SOIL EROSION IN NORTHERN NIGERIA: POTENTIAL IMPACT AND POSSIBLE SOLUTION : A REVIEW

Abstract

Aim

This research aims to discuss the environmental soil erosion problem in northern Nigeria: their potential impact and possible solution for sustainable agriculture and livelihood management

Methods

This research was carried out by reviewing the literature. The data were derived from; books, journals, internet and conference reports, and Google Scholar, and some university library catalog was used to search the literature. The search terms used are soil erosion, climate change, land degradation, Sahel, drylands, soil conservation, agroforestry, and sustainable land management.

Result

This paper reviewed environmental problems such as soil erosion which are generally considered as the most serious consequences and their impact will remain the main issues for the 21st century. Soil loss will however be prevented or decreased by appropriate crop management such as cover cropping, multiple cropping, and high-density planting. Cover crops have certainly influenced the properties of physical soil which include infiltration rate, moisture content, bulk density, increase organic matter content, the levels of Nitrogen (N) by use of Nitrate (N_2) fixing legumes, exchange of cation capacity and crop yields.

Conclusion

The use of cover crops, multiple cropping, agroforestry, and conservation tillage are provided as some of the effective means of controlling soil erosion in the northern part of Nigeria. Therefore, the recommendation here is that the government extension services should incorporate farmers in the affected areas.

Keywords: Soil erosion; agriculture; degradation; agroforestry

1.0 Introduction

Environmental problems such as soil erosion are generally considered the most serious consequences and their impact will remain the main issues for the 21st century (Lal, 2003). Because of the negative impact due to the erosion, food security and the livelihood of the living population have been affected (Eswaran *et al.*, 2001). The problems have become the main threat to global agricultural sustainability and have caused a reduction in actual and potential soil productivity (Lal, 1991; Viloria et al. 2023). Nigeria is one of the countries affected by land degradation (FMEN, 2001). It was reported by the Food and Agriculture Organization (FAO, 2005) that soil degradation by erosion is common in Nigeria and its severity was noted to account for 37.5% of 342, 917 km^2 as low, 4.3% of 39,440 km^2 as moderate, 26.3% of 240, 495 km^2 as high and 27.0% of 255, 167 km^2 as very high. Also, in addition, it was estimated that about 50% of Nigerian land surface is being affected by deforestation, erosion drought, and salinization leading to desertification, commonly seen in dryland areas of the northern part of the country (FMEN, 2001). The factors that are contributing to the increase of soil degradation leading to erosion in the northern part of Nigeria include population growth, the land tenure system, poor agricultural practice, poor vegetation cover, and poor environmental government policy (Usman, 2007). Redistribution and management of the soil environment as affected by soil erosion are important for high economic food security and soil quality improvement (Usman, 2007). Therefore, this research aims to discuss the environmental soil erosion problem in northern Nigeria: their potential impact and possible solution for sustainable agriculture and livelihood management.

2.0 Methods

This section details the methodology for the review manuscript on soil erosion in northern Nigeria:

a. Research question: The research question for this review paper will be "What is the current state of knowledge about soil erosion in northern Nigeria, and what factors are contributing to soil erosion in this region?"
b. Literature search: A comprehensive literature search will be conducted to identify relevant studies on soil erosion in northern Nigeria. Databases such as Web of Science, Scopus, and Google Scholar will be searched using keywords such as "soil erosion," "northern Nigeria," "land degradation," "agriculture," and "environmental degradation." Additionally, relevant articles cited in the identified studies will also be examined.

c. Inclusion criteria: Studies will be included in this review manuscript if they provide information on the state of soil erosion in northern Nigeria, identify contributing factors to soil erosion, and propose solutions or recommendations to address soil erosion. Studies will be excluded if they are not relevant to the research question, are not published in English, or are not peer-reviewed.

d. Data extraction: Relevant data from the identified studies will be extracted and summarized in a tabular format. The data extraction process will include information on the study design, study location, study population, study objectives, key findings, and recommendations.

e. Data analysis: The extracted data will be analyzed thematically to identify patterns and trends in the state of soil erosion in northern Nigeria, the contributing factors, and potential solutions or recommendations. The analysis will be conducted using a narrative synthesis approach to synthesize the findings of the identified studies.

f. Writing: The findings of the review manuscript will be synthesized and presented clearly and concisely. The manuscript will be written in a systematic format, including an introduction, methods, results, discussion, and conclusion sections. The discussion section will provide an in-depth analysis of the state of soil erosion in northern Nigeria, the contributing factors, and potential solutions or recommendations. Finally, the conclusion section will summarize the main findings and provide recommendations for future research and policy.

2.1 Geography of the study area

Nigeria is one of the largest countries in Africa and has the largest population of 150 million (FMEN, 2001). The country is located approximately between latitude 4^{o} and 14^{o} north of the Equator (Salako, 2003) and between longitude 2^{o} 2' and 14^{o} 30' east of the Greenwich Meridian, with a surface area of about 91.07 million ha, in which about 57% is believed to be under cropping and pasture management (Cleaver and Schreiber, 1994). Nigeria has a total surface area of approximately 923,770 square kilometers (FMEN,2001) of which 35% is believed to be arable land, 15 as pasture, 10% as forest reserve, 10% for settlements and infrastructural development while the remaining 30% is regarded as uncultivated areas (FMEN, 2001). The total land area of the dryland in the country is approximately 170,000 km^2 (Anderson, 1988).

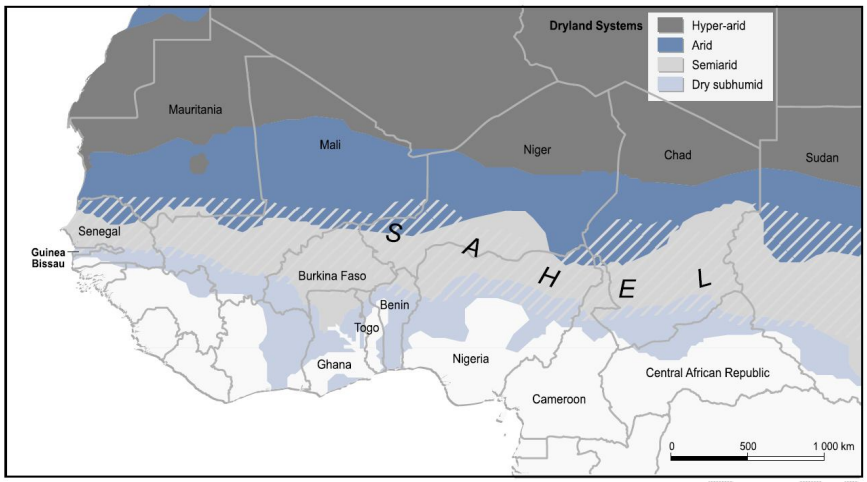

Figure 1: West Africa map shows the Sahel region where the northern Nigerian dryland areas are located. After FMEN (2001)

2.2 Soil Erosion in Northern Nigeria

Soil erosion is one of the serious environmental problems in northern Nigeria (Muhamman and Gungula, 2006). Usman (2007) identified two main types of soil erosion in northern Nigeria comprise accelerated and geological soil erosion. Geological soil erosion occurs under the protective cover of natural vegetation, while accelerated erosion exceeds the normal rate and becomes unusually damaging (Brady, 1990; Usman, 2007). Both geological and accelerated soil erosion has been recognized as the most serious problems that affect the surface soil environment in most of the arid and semi-arid regions of the world (Gomes *et al*., 2003). It was reported that about 351,000 ha of land in northern Nigeria is affected by soil erosion, which comprises about 13 States of the region (FMEN, 2001). The affected states are Adamawa, Bauchi, Borno, Gombe, Jigawa, Kaduna, Kano, Katsina, Kebbi, Niger, Sokoto Yobe, and Zamfara. A typical example of this has been given by Usman (2007): (Figure 2).

On the other hand, the high increase in population in northern Nigeria has increased the demand for land, and this has been the result of intensive cultivation with few or no management practices (Weber *et al*., 1996). This condition of intensive cultivation decreases the fertility of the soil, destroys soil organic matter, increases soil acidity, and speeds up soil erosion due to devastating wind speed during the dry period (Stockwell and Fisher, 1996). As such, northern Nigerian farmers are forced to exploit the productivity of their farmland, by increased application of synthetic chemicals such as fertilizers, pesticides, and herbicides (Usman, 2007). These types of farmers' agricultural practices are unsustainable and may expose the soil to hazardous conditions such as salinization due to erosion by water (Su *et al*.,

2002; Gomes *et al*., 2003). Also, human activities such as deforestation, poor farming system, and over-exploitation of forest trees might have sped up the soil erosion process in the region (e.g. Risse, 2001).

Figure 2: Soil erosion in northern Nigeria. After Usman, (2007).

2.3 Potential Impact of soil erosion in Northern Nigeria

As stated earlier that soil erosion is one of the environmental problems affecting farmlands in northern Nigeria. The Federal Ministry of Environment Nigerian (FMEN, 2001) reported that Nigeria is losing about 500 km^2 of cropland annually due to soil erosion and the problem is more severe in the dryland areas due to lack of vegetation and proper land use practice (Tribune, 2007). This has led to the loss of about 350, 000 ha of arable land yearly in the region, and it leads to a high increase in food prices and poverty rate (Tribune, 2007). However, the Federal Government of Nigeria (FGN, 2005) report that the impact of soil erosion and other related problem has affected some population in many States (Table 1).

Table 1: percentages of the harmful effects of soil degradation in northern Nigeria for 2003 and 2005: (FGN, 2005)

State	Percentages of 2003	Percentages of 2005
Katsina	7	18

Bauchi	3	10
Jigawa	0	11
Adamawa	2	8
Yobe	0	23

[1] The summary of the potential effects of soil degradation in some northern states of Nigeria, in which surveyed indicated the percentage of people that cannot afford food for a month due to high increases in price.

2.3.1 Impact and Causes of Nutrient Loss from the Soil

There are two main causes of nutrient losses in northern Nigeria which comprise soil erosion by both wind and water and land degradation due to desertification, leaching, deterioration of soil structure, and loss of organic matter (FMEN, 2001). Research carried out by Mohamman and Gugula (2000) in Adamawa state of northern Nigeria, indicated that soil erosion by wind and water not only removes the topsoil but hinders the emergence of crop growth and yield due to the loss of nutrients. However, Usman (2007) reported that water erosion erodes the top surface soil and might alter its texture and structural mineral quality. It is, therefore, important to note that areas affected by soil erosion in northern Nigeria are more likely to have low nutrient content than areas that are not affected by the erosion as similarly reported by Mango (1993) in Siaya District of Kenya.

2.3.2 Impact and Causes of soil degradation on crop yield

Losses of soil nutrients such as Nitrogen (N), Potassium(K), phosphorus (P), and calcium (Ca) in the soil result to decrease in soil quantity and crop yield in some parts of northern Nigeria (Agregheore, 2005). Generally, this loss of soil nutrients has become the main cause of food crises in most African countries and global crop production (Hartemink, 2003). According to Lal (1991), poor crop development due to loss of nutrients under the affected erosion areas is more severe in the African region, for example, the annual decrease of crop production in 1989 was accelerated by erosion. It was estimated that about 8.2 million ha of cereal crops, 9.2 million ha of roots and tubers, and 0.6 million ha of pules have been decreased (Lal, 1995). However, some studies indicated that about 104 million ha out of 644 million ha are affected by soil erosion (Hartemink, 2003). Therefore, in northern Nigeria, crops are likely to suffer more in erosion-affected areas leading to low-yield production as similarly documented by Usman (2007).

3.0 General Discussion

3.1 Possible Solutions for controlling soil erosion in Nigeria

World Resources Institutes (WRI, 2000) highlighted two main possible ways to control soil erosion: (a) by understanding the environment itself and then knowing how it works and (b) by valuing both the human and natural resources in hopes to achieve sustainable development. Some of the examples of these possible ways are discussed below.

3.1.1 Crop management

Cover crops play a vital role in soil conservation (e.g. Figure 3; Lal *et al.*, 1979). Soil loss will however be prevented or decreased by appropriate crop management such as cover cropping, multiple cropping, and high-density planting (Junge *et al*., 2008). Cover crops which include legumes P. *Phaseoloids*, M. *Pruriens*, and *paspalum notatum* are plants that usually use to grow very fast and close (Lal, 1995), and their dense canopy can prevent rain drops from shedding the soil particles and this will keep soil loss to supportable edges (Usman, 2007). Cover crops have certainly influenced the properties of physical soil which include infiltration rate, moisture content, and bulk density (Hulugalle *et al.*, 1986), such properties increase organic matter content, the levels of Nitrogen (N) by use of Nitrate (N_2) fixing legumes, exchange of cation capacity and crop yields (Ibewiro *et al*., 2003).

Figure 3: mulch in practice in Nigeria. After Junge *et al*. (2008).

In tropical regions, the soil is often exposed to heavy rainfall and high temperatures, which can cause erosion and nutrient depletion (Rey et al. 2019; Olivares et al. 2011; 2015). Cover crops help protect the soil by preventing erosion and reducing soil compaction (Lobo et al. 2023), thus improving soil structure and increasing its ability to hold water (Hernandez and Orlando, 2020; Hernandez et al. 2020). Cover crops can help improve soil fertility by

fixing nitrogen from the air and adding organic matter to the soil (Olivares et al. 2022). This improves the soil's nutrient content and reduces the need for chemical fertilizers, which can be expensive and harmful to the environment (Lopez-Beltrán et al. 2019; Olivares and Lopez, 2019). Certain cover crops can also help control pests by attracting beneficial insects that prey on harmful insects (Olivares et al. 2021; Bertorelli and Olivares, 2020. This can reduce the need for pesticides, which can be harmful to the environment and human health.

3.1.2 Multiple Cropping

Multiple cropping is a farming system that involves different kinds of crops on the farmland (Morgan, 1995). It has been practiced traditionally by Nigerian farmers, and even now is common in some parts of the country (Olukosi *et al*., 1991). Studies about the mixed cropping system have been intensified since the late 1960s (Norman, 1974), and since that period several studies have been carried out on improving the mixed cropping system (Junge *et al.,* 2008). A typical example of this is shown in Figure 3.

Overall, multiple cropping can be an effective strategy for improving agricultural productivity and sustainability as indicated by various investigations in tropical territories of Latin America (Olivares et al. 2018; Hernandez et al. 2018a; Arias et al. 2018). By diversifying crops, making more efficient use of resources (Guevara et al. 2012a; 2012b), improving soil health (Hernandez and Olivares, 2019), and building climate resilience (Parra et al. 2012; Cortez et al. 2018), multiple cropping can help farmers achieve better outcomes for themselves and their communities (Orlando et al. 2016; Hernandez et al. 2018b; Campos et al. 2018).

3.1.3 Agroforestry

Several studies have been carried out by groups of researchers in which they indicate the effectiveness of the Agroforestry system in controlling and preventing soil against erosion (Usman, 2007; Junge *et al.,* 2008). For instance, research that was carried out by Lal (1989), indicates that the decrease of soil erosion by alley cropping apparently depends on the layout between the hedges and species, and the result also indicated that 4-m spaces were suitable for soil erosion control with *L. leucocephala* and 2-m spaces for *G. sepium*. The perennial stage is important as numerous species become very effective sediment traps for about 2 to 3 years after planting (Lal, 1990). Also, intensive rooting by woody perennials will however increase the structure and infiltration rate of soil, the quantity of runoff and therefore soil loss are decreased by alley cropping (Kang *et al*., 1995). A typical example of this is shown in Figure 4.

Figure 4: Alley cropping system in Nigeria. After Junge *et al.* (2008).

Many studies indicate that the agroforestry systems can support a wide range of biodiversity, including flora and fauna that are adapted to the local climate and soil conditions (Camacho et al. 2018; Gracia et al. 2020; Montenegro et al. 2021). This can help promote ecosystem health and resilience in the face of climate change and other pressures. Trees in agroforestry systems can help improve soil health by reducing erosion, adding organic matter, and cycling nutrients. The roots of trees can also help break up compacted soil, improving water infiltration and reducing runoff (Campos and Franco, 2015; Rodriguez et al. 2015; Campos, 2016).

According to carbon sequestration, the trees in agroforestry systems can store large amounts of carbon, which can help mitigate the impacts of climate change by reducing greenhouse gas emissions. This can also provide an additional source of income through carbon credits or other incentives.

3.1.4 Conservation Tillage

Conservation tillage refers to a method of seedbed preparation that comprises the presence of residue mulch and an increase in surface roughness as the main criteria (Lal, 1990). Minimum Tillage is a soil conservation practice in which soil preparation is decreased to the minimum essential for crop production and where about 15% to 25% of residues are on the surface of the soil (Morgan, 1995). Also, no-till or zero tillage is characterized by the removal of all mechanical seedbed preparation except for a hole in the ground for seed location or the opening of a narrow strip (Usman, 2007). In addition, ridge tillage is the practice of sowing

or planting crops in rows on the top, along both sides, or in the channels between the edges which are already prepared at the commencement of each cropping period (Junge *et al.*, 2009). Tied ridging comprises extra cross-ties in the furrows between the nearest contour ridges (Lal, 1991). Lal (1984), researched quantifying the effects of different practices of tillage on runoff and erosion, in which the results show that soil loss was about 42 times higher from the plow watershed (5.5 t ha-1) than the no-tillage watershed (0.1 t ha-1). This result indicated that conservation tillage is very effective for the control of soil erosion through the protective effect of residue mulch as noted by Usman (2007).

4.1 Conclusion and Recommendation

Soil erosion has been viewed as one of the environmental soil problems in northern Nigeria. It affects both the land and human population and has potentially affected crop development. The use of cover crops, multiple cropping, agroforestry, and conservation tillage are provided as some of the effective means of controlling soil erosion in the northern part of Nigeria. Therefore, the recommendation here is that the government extension services should cooperate with farmers in the affected areas to adopt a more sustainable measure of converting soil erosion through the use of cover crops, multiple cropping, conservation tillage, and agroforestry.

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