Chapter

Erosion Quantification and Management: Southeastern Nigeria Case Study

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Abstract

Soil erosion in Southeastern Nigeria is assuming an unusual dimension despite efforts by successive governments to control the phenomenon. Agronomic activities on eroding surfaces can give rise to landscapes much different from the original. Research activities in erosion quantification, the findings and how their applications have contributed to soil erosion management are highlighted. A key factor is the community efforts which have been relegated to a top-down approach occasioned by land use, land tenure and technological changes. The system is often a preventive management approach which achieves ecological and economic benefits. This chapter also discusses the indigenous methods of soil conservation and proposes their inclusions for sustainable management. To manage soil erosion in the region, emphasis must be placed on preventive management rather than crisis-management. Such approach will ensure that fewer resources are expended and land is appropriately conserved. To this end, soil can play its many environmental roles adequately.

Keywords: soil erosion, indigenous knowledge, soil conservation, erosion quantification, land use

1. Introduction

Methodologies for sustainable management of land degradation, economic growth and poverty reduction have become topical issues in present African research activities because of the danger posed by their neglect [1]. Land degradation especially the soil erosion aspect has been recognized as a serious threat to environmental sustainability. It impacts life on earth through degradation of land resources, loss of farmlands, decline in soil fertility due to top soil losses, contributes to climate change due to a compromise in soils C-sink potentials. In lowlands, eroded soils are often deposited as sediments on both land and river bodies. Thus further impoverishing rural communities who are often ill- equipped to manage the threat on land and water resources. As a result of the many implications of soil erosion on the environment, many efforts have been made to adequately understand the phenomenon so as to better manage it. Many of such efforts have failed due to little consideration of the several factors and their environmental peculiarities. The factors include: rainfall, soil properties, topography, and land-use and management. Since soil erosion begins in the farmer's field, scientific results could

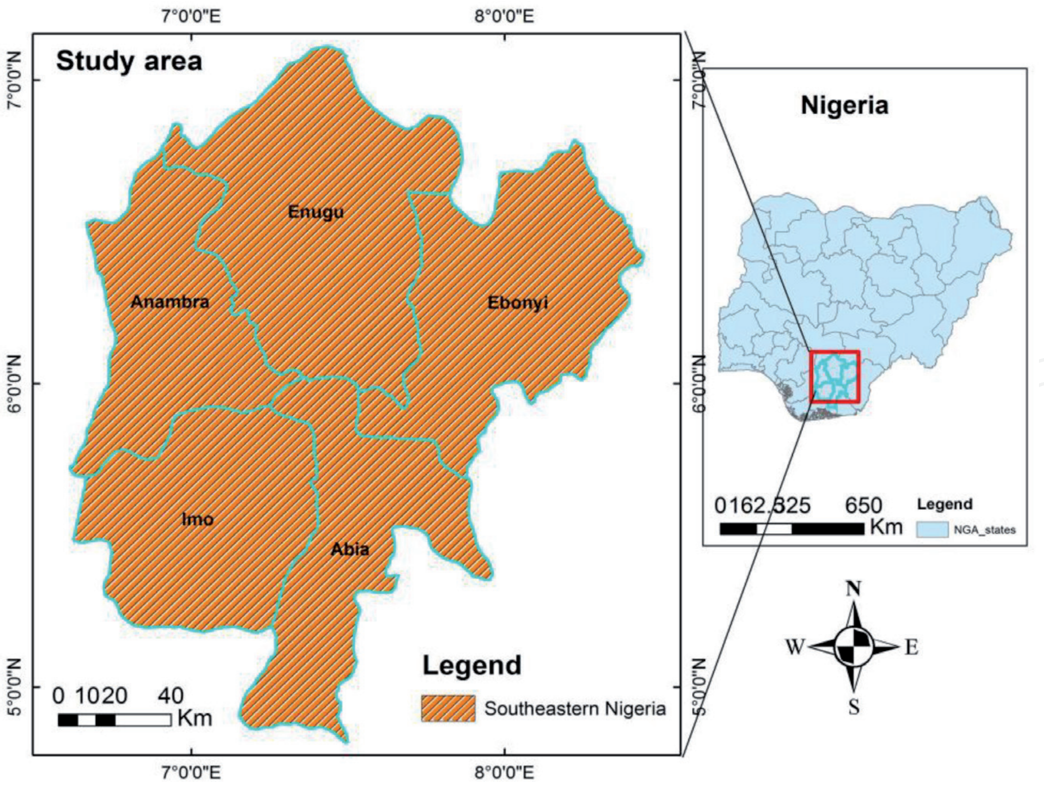

Figure 1.
Location of the reviewed area showing the states

be complemented by indigenous knowledge interventions in order to achieve better results. Local people have not only found nomenclatures for their soils, the indigenous knowledge has also extended to practices that have been through longterm observation of their interaction with the environment and transferred from generation to generation. Ezeaku and Salau [2] defined indigenous soil knowledge system as "the knowledge of soil properties and management possessed by people living in a particular environment for a long period of time. Soil conservation practices applicable to the North- Western zone of Nigeria include: contour farming, ridge tying, strip cropping, crop rotation, planted fallows, conservation pits, crop livestock farming and adequate fertilizer use [3, 4]. Howevever not much studies have been carried out in the Southeastern Nigeria (**Figure 1**) which is particularly an erosion prone zone.

2. Soil erosion and landscape evolution

Landscapes evolve under the influence of a complex suite of natural processes, many of which may be either directly or indirectly influenced by land use [5]. For example, a long history of cultivation can leave significant footprints on the original landscape. Under an unfavorable land-use condition, soil particles are moved from one position to another through agents of erosion such as wind, water and gravity. The series of particle movement consisting of detachment, transportation and deposition contribute to the evolution of landscapes. This is more so when the phenomenon occurs at accelerated dimensions as a result of continued anthropogenic activities. The effect of the denudation is a drop in soil surface level [6]. Future landscape evolution driven by soil erosion is expected to be exacerbated by land-use change, agricultural intensification and climate change [7, 8], coal mining and exploration [9], terracing [10], other mining activities, road networks and agricultural practices [11]. With current efforts to make resources available to the ever increasing population, the impact of these events in terms of magnitude and impact is expected to increase and destabilize geomorphic systems. In Southeastern Nigeria, Nwajide [12] observed that a major exogenic geological hazard is soil loss due to sheet and gully erosion. Of which the sheet type occurs as more or less removal of topsoil by flood but does not appear to threaten agricultural production or human habitation. Nevertheless, during major floods, sheet erosion may threaten small holders' food production for a period of time (**Figure 2**). However, its impact is often considered to be obliterated by the rapid rate of soil regeneration. The gully types have been observed to be the most obvious because of the remarkable impression they leave on the surface of the earth [13]. A gully is a distinct channel carved by running water into an unconsolidated substratum, and through which water flows only during and immediately after heavy rains. They are also a visible manifestation of the physical loss of the land due to erosion (**Figure 3**). Idike [13] observed that most studies of soil erosion in Southeastern Nigeria had strong focus on gully incision and gully prone regions but less on the little noticed sheet erosion. Such erosion contributes to land degradation but often in slower dimensions that land users fail to notice and are they often occur alongside with gullies in erosion prone areas. It is quite clear that soil erosion alters hydrology and landscape and connectivity patterns therefore necessitating efforts towards its better quantification.

Figure 2.
Inspection of lowland sites affected by sheet erosion following the 2012 flood at Odekpe, Southeastern Nigeria.

Figure 3.
A gully incised landform at St. Francis Enugwu-Ukwu, Southeastern Nigeria.

3. Soil erosion quantification techniques

In Nigeria, the detailed history of erosion quantification evolution may have been lost. However, there are remarkable timeline of events that are observable from literature. Earlier (1930–1955), soil erosion studies were descriptive, involving much field surveys and subsequent mapping. It was dominated by geographers and geologists who made efforts to understand the soil and its environment at regional scales (for example, see [14–16]). The second phase of soil erosion researchers (1955–1985) were mainly agriculturally-inclined (agronomists and soil scientist) with fewer geomorphologists, who established runoff plots, simulated soil loss using desurfacing approaches and a host of other techniques which were experimented in order to understand soil-water, erosion-productivity interactions in fields [17, 18]. The transitional period (1985–2000) focused on attempts to integrate technology towards broadening the scale of soil erosion research [19–24]. Presently (2000-date), soil erosion research has been multidisciplinary, multidimensional (local, regional and global) and with strong links to global issues such as social inclusion, sustainability and climate change. It is worthy to note that researchers continue to apply different methods depending on their objective and no method is obsolete Per se but a compromise of the other. The methods that have been applied by researchers in Southeastern erosion quantification are summarized in **Table 1**. The common erosion quantification methods are discussed below.

3.1 Mapping and direct field observations

Photographs can be used for detecting morphological change at varying scales and for recording the spatial relationship of landforms in order to provide three-dimensional information that can be used to construct Digital Terrain Models (DTMs) (for example, see [31]). It is also carries supplementary details useful for interpreting erosion rates or patterns. Maps produced as a result of detailed reconnaissance land resources surveys generally also contain information on the erosion hazard and on evidence of past erosion. Areas affected by sheet-rill-and gully- erosion can be recognized on aerial photographs and the growth of the erosion affected areas or the effects of conservation measures can be be traced from available maps or photographs and additional information collected in the field. Information obtained in the field may include using a simple scoring system to rate the severity of the erosion from e.g. the exposure of tree roots, the surface crusting, the thickness of the A horizon, erosion forms and shapes etc. Onweremadu [32] used field sampling aided by morphological landscape changes to identify erosion units for conservation treatments. However, field surveys can be time consuming but with the development of remote sensing techniques, more efficient methods of obtaining spatiotemporal erosion information are emerging. The disadvantages of using mapping as a tool for assessing soil erosion are the needs for cartographic skills, challenge of ascertaining whet difficulties in interpreting whether the current situation of the erosion phenomenon time constraints and variations in map quality.

3.2 Runoff plot studies

Runoff-plot methods are designed by using artificial boundaries to define a plot area and sediments are collected from a receptacle downslope. They could also be closed plots systems which uses rainfall simulators to study erosive events or open systems. Runoff plots are valuable research tools in soil erosion and surface runoff (soil loss) studies, evaluating conservation measures, effect of different crops and

Location	Erosion Type	Quantification method	Result	Management recommendation	Author(s)
Abia State	gully	GPS and GIS	False bedded sandstone formed the major area for gully dispersion especially where slope was greater than 15 degrees	Proper land use	[25]
Onitsha, Port Harcourt, Owerri, Enugu, Uyo, Calabar, Ikom and Ogoja	Sheet	USLE, Rainfall erosivity	Severe erosion causing rains are associated with the rainy seasons; Calabar, Owerri and Port Harcourt had very high erosivity index	Monitoring hydrologic and climate related factors as well as land-use management	[26]
Anambra	Sheet	GIS and RUSLE-based	Mean value of estimated soil loss of 214.82t ha-1.;High rainfall erosivity combined withhigh slope factor and decreasing vegetal cover	Comparison between estimated and measured soil loss	[27]
Anambra and Enugu States	Sheet, interill and rill erosion	SLESMA and USLE erosion models	Coincidental and significant relationship between the USLE estimated maps and extent of actual gullying on ground	assesment of individual soil erodibility and not rating based on soil taxonomy	[24]
Orlu-Okigwe Asix of Imo State	Gully	Field and Landsat data	Surface phenomenon of washing away of loose top soils is not the only factors responsible for gullies but also deep-seated near-surface structural weakness along gully axis.	Emergency environmental monitoring	[28]
Anambra Basin	Gully	Field, Remote sensing and Geotechnical analysis	Development of gullies on steep slopes and non-vegetated areas are facilitated by cohensionless and very permeable nature of Ajali and Nanka sandy formations	Agronomic and engineering practices could help mitigate formation and expansion of gullies	[29]
Orashi Catchment, Anambra State	Not known	Field, expert judgment and remote sensed data	Vegetation and slope are the main factors governing erosion susceptibility	Change in landuse to a more integrated basin development system and public awareness on soil conservation and strategic planning	[30]

Table 1.
Summary of some erosion quantification approaches and management recommendations in Southeastern Nigeria.

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management practices. They are commonly used to monitor hillside erosion but the design of runoff plots (in terms of plot dimension, runoff and erosion collection system, methods to monitor sediment concentration etc) are not standardized, making their results technique dependent [33]. Li *et al.* [34] anticipated that runoff research will tend to be more precisely location and model-inclined, technologically advanced and quantitatively precise in future. Iwara and Ewa [35] constructed erosion plots on natural fallow vegetation varying ages in southeastern Nigeria. They observed that July to September experienced highest amount of runoff and sediment losses. A better performance of the 10 and 3-year old fallow over the 5-year old fallow lead them to the conclusion that surface cover type and extent had greater influence over erosion processes than the age of fallow. The use of runoff-plot often alters the natural hydrology of fields due to their artificial boundaries and therefore may not accurately represent the actual erosion conditions. Extrapolation of the plot scale experiment beyond the area of observation may also be erroneous.

3.3 Erosion pin technique

The erosion pin method is a simple and feasible approach for soil erosion monitoring by inserting rods or nails into surface of slopes and using the basis of length of pin exposed or movement of washer placed on the pin. The technique has been successfully been modified and its photo-electronic erosion pin (PEEP) modification was efficiently used to monitor stream bank erosion by Lawler in 1989 [34, 36]. Erosion pin can aid in dynamic monitoring of the initial stage of gullying by identifying surface roughness, detachment and deposition. It can also conveniently monitor bank collapse and other short-term field monitoring. Some of its limitation include: susceptibility to environmental and human interference, need for close contact with assessed land and small range of observation. It can also be used to monitor gullies and landslides.

3.4 Erosion marker technique

Erosion markers allow carrying out analyses at larger temporal and spatial scales than those that are achieved through experimental plots. Bio-markers such as tree ring characteristics have been used to estimate the rates of soil erosion from decennial to millennium time scales by applying dendrogeomorphology [37]. The original landscape in relation to exposed roots can be a marker of soil erosion processes. However, as it is not always easy to identify the original land surface level, the vertical distance from an exposed root to the present ground surface may represent an underestimation of the total depth of the material [38]. The use of biomarkers is useful for long-term erosion quantification but it is subject to errors due to the natural variability of plants.

3.5 Radionuclide tracer method

Over the last few decades, geochemical methods have also been used to quantify erosion rates at different temporal scales. Examples of radionuclides which have been used as erosion tracers include ^{137}Cs, ^{210}Pb and ^{7}Be. The application of environmental radionuclides in soil erosion surveys is based on the premise of adsorption and redistribution of fallout by soil and sediment particles following erosion and sedimentation [39]. Radionuclide observations showing losses compared to the reference value indicate erosion. Observations greater than the reference value shows deposition. Unfortunately, this approach is yet to be applied to Southeastern Nigeria. Its first application in Ibadan, Southwestern Nigeria was reported to be a valuable alternative to conventional methods for soil erosion for obtaining quantitative data on soil erosion and deposition [40].

3.5.1 ^{137}Cs tracer method

^{137}Cs tracer technology rapidly developed and became the major means for monitoring soil erosion, determining soil erosion and sedimentation rates, quantitatively analyzing soil net loss, and other applications in the field [34]. The principal limitations of the ^{137}Cs approach include the costs of analytical equipment and the difficulties experienced in interpreting medium term estimates of average soil redistribution rates in the absence of complementary information on land use patterns and intensity. The method also requires a long measurement time and a high cost of laboratory analysis.

3.5.2 $^{210}Pb_{ex}$ tracer method

According to Li *et al.* [34], the $^{210}Pb_{ex}$ tracer method can distinguish the changes in atmospheric particles and human causes of trace elements, the reconstruction of pollution sources, and the history of river deposition and erosion in the past 100 years. However, its limitations include complex sample processing, high accuracy requirements, and difficulty in obtaining the flux of deposition for a particular year. In future, development of this technique is to further improve the quantitative relationship between the amounts of $^{210}Pb_{ex}$ loss and soil erosion. Its combination with other tracers and models is also likely.

3.5.3 ^{7}Beryllium tracer method

Li *et al.* [34] observed that this method can be applied to evaluate soil erosion under a particular intensity of land use, thereby providing an important basis for the monitoring and control of soil erosion. However, the application of ^{7}Be tracing still has some problems. For example, the shallowness of ^{7}Be distribution complicates sampling. It is, however, important to recognize that the use of ^{7}Be measurements is best suited to situations where significant erosion events are separated by 5 months in order to minimize the effect of previous erosion [39]. Since ^{7}Be could reflect the effects of soil erosion factors. Therefore, the scope of applications of the ^{7}Be tracer method can be broadened to explore the comprehensive effect on specific small watersheds based on the hydrological and meteorological conditions of soil erosion [34].

3.5.4 Magnetic tracer method

The application of magnetic tracers has two aspects: (i) to trace sediment sources using magnetic minerals in the environment, (ii) to indicate environmental change in basins. Hence Li *et al.* [34] synthesized that the magnetic tracer method can reflect the history of land use pattern, vegetation succession, and soil erosion in a watershed. It can also identify the soil distribution and the erosion rate for certain period. Therefore, this method can be used to provide a theoretical basis for soil erosion prediction and monitoring, and a history of the development of small watersheds. The advantages of this method are the transportability of the equipment, the methods simplicity; meeting the need of large samples and non-destructive nature. The method is however constrained by inability to trace magnetic properties and depth of soil erosion or deposition. Presently, magnetic tracers have been used to study soil formation, classification of soils, and the quantitative description of evolution, occurrence, and development of erosion.

3.6 Soil erosion models

Soil erosion models are quantitative approaches in study of soil erosion. Based on literature searches, the application of models in Southeastern Nigeria is still minimal. Models can be classified into three groups viz. Empirical, Physically-based and Conceptual (partly empirical/mixed) [41].

3.6.1 Empirical statistical model

Empirical models are based primarily on observation and inductive logic from the environment. Empirical models such as the Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), the Unit Stream Power Based Erosion/Deposition model (USPED), Erosion Productivity Impact Calculator (EPIC). Empirical models are mainly based on the USLE and remain widely used till date even in regions with limited data. Li *et al.* [34] documented the advantage and disadvantage of these models to include: (1) the formula is concise and the meaning of each factor is clear. (2) The calculation method of the factor has been basically mature and the parameters are easy to obtain for the continuous improvement and perfection of the model. (3) After several years of verification and testing, the accuracy of the model meets the needs of the application. In the tropics, the incompetence of the USLE in its rainfall erosivity component has been overcome by the incorporation of rainfall erosivity values in the RUSLE [27]. Applying the equation in the Anambra area, they observed that about 1804.39 km^2 (39.49%) of the area had slight erosion rate of 0–10 t/ha/yr., while rates of erosion in 746.60 km^2 (16.34%), 1025.38 km^2 (6.28%) and 45.59 km^2 (1.02%) of the area are 10.6–85.3, 85.4–235.2, 235.3–608, 608.1–2200 and > 2200.1 t/ha/yr. respectively. They noted that high rainfall erosivity, moderate to high slope and decreasing vegetal cover were the major factors driving soil loss in the area. In an earlier study, Igwe *et al.* [24] compared the USLE and the Soil Loss Estimation Model for South Africa (SLESMA) in producing soil erosion working maps in Anambra and Enugu States, South-East Nigeria. They found out that the USLE model reflected better the actual field situations except for its high values, absolute values compared to the global scale. The values were categorized into very slight (<50 Mg/ha/yr); slight (50–150 Mg/ha/yr); moderate (151–500 Mg/ha/yr); severe (501–1500 Mg/ha/yr) and very severe (>1500 Mg/ha/yr). A similar high value of above 200 t/ha/yr. was reported in Uyo metropolis, Nigeria by Fashae *et al.* [42] who observed that the values corresponded with areas with active gullies and altered vegetation cover. Obinna *et al.* [43] applied RUSLE model on the entire Southeastern Nigeria and observed that the results corresponded with known areas of gully menace in the region. Most of the erosion hotspots were located around the north-eastern part of the region covering most parts of Ebonyi State, some parts of Enugu State (Northwest axis), Anambra State (South East and Central axis), and most parts of Abia State. It could, therefore, be concluded that the high number of active gully occurrence may translate into the likelihood of other forms of erosion in the tropics.

3.6.2 Physical process model

The physical process model is based on the study of the processes and mechanisms of soil erosion e.g. stream flow or sediment transport. Examples of physical models include Water Erosion Prediction Project (WEPP), European Soil Erosion Model (EUROSEM). The WEPP model can simulate soil erosion, non-regular steep slope, and soil, tillage, and management measures by calculating the temporal and spatial distribution of soil erosion and predicting the movement of sediment in the slope and basin [34]. The WEPP model reflects the applicability and ductility of the temporal and spatial distribution of erosion and sediment; thus, numerous scholars still use this method. Although the physical model greatly compensates for the defects of the empirical model, this approach also has some shortcomings. (1) The physical mechanism of soil erosion is relatively complex and unclear. Some parameters in the physical process model are still dependent on the empirical model. (2) The large range of the study area is the major obstacle that hinders the use of the model because of the exacting demand of the model parameters. (3) The structure of the physical process model is complex and may change because the form has not been unified.

3.6.3 Conceptual model

Conceptual models lie somewhere between physically-based models and empirical models, and are based on spatially lumped forms of water and sediment continuity equations. Parameter values for conceptual models have typically been obtained through calibration against observed data, such as stream discharge and concentration measurements [44]. ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation), CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), and MODANSW (MODifiedANSWers) are basically conceptual and event based models [41].

3.7 Remote sensing

Remote sensing allows detection of erosion in large areas using aerial photographs and satellite remote-sensing data without disturbing the studied land area. The assumptions in the use of this method include, first, that the geomorphic processes of interest produce detectable changes in the spatial or temporal pattern of electromagnetic radiation and, secondly, that any geometric distortions arising from the sensor can be discriminated from real changes in landscape features [39]. Quickbird, SPOT 5 and IKONOS are very promising for identifying erosion features, such as individual gullies. NigeriaSat-1 image data and Landsat ETM data have been applied for a comparative classification of landuse patterns and gully development in southeastern Nigeria [45]. There are also opportunities in obtaining data using cheaper sources such as unmanned aerial vehicles (UAVs), ordinary cameras, and smartphones. Due to the capability of this method to provide spatial and often real-time data over large areas, it is adjudged the best method suitable for Southeastern Nigeria. It is hoped that its potential will be more explored in future.

4. Factors of soil erosion

Ofomata [19] viewed the factors of soil erosion as two major components: physical (geological or "natural") and anthropogenic (human or "accelerated"). Highlighting that the human component is often exaggerated and the physical component underestimated, he divided the physical factors of soil erosion into four: climate (mainly rainfall), surface configuration (relief/slope), surface materials and vegetation. Igwe *et al.* [24] recognized rainfall, topography/relief, soil factors (geology and soil characteristics), vegetation, land use and management as the main agents that determine the extent of soil erosion hazard. The factors affecting soil erosion by water is commonly expressed in the Universal Soil Loss Equation (USLE) (Eq. (1)) as a multiplicative equation counting six environmental factors:

$$A = R \times K \times L \times S \times C \times P \tag{1}$$

Where A is the mean annual soil loss (metric tons per hectare per year), R is the rainfall and factor or rainfall erosivity factor (mega joule millimeters per hectare per hour per year), K is the soil erodibility factor (metric tons hours per mega joules per millimeter), L is the slope length factor (unitless), S is the slope steepness factor (unitless), C is the cover and management factor (unitless), and P is the support practice factor (unitless).

4.1 Rainfall erosivity factor R

The R-factor is the sum of individual storm *EI*-values for a year averaged over long time periods (>20 years) to accommodate apparent cyclical rainfall patterns [46]. The *EI* term is an abbreviation for energy multiplied by the maximum intensity in 30 minutes. In the humid tropical environments, rainfall amounts and intensities often exceed the infiltration rate of excessive runoff. Ojo-Atere *et al.* [47] opined that the phenomenon was common in cultivated fields where at the peak of the rainy season, intensities of rainfall often exceed the infiltration rate of 25 mm/hr. and the soils are also nearly saturated throughout the rainy season. In fact, an earlier study by Roose [48] attributed the severe erosion damage of bare soils in the tropics to the special erosivity of the tropical rainfall rather than the ferrallitic or ferruginous soils. Salako [49] evaluated the temporal variation of rainfall erosivity between sub-humid zone (Ibadan) and the humid zone (Port Harcourt) of Nigeria. He observed a strong positive relationship between rainfall erosivity and rainfall amount.

According to Salako [50], data required are such that rates of rainfall at short-intervals (preferably ≤15 minutes) must be known, and these are very rare in many developing nations. Note that although EI_{30} is recommended by RUSLE, E_{15} was recommended for the tropics to avoid underestimation of the R-factor. The trends in rainfall erosivity have been generally evaluated using commonly available annual rainfall amount data. Lal [17] postulated a combination of daily rainfall (A) amount and maximum intensity (I_m), expressed as AI_m as a reliable index for evaluating index of tropical rainfall. Obi and Ngwu [51] observed that Lal's index of AI_m had an advantage over other indices of KE > 1 and EI_{30} in Southeastern Nigeria. Extensive studies by Igwe *et al.* [24] applied a method proposed by Arnoldus [52] to calculate the R-factor of USLE because autographic rainguage was not present in the study location and this gave the equation an advantage over the other equations. This method used monthly rainfall data to construct sub-annual R factors and then aggregated the R factors to an annual scale (Eq. (2)). It was modified from Fournier [53]'s map of the theoretical risk of erosion in Africa based on the damaging effect of precipitation.

$$FI = \frac{pi^2}{P} \tag{2}$$

pi is the average precipitation in the wettest month of the year, *P* is the mean annual total of rainfall.

Due to unsatisfactory results in West Africa, the Fournier index was modified. The modified index is given as Eq. (3):

$$MFI = \sum_{i=1}^{12} \frac{pi^2}{P} \tag{3}$$

Where MFI is the modified Fournier index, *pi* is total monthly rainfall and *P* is the total annual rainfall.

In West Africa, Eq. (4) is best to determine rainfall erosivity.

$$\mathrm{R} = 5.44MFI - 416 \tag{4}$$

where R is the rainfall erosivity factor (mega joule millimeters per hectare per hour per year) and *MFI* is the modified Fournier index.

4.2 Soil erodibility factor K

This factor relates to the rate at which different soils erode, due to inherent properties Generally, soil properties which affect detachability include; particle size distribution, organic matter content, soil moisture, presence of cementing material such as Fe and Al oxides, stability of aggregates, clay mineralogy, rock fragments and balance of cations on the exchange complex, permeability, soil structure and strength [54]. In southeastern Nigeria, clay content, level of soil organic matter (SOM) and sesquioxides such as Al and Fe oxides, clay dispersion ratio (CDR), mean-weight diameter (MWD) and geometric-mean weight diameter (GMD) of soil aggregates were observed to influence soil erosion hazards [55]. Different parent materials were studied by Obi *et al.* [56] using four (4) methods: wet-sieving method, the Wischmeier nomograph, portable rainfall stimulator and runoff plot measurements. They recommended that the nomograph approach were unsuitable for soil erodibility studies in Southeastern Nigeria. The influence of geology on soil erodibility has been noted. For example [55] reported that sites with the worst catastrophic gullies in the classical gully sites the whole of sub-Saharan Africa exists in Southeastern Nigeria on sandy geological formations of False-bedded sandstone, Coastal Plain sands, Nanka Sands and the Bende Ameki compare to their Shale formation counterparts. Nwajide [12] observed that most soils in Nigeria bear the property of the underlying parent material from which they were formed. This follows the behavior of the soil under erosive conditions. For example soils formed on limestone, dolomite and igneous rock were more resistant than soils of sandstone and clay sedimentary formations [24]. However, information on erosion categories of various sedimentary formations of South East Nigeria is rather scanty.

According to [47], soils in the tropics with high sand contents (>60%) and low silt and clay values (<12%) and (<40%) respectively are highly erodible. Also, the weak, fine crumb surface horizon and weak subangular subsurface horizons of the former increases its vulnerability to erosion. In contrast, [24] noted that both large and fine particles were more resistant to transport because greater forces were required to entrain the former and the resistance due to cohesiveness of the latter.

4.3 Topograpy factor LS

LS reflects the influence of length and steepness of slope on soil erosion, it determines the behavior of the surface runoff. It is defined as the distance from the point where overland flows starts to the point where either the slope steepness decreases to such an extent that deposition occurs, or where surface runoff enters a well-defined channel. According to Ojo-Atere *et al.* [47], topography modifies soil profile development in three ways: (1) by influencing the quantity of precipitation absorbed and retained in the soil, thus affecting soil moisture relations, (2) by influencing the rate of removal by soil erosion and (3) by directing the movement of materials in suspension or solution from one area to another. The thinness of the solum, less organic matter and less distinct horizons than soils on level or undulating topography has been attributed to erosive exposure of the lower horizons due to slope steepness. In Southeastern Nigeria, soil erosion can occur even at slope of 5% as highly friable sandstones from the upland yields to detachment due to concentrated runoff [19]. Even in highlands or cuestas with somewhat stable lithology and erosion resistance, aggressive runoff from them devastates the lowland areas especially at the toe slopes and river head-waters [57].

LS is expressed as a unitless ratio with soil loss from the area in question in the numerator, and that from a standard plot (9% slope gradient, 22.13 m slope length) in denominator. Although L and S factors can be determined separately, the problem has been simplified by causing the L and S factor and considering the two as a single topographic factor [58]. Eq. (5) below considers the effect of L and S factors:

$$L = \left(\lambda / 22.13\right)^{m} [65.4 \sin^{2} Q + 4.56 \sin Q + 0.065] \tag{5}$$

where λ is the slope length (in meters) and m is an exponent factor equivalent to 0.5 for slopes steeper than 5%, 0.4 for slopes between 3–4%, 0.3 for slopes between 1–3% and 0.2 for slopes less than 1% (based on a Wischmeier' nomograph) and Q is the slope angle.

4.4 Crop management factor C

Erosion and runoff are markedly affected by different types of vegetative cover and cropping system (vegetation type). The factor is defined as the ratio of soil loss from a field with a particular cropping and management to that of a field with a bare, tilled soil. The factor ranges from 0 to 1.0, a value of 0 indicating a 100% protection of the soil against erosion and 1.0 where there is little soil cover (e.g. freshly graded bare soil on construction site) [59]. Vegetation intercepts raindrops by facilitating infiltration of water, improving organic matter soil composition, thereby ensuring minimal erosion. The stage of growth of the crop will influence the management need (e.g. fertilizer), ability to hold soil together and canopy protection. Landuse activities that deprive soil surface of its vegetation, contributing directly to sliding, slumping, sheet and gullying include; road construction, sand mining, urbanization, industrialization and general infrastructural development [19].

4.5 Erosion control practice factor P

The erosion control practice factor P is the ratio of soil loss under a particular practice compared with the soil loss occurring under normal tillage. It therefore accounts for the positive impacts the support practice. Control practices reduces erosion potential by influencing drainage patterns, runoff concentration, runoff concentration, runoff velocity and hydraulic forces exerted by runoff on soil [60]. This factor ranges from 0 to 1 and is 1 where there are no support practices an 0 under good conservation practice. The conservation measures usually included in this factor are contouring, contour strip cropping, grassed waterways, terracing and surface mulching. Conservation measures like conservation tillage, crop rotations, residue management etc. are incorporated in the C-factor [59]. The effectiveness of conservation practices and thus the value of the P-factor generally depends on the slope steepness.

5. Landscape management in focus

In colonial times, the British Government worked on natural resource management as interest was high in expanding commercial farming enterprises. The practices were often implemented without consideration of the natural schemes used by local people to protect their soils from erosion and fertility declines. Trees were exploited without ecological considerations and conservation approach was a top-down type. Most farmers quickly abandoned such conservation model. However with increasing resource demands, most farmers are presently using unsustainable farm practices. As such, soil erosion occurrence is exacerbated. However, little study has attempted to understand occurrence of erosion in farmer's field yet sheet erosion, rills and gullies occur there. Local people with experience have recognized the peculiarity of their soils and adopted practices that are suited to their soils. The practices identified include; ditches, water harvesting 'umi', ridging, agroforestry, manure application, mulching, soil stabilizing stones, multiple cropping and embankments. Others are fallowing, conservation tillage etc.

5.1 Some soil and water conservation practices observed in Southeastern Nigeria

5.1.1 Traditional drainage ditches

These are structures constructed by digging deep within the farm or outside so as to divert runoff water and debris before reaching the farmland (**Figure 4**). It also serves as a watercourse, channeling runoff into ground water with minimal sheet erosion. This practice reduces the distance over which runoff travels over farmland and reduces water logging conditions. Morgan [61] reported that such drainage practices are constructed along the slope, often covered with grass to prevent destruction, and primarily installed in areas with high rainfall rates. The depth of this structures are variable depending on the slope of the land and need of the farmer. Locally, farmers in the study area call the traditional ditches "Umi".

5.1.2 Ridges

Ridge preparation is carried out by hoe with minimal disturbance which is a practice of conservation tilllage. Ridges are constructed across the slope so as to reduce the velocity of water movement (**Figure 5**). However, in some areas farmers

Figure 4.
Traditional drainage ditches.

Figure 5.
Broken ridges across the slope allows water movement with minimal soil loss.

tend to ignorant of implication of slope direction. The ridges are low and with large spaces between. This is to facilitate ease of water flow along the ridges. Also broken ridges are observed to be conservation measures against erosion.

5.1.3 Embankment structures

Barriers made of vegetation (dried or live), short walls (earthen or concrete) (**Figure 6**) are used to reduce the velocity of runoff water which could lead to water erosion. Embankments can function as sediment filters, aid in runoff velocity reduction, infiltration facilitator and could serve as boundaries. Farmers' in the study area view this as a very important measure of checking sheet and gully erosion.

5.1.4 Manuring/residue mulch

Farmers shred parts of trees, leave the vegetative remains after harvest and sometimes add animal wastes to the soil (**Figure 7**). Eventually, the faster decomposing part serves as nutrient to restore soil physical, chemical and biological

Figure 6.
(a) Dried vegetative barrier (b) Wall barriers

Figure 7.
Animal wastes applied to enhance soil properties.

properties while the woody part is utilized as firewood. FAO [62] reported that the practice of manuring serves conservation needs by; protecting soil surface from adverse weather conditions, increasing infiltration and reducing runoff velocity, increase organic matter supply, reduces evaporation, nutrient recycling.

5.1.5 Multiple cropping/agroforestry

Most farmland in the study area consist of woody perennials and annuals in the same land unit. Examples of annuals observed include; Mango, Citrus, Oil palm, Banana, Plantain etc. (**Figure 8**). Young [63] attributed the potential of agroforestry as an erosion control measure to its capacity to supply and maintain a good soil surface cover by the tree canopy and the pruning material. The deep roots will helpto stabilize the soil and increase moisture absorption through transpiration by the trees and crops [62].

5.1.6 Rainwater harvesting

Reservoirs-like constructions, constructed for the purpose of storing the surface run-off, generated from the catchments area. In the study area, this practice began a long time ago and is still being practiced with modifications such as larger collection reservoirs. The harvested water does not only serve irrigation purposes and

Figure 8.
Agroforestry practices common in the study area.

Figure 9.
Stones incorporated into the soil so as to stabilize it against erosion.

erosion prevention, it also saves cost for the farmer's family. Other uses include; storing nutrients and rich soil materials as well composting etc. The reservoirs used for water harvesting vary in size depending on the need of the farmer.

5.1.7 Surface roughening

Farmers incorporate stones, charcoals, kernel shells, pieces of wood etc. so as to roughen and stabilize the soil against the effect of water erosion (**Figure 9**).

6. Conclusion

Soil erosion and other anthropogenic activities can leave remarkable footprints on earths' surface. In erosion prone landscapes, the earth's surface is continually evolving due to events and processes such as (i) road and foot tracks, (ii) land use and land cover changes, (iii) hydrogeological dynamics (iv) soil erodibility etc. To understand soil erosion, efforts have been made to assess and quantify the phenomenon. However, literature on soil erosion research in Southeastern Nigeria is still minimal and some promising techniques are yet to be tested. This may be partly the reason why soil erosion related land degradation remains critically high amidst scarce and often inaccurate data. Another reason is the non-inclusion of the sustainable home-breed sustainable solutions into erosion management plans. Such knowledge could assist in both research and practice in developing robust environmental conservation approaches; that is cognizant of cultural and socioeconomic situation of the area. Local people knowledge of the soil has helped to protect soil from erosion while ensuring that its fertility is maintained. When improved, better conservation outcomes in Southeastern Nigeria can be achieved.

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