil loss source regions (De Roo, et al., 1996; Erdogan, et al., 2007).

Although, there are critical challenges in estimating precise soil loss on erosion land, the basic equation as given by Wischmeier and Smith (1978) is:

$$A = R \times K \times L \times S \times C \times P$$

A is the direct estimated average predicted soil loss in tonnes per hectare per year due to water erosion; R is the Rainfall erosivity factor; K is the soil erodibility factor; L is the slope length factor; S is the slope steepness factor; C is the crop cover and management factor; and P is the conservation practice factor.

2.3. Rainfall Erosivity factor (R)

The climatic factor (R) is the maximum 30-minute rainfall energy and intensity multiplied by the rainfall erosivity index (EI) (EI30). The rainfall-runoff erosivity of the study area was determined by calculating the erosivity value for each storm using the method described by Wischmeier and Smith. (1978). The sum of each storm's erosivity was then used to calculate the annual erosivity value (R). The more intense and prolonged the storm, the greater its erosion potential.

In this study, in order to calculate the R-factor, the average of twenty years’ worth of historic annual precipitation was collected from meteorological stations 20 and 45 kilo meters from the study site. The R-value corresponding to the mean annual rainfall was then determined using the R-correlation established by Hurni (1985) and successfully utilised in the tropics by Aneke (1985) with some modification to its parameter estimations to suit Guinea Savannah conditions, which was derived from partial regression analysis. R-Factor is determined by the equation:

R = -8.12 + 0.562P

Where, R is the erosivity factor and P is the mean annual rainfall (mm $year^{-1}$).

2.4. Soil Erodibility Factor (*K*)

The culturable-Command area (CCA) was divided into three catchments, each catchment was divided into 200 x 200m grid and for analysis, 232 soil samples were collected from the grid's centre. To determine the physical and chemical properties of the soil, soil samples were analysed using standard laboratory procedures. Organic Matter (OM), Soil Texture, Structure, and Permeability were the properties studied. The hydrometer method (Gee and Bauder, 1986) was used to determine particle size distribution, while the wet combustion method (Walkley and Black, as outlined by Nelson and Sommers) was used to determine organic carbon. (1982). Soil structure was identified in the field using a soil structure assessment kit to determine soil structure class code. The structural class code was determined using the USLE nomograph and the observed shape and size of the soil structure. (Wischmeier and Smith, 1978); whereas, the permeability class code was obtained from soil textural classes (Booman, et al., 1995), which are encoded based on the observed soil texture from the textural triangle. Using the following equation, K-factor was calculated from estimated soil properties, namely texture, organic matter, structural and permeability:

$K = 2.8 \times 10^{-7} M^{1.14} (12 - a) + 4.3 \times 10^{-3} (b - 2) + 3.3 \times 10^{-3} (c - 3)$

Where, M is the particle size parameter (%sand +% silt) x (100 -%clay), a is the percentage organic matter, b is the soil structure code (taken in this study as 3 for medium and coarse granular, while c is the profile permeability class taken as 2 for moderate to rapid.

The USLE standard of 9 percent gradient and slope length of 22m has been replaced with more computer based with compactible units which gives greater erosion rates on longer and steeper slopes when compare with USLE (McCool et al., 1989). These factors are used in this studies and calculated as follows:

$$L = \left(\frac{l}{22}\right)^m$$

Where L is slope length factor, l is slope length in meter, m is dimensionless exponent. McCool, et al., (1989) also declared that where rill erosion and interrill erosion were about equal on a 9 percent, and greater than 22-m-long slope, then m could be found from the equation:

$$m = \frac{Sin\ \emptyset}{Sin\ \emptyset\ + 0.269\ (\sin \emptyset)^{0.8} + 0.05}$$

Where $\emptyset$ is field slope steepness in degrees. The slope length was measured for the three catchments from the point where surface flow originates from to the outlet channels (Table 1).

2.5. Crop management factor (C)

Crop management factors for various land uses were derived from satellite images acquired from the National Remote Sensing Center in Jos, Nigeria. The attributes were based on land use and land cover maps and data analysis. The cover and management factor is the ratio of soil loss from land with a particular type of vegetation to the corresponding soil loss from fallow land during rainfall (‘Wischmeier and Smith, 1978). The accuracy of the land use and land cover classification of the study area was determined using a systematic sampling technique. Overall accuracy, user accuracy, producer accuracy, and the Kappa coefficient were used to determine similarities between image classification and ground features (Vinay and Mahalingam, 2015). Finally, three land uses and cover types were identified: cultivated, rock outcrop, and shrubland. C values corresponding to each land use and land cover class were assigned (Table 2). In the Barc Farms, the average value of cover and management factors was 0.058. The cultivated land had the highest cover factor, indicating that higher erosion is likely in the study area.

Table 1. Topographical features of the study area

	Catchment-A	**Catchment-B**	**Catchment-C**
Area (ha)	1200	640	1422
Slope Length (m)	638	722	840
Av Slope	5.2	4.6	7.3

2.6. Conservation Practice Factor (P)

The erosion control factor (P) is the ratio of soil loss caused by specific conservation practices such as contouring, strip-cropping, or terrace measurement to the corresponding loss caused by up and downslope cultivation (Wischmeier and Smith, 1978).

Table 2. Description of three identified land use/land cover types.

Land use/cover Classes	Descriptions	C-factor
Cultivated land	Land used for cultivation of annual crops	0.15
Land with Shrubs	Area covers with shrubs, grazing and grassland areas. Bared land with scattered herbs.	0.01
Rock outcrops	Areas not suitable for crops but contributes to the erosion rate and volume	0.014

3. Result and discussion

Rainfall erosivity (R)factor of the study area obtained from the rainfall analysis for 20 years was 694.38 mm, the result shows that the average K-factor for the study area are 0.057’, 0.061’ and 0.085 respectively. The soil analysis result is reported in Table 3. The L-factor was calculated to be 11. 68 when *m* was found to be 0.73’ while the particle size parameters for the three catchment for calculated to be 5184, 5451 and 7396 for catchment A, B and C respectively. Slope gradient factor calculated using the equation prescribed for slopes longer than 4m and s <9 (McCool, et al., 1987). The crop factor and conservation practices were obtained from using nomograph as earlier discussed. Therefore, using the USLE, the average soil loss of the study area was fond to be 42.19 ton/hac/year. The R-factor and K-factor are high figures for arable farmland (Lal, 2005, Schwab, et al., 1994, Hudson, 1994). From the study, the organic matter content was also found to be low compare to other studies in the Lowland Plateau (Olowolafe, 2002). The high K-value indicates high erodibility and vulnerability to soil erosion, which could be attributed to low clay and organic matter contents as less soil colloid aggregation.

Table 3. USLE Parameters of Soils of the study area

	M-value	K-factor	Catchment A value (t/ha/yr)
Catchment - A	5184	0.057	4.27
Catchment-B	5451	0.061	4.57
Catchment-C	7396	0.085	6.37
Av. Value	6010	0.068	5.07

4. Conclusion

In carrying out this study, the USLE equation was used with remote sensing extract to assess the Erosivity factor (R) and Erodibility factor (K) as well as soil loss in the hotspot of the study area. The study area's average soil loss exceeds the tolerance limit. The high rate of soil erosion can be attributed to the watershed's slope length and gradient. Soil conservation practices must be implemented immediately across the entire farm mores, the state government is trying to resuscitate the farm and when that is done, no doubt the entire catchment can be turned to food hub for the region. The land use management strategies should match the characteristics of the topography, terracing, and cut and carry system can be integrated to sustainably manage erosion-prone areas of steep mountain areas.

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