https://dx.doi.org/10.24001/ijaems.3.12.6 *ISSN: 2454-1311*

Adaptations to Soil Erosion: A Review

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Abstract*—Soil erosion which is now one of the impacts of climate change due to increased precipitation events across the globe needs adaptations for adjusting to the actual and expected change in its occurrence more than mechanical/engineering measures for the management of the phenomenon. The objective of this paper is to conduct an in-depth review of adaptation strategies to soil erosion. The research made a review of academic/journal articles, internet materials, news articles, conference papers, books and publicly available materials on adaptations to soil erosion. From the review, most authors have a unity of opinion on adaptive strategies to soil erosion, including the use of mulching, cover cropping, reduced tillage, contour bonds, tree planting, wood logs and ploughing across the slope as they have been found to increase soil yield and reduce soil loss as well as its accompanying adverse impacts. Recommendations of the study includes: (1) enhancement of the existing adaptive measures; (2) a shift from rain-fed agriculture to dry season farming; (3) training the affected people on adopting the adaptive measures which are currently ignored in most communities; and (4) encouragement of the participation of land holders through grants in soil erosion management based on the adaptive techniques.*

Keywords*— *Adaptive Measures, Climate Change, Environmental Sustainability, Rainfall, Review, Soil Erosion.

I. INTRODUCTION

Soil is an important natural resource which when effectively managed could increase the livelihoods of households in sedentary agricultural communities (Bukari, 2013). Soil erosion is recognized as one of the world's most serious environmental problems, globally about 80% of the current degradation of agricultural land is caused by soil erosion (Mohamed 2015). Jing, Wang and Zheng (2005) were of the opinion that soil erosion is a serious environmental, economic and social problem; it does not only cause land degradation and soil productivity loss, but also threatens the stability and health of society in general and sustainable development of rural areas in particular. Shougang and Ruishe (2014) opined that soil erosion is one of the most serious environmental problems in the world today because it threatens agriculture and also the natural environment. Soil erosion in the African continent as a whole has caused an average annual crop yield decline of 8.2% and 6.2 for Sub-Saharan African and that if higher soil erosion rates continue unabated average possible food production will drop (Pimentel, 2006).

Soil erosion is a natural geomorphologic process resulting from water and land interactions but accelerated to become an environmental hazard by human activities such as clearing of forests for cultivation, poor farming practices and encroachment into marginal lands (Farayi, 2011). Denton (2000) defined soil erosion as the physical wearing of the earth's surface by the action of water or wind, it has been occurring for some 450million years, since the first land plants formed the first soil. Soil erosion is the removal of topsoil than the soil forming processes can replace it, due to natural, animal and human activities such as over grazing, over cultivation, deforestation and mechanical farming (Francis, 2012). Soil erosion is an accelerated process under which soil is bodily displaced and transported away faster than it can be formed (Igbokwe, Akinyede, Dang, Ono, Nnodu and Anike, 2008)

Favis-Mortlock (2005) opined that there are two main types of soil erosion; geological and accelerated soil erosion, geological soil erosion happens at the same rate as soil is formed while accelerated soil erosion is the loss of soil at a much faster rate than it is formed. On the basis of causes of soil erosion; it can be classified as erosion by gravity, water splash, erosion due to rain water, rill, gully and stream bank erosion due to the action of flowing water (Madhu, 2008).

Agents of soil erosion could either be wind, water, ice, waves and gravity, depending on the external dynamic agent that generates detachment, transportation and deposition of soil particles (Junge, Abaidoo, Alibi and Starhr, 2007).The rate and magnitude of soil erosion is

https://dx.doi.org/10.24001/ijaems.3.12.6 *ISSN: 2454-1311*

affected by rainfall intensity and runoff, soil erodibility, slope gradient and length, vegetation, and control treatments (Ritter, 2012). Soil erosion is influenced by natural and anthropogenic factors; natural factors influencing soil erosion are soil texture, soil structure, rainfall intensity, slope, soil type, climate, erosivity, erodibility and by the covering degree of the soil with vegetation, but most importantly by anthropogenic factors, through actions such as land cultivation, deforestation, construction (Kirchof and Salako, 2012).Adaptation refers to the process of adjusting to actual or expected climate change and its impacts (Quandt and Kimathi, 2016). The appropriateness of a particular adaptation strategy is highly dependent on time and place as they are influenced by the cultural and indigenous observations and practices (Obert, Paramu, Chipo and Owen, 2016). Some of the adaptive strategies to reduce the effects of soil erosion include shifting cultivation, ridging across slopes, planting on raised mounds and avoidance of deep ploughing (Bukari, 2013). His work further revealed that farmers who successfully applied the traditional methods improved upon their output levels per land area and the standards of living of their families. This study focuses on adaptations to soil erosion so as to build in sustainability into management of the phenomenon.

1.1 Statement of the Problem

The efforts to eradicate poverty, which is one of the Millennium Development Goals (MDGs), can only succeed when soil erosion is kept to a minimum (Pimentel, 2006). Soil erosion is common in all areas of the world, but developing countries suffer more because of the inability of their farming populations to replace lost soils and nutrients (Mohamed, 2015). He further stated that soil is one of the natural resources on Planet Earth, but though soil is a renewable natural resource, yet it can become finite, with the passage of time, through its degradation. Phatak, Dozier, Bateman, Brunson and Martini (2002) opined that globally it has been estimated that about 1.1 billion hectares of land is affected by soil erosion, with annual global loss of agricultural land due to erosion estimated at 3 million hectares (Woreka, 2004).

Behera and Panda (2009) stated that it is impossible to achieve food security without overcoming the problem of nutrient depletion. The continuation of high soil erosion will eventually lead to a loss in crop production even though fertilizers and other inputs often result in increased yield in the shortterm (Pathak, Wani and Sudi, 2005). Francis (2012) asserted that soil erosion results in infertility and lead to desertification and devastating flooding. Soil erosion impacts negatively on crop productivity and environmental quality and depresses the socio-economic status of lithosphere; it is therefore a threat to the landowners' livelihoods as well as the overall health of an ecosystem (Egbai, Eric and Ogogo, 2012).

1.2 Objective

The objective of this paper is to conduct a review of adaptations to soil erosion.

II. CONCEPTUAL FRAMEWORK: ENVIRONMENTAL SUSTAINABILITY

This research is based on the concept of environmental sustainability. Environmental sustainability is defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity (Morelli, 2011). From this definition, it can be distilled that the major goal of environmental sustainability is to achieve sustainable development.

The World Conference on Environment and Development (WCED) (1987) defined sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Adaptations to soil erosion will reduce the adverse impacts of the phenomenon on the environment and socio-economic conditions of the affected people. Therefore, this study is set to review adaptations to soil erosion with a view to making recommendations that will build in sustainability into soil erosion management.

III. METHOD

The researchers gathered 39 materials for the research and summarized the characteristics of 10 deemed to be more relevant to adaptations to soil erosion in the review. This literature research made a review of academic/journal articles, internet materials, news articles, conference papers, books and publicly available materials on adaptations to soil erosion. This enabled the researchers to make a synthesis of various researchers' views on adaptations to soil erosion.

IV. LITERATURE REVIEW

Soil erosion is a worldwide natural disaster and a number of studies have been undertaken with a view to grasp a clear understanding of its origin, processes, factors, effects and control (Hughes, Prosser, Stevenson, Scott, Lu, Gallatand Morgan, 2001). Globally, about 80% of the current degradation of agricultural land is caused by soil erosion (Angima, Scott, O'neil, Ong and Weesies, 2003).

https://dx.doi.org/10.24001/ijaems.3.12.6 *ISSN: 2454-1311*

Wakindiki, Rungumaand Mochoge (2000) studied local adaptations to soil erosion in Tharalm Kenya, and found out that farmers had developed ingenious soil and water conservation practices in response to soil erosion and low soil moisture. According to them, the main indigenous adaptation methods used were intercropping, trash lines, stone bunds, minimum tillage and grass strips. They also discovered that farmers' decision to adapt a particular technique was influenced by the technique's ability to control runoff, associated crop yield increment, farming system, availability of the raw material, and the labour requirement. Mgbenka, Nicholas, Igbokwe and Ebe (2012) studied soil and water conservation in Eastern Region of Nigeria and stated that the adaptive soil erosion control measures are water-harvesting, grass strips, crop rotation, planting trees and shrubs.

Troeh, Hobbs and Donahue (2014), in their book on soil and water for productivity and environmental protection, stated some techniques for adaptation to soil erosion which include biomass mulches, crop rotations, no-till, ridge-till, added grass strips, shelterbelts, contour row-crop planting, and various combinations of these. Basically all of these techniques require keeping the land protected from wind and rainfall energy by using some form of biomass cover on the land which means either leaving most of the crop residues on the cropland or planting cover vegetation on a harvested cropland.

An Assessment of Farmers' perception and adaptation mechanism to soil erosion by Abiy, Getahunand Genene (2015) in Ethiopia showed that farmers in the area were mainly annual crop producers on slope farmland with traditional adaptation methods and most of the farmers use contour farming, furrow making, residue laying on farmland, and strip cropping methods for maize sowing during furrow making (*gulgualo)*, trash line *(gilalo)*and contour farming methods for millet and chili pepper sowing. Mohamed (2015) studied the causes the effects of soil erosion in Somaliland and stated that the major local adaptation to soil erosion in that area was crop rotation which is designed for nutrient cycling and reduced tillage. Eze and Osahon (2016) studied the perception of soil erosion control in Southeast, Nigeria and reported that the farmers controlled erosion using techniques like mixed cropping, strip cropping and tie ridging.

Bukari, (2013) conducted a research on indigenous perceptions and adaptations to soil erosion in Zampe community of Bole, Ghana and noted that some of the adaptive strategies to reduce the effects of soil erosion include shifting cultivation, ridging across slopes, planting on raised mounds and avoidance of deep ploughing. The most important and common strategy to control soil erosion in the tropics and sub-tropics is convincingly known as conservation tillage (Erenstein 2003). The causes and effects of soil erosion were assessed by Balasubramania, (2017) in Mysore who came up with adaptation methods used by individuals to control soil erosion which were: crop rotation, reduced tillage, mulching, and cover cropping. Edward and Simon (2001) noted that conservation, minimum tillage, mulches and cover crops prevent runoff initiation by intercepting raindrops in a handbook of processes and modelling in the soil-plant system.

Dimelu, Ogbonna and Enwelu (2013) studied the soil erosion conservation practices in Enugu, and the results showed that the soil conservation techniques used as adaptive measures were crop rotation, mulching, liming, contour bonds and terracing. They noted that the farmers that practised crop rotation and mulching had a significant increase in their crop yield and this conservation practice was encouraged for increased production, income for farmers and enhanced food security for the nation. Ina study conducted in Kogi by Onu and Mohamed (2014) on soil erosion prevention and control, it was revealed that mulching, cover cropping, strip cropping and contour bonding were the local controls for soil erosion. Tesfaye and Kasahun (2015) studied the soil erosion control practices in Oromia, Ethiopia and stated that the control measures used were crop rotation, compost, animal manure and intercropping.David and Michael (2013) carried out a literature review ofsoil erosion threats to food production and asserted that the control measures taken to by the local people were biomass mulches, crop rotation, no-till, ridge-till, added grass strips, shelterbelts and contour row-crop planting. A study on the perception of soil erosion problems and conservation in Ghana by Farida and Fariya (2015) showed that use of stone bunds, local grass, tree planting, drainage, ploughing, trench and wood logs were adaptive measures to the phenomenon. They noted that the local conservation methods increased yield because soil erosion was reduced. In a study by Eze and Mbah (2013) on challenges to soil erosion control measure in Anambra State Nigeria, it was revealed that the major adaptive control measures by the farmers were strip cropping and making ridges across the slope.

https://dx.doi.org/10.24001/ijaems.3.12.6 *ISSN: 2454-1311*

Table.1: Summary of Characteristics of some of the Studies that Describe Adaptations to Soil Erosion

S/N	Author(s)	Topic of Research	Method(s)	Results	Recommendations	Conclusion
1	Abiy, Getahun and Genene (2015).	Assessment of Farmers' Perception and Adaptation Mechanism to Soil Erosion Problem in Shomba Kichib, Gimbo District, Kaffa Zone, South West Ethiopia.	Direct observation, Interview, Structured questionnaire.	The results showed that farmers used traditional adaptation methods such as contour farmingfurrow making, residue laving on farmland, and strip cropping for maize sowing.	Farmers whose land slope is more than 8% should get continuous awareness creation training at Farmers Training Centres (FTCs). The training should also focus on the role of integrating physical and biological soil and water conservation practices.	The very sloping nature of the study area has to be given due emphasis and priority for an appropriate designed soil and water conservation practices.
2	Balasubramanian (2017).	Soil Erosion – Causes and Effects in Mysore.	Focus group discussion, Review of literatures.	Soil conservation practices farmers use to cub soil erosions were crop rotation, reduced tillage, mulching, cover cropping and cross-slope farming.	Soil conservation practices are tools the farmer can use to prevent soil degradation and build organic matter.	Soil erosion remains a key challenge for agriculture in several countries. Proper management of this valuable resource is vital to sustain long-term agricultural productivity.
3	Bukari (2013).	Indigenous Perceptions of Soil Erosion, Adaptations and Livelihood Implications: The Case of Maize Farmers in the Zampe Community of Bole in the Northern Region of Ghana.	Focus group discussion, Questionnaire.	The findings indicated that some of the adaptive strategies to reduce the effects of soil erosion included shifting cultivation, ridging across slopes, planting on raised mounds and avoidance of deep ploughing.	Modern agricultural extension services were needed, not to replace, but to complement the local knowledge systems in order to ensure sustainability.	It was revealed that farmers who successfully applied the traditional methods improved upon their output levels per land area and the standards of living of their families.
4	Dimelu, Ogbonna and Enwelu (2013).	Soil Conservation Practices among Arable Farmers in Enugu North Agricultural zone, Nigeria.	Interview.	Most of the farmers used conservation practices such as crop rotation, mulching, liming, contour bonds and terracing.	The farmers who practised crop rotation and mulching had a significant increase in yield, so more farmers should adopt it.	The conservation practice holds a great potential for increased production, income for farmers and enhanced food security for the nation.

https://dx.doi.org/10.24001/ijaems.3.12.6 *ISSN: 2454-1311*

S/N	Author(s)	Topic of Research	Method(s)	Results	Recommendations	Conclusion
5	David and Michael (2013).	Soil Erosion Threatens Food Production	Review of literatures.	Soil conservation techniques including biomass mulches, crop rotations, no-till, ridge-till, added grass strips, shelterbelts, contour row-crop planting, and various combinations of these were the adaptive measures from works reviewed.	Basically all the adaptive techniques should be employed for the land to be protected from wind and rainfall energy by using some forms of biomass cover on the land which means either leaving most of the crop residues on the cropland or planting cover vegetation on a harvested cropland.	Worldwide, soil erosion continues unabated while the human population continues to increase rapidly and 66% of the world population is now malnourished. If soil conservation is ignored and population control is ignored, more malnourished people and more deaths will occur.
6	Farida and Fariya (2015).	Farmers' Perception on Soil Erosion Problems and Conservation Methods among Rural Farmers in Talensi-Nabdam, East Region of Ghana.	Interview.	The conservation method adopted by the farmers include; stone bunds, grass, manure, local grass, tree planting, drainage trench, wood logs and ploughing across the slope.	The conservation process increased soil yield, so more of this method should be adopted by more individuals in the area, so as to stop the soil erosion menace.	If soil conservation is ignored there will be loss of soil and reduced food production.
7	Mohamed (2015).	Cause and Effect of Soil Erosion in Boqol-jire Hargeisa, Somaliland	Review of literatures, Interviews.	Crop rotations are designed for nutrient cycling, integrated pest management is applied for the prevention of pests, and reduced tillage is carried out for soil conservation.	Crop rotation should be practised by all farmers to ensure nutrient cycling.	Farmers' perception and attitudes towards soil erosion and conservation practices is decisive in protecting soil losses from erosion.
8	Onu and Mohamed (2014).	Competency Improvement needs of Farmers in Soil Erosion Prevention and Control	Survey, Interviews, Questionnaire.	The study showed that farmers used mulching, cover cropping, strip cropping and contour	Rural-based programmes should be held for the competencies in soil erosion prevention and control for increased crop	Soil erosion prevention is much better however when it happens proper conservation

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S/N	Author(s)	Topic of Research	Method(s)	Results	Recommendations	Conclusion
		for Enhancing Crop Production in Kogi State, Nigeria.		bonding to control soil erosion.	production.	measures should be consistently used.
9	Tesfaye and Kasahun (2015).	Assessment on Farmers' Practices in Soil Erosion Control and Soil Fertility Improvement in rift Valley Areas of East Shoa and West Arsi Zones of Oriomia, Ethopia.	Interview.	To tackle the problem a good number of farmers used measures such as crop rotation, compost, animal manure and intercropping to adapt to soil erosion.	Participatory soil and water conservation mechanism involving farmers should be implemented taking into consideration farmers' decision on soil and water conservation activities more fruitful and sustainable.	It was discovered that deforestation is the major cause of soil erosion in that area, so it should be controlled.
10	Wakindiki, Runguma and Mochoge (2000).	Technical Note on Local Adaptations to Soil Erosion and Low Soil Moisture in the Semiarid Tharaka District, Kenya.	Personal interview, Direct observation, Workshop discussion, Structured questionnaire.	Soil and water conservation practices in response to soil erosion and low soil moisture, the main indigenous methods used were intercropping, trash lines, stone bunds, minimum tillage and grass strips.	Sustainable soil and water conservation programmes should incorporate indigenous soil and water conservation.	Generally farmers' decision to adopt a particular technique was influenced by the technique's ability to control runoff, associated crop yield increment, farming system, availability of the raw material, and the labour requirement.

Source: Researchers' design, 2017.

V. RESULTS AND DISCUSSION

Adaptations to soil erosion become very necessary in the face of high costs of mechanical/engineering techniques which are not within the reach of the affected people and landholders. From Table 1 which summarizes the characteristics of some of the studies reviewed in this research, the topics of all the studies capture adaptation to soil erosion and also made use of standard methods for carrying out research such as observation, interview, questionnaire and focus group discussion. Almost all the researchers across the globe (eg. Abiy, Getahum and Genene, 2015; Balasubramanian, 2017; Bukari, 2013; Dimelu, Ogbonna, Enwelu, 2015; Farida and Fariya, 2015) have a unity of opinion on adaptive measures for soil erosion, including strip cropping, crop rotation, wood logs, ploughing across the slope, mulching and contour bonding which are indigenous methods affordable by the affected people in various communities.

Based on the results of the studies, they made a number of recommendations that would help in the encouragement and enhancement of adaptive measures for soil erosion management. Such recommendations include participatory soil and water conservation programmes (eg. Wakindiki, Runguwa and Mochoge 2000; Tesfaye and Kasahun, 2015) and practice of crop rotation by all farmers to improve nutrients enrichment of soils that

https://dx.doi.org/10.24001/ijaems.3.12.6 *ISSN: 2454-1311*

enhances water retention capacity and reduces incidence of soil erosion. It is noteworthy that none of the studies came up with a recommendation on adaptation that is climate change related given the fact that the exposure of the soil during the climate change-induced due to agricultural practices which increases the incidence of soil erosion.

VI. RECOMMENDATIONS

Soil erosion is one of the environmental phenomena to which the adage: "Prevention is better than cure" is most applicable. A number of terrified such as the bad levels of Loess Plateau China, Dustbowl of Arizona and Dakata in US and Agulu-Nnaka-Oko in Anambra State Nigeria would not have arisen if adequate adaptive measures were taken to manage them by the affected people at their early stage of formation. In light of this background and based on the results of this review that the following recommendations have been made;

1. Increasing vegetation cover of soils in this climatic change-driven 21st century characterized by increased incidences of rainfall is very expedient so as to reduce the power of rainfall to induce soil erosion. To this end, laws for afforestation and against deforestation should be enacted by governments with provisions to punish offenders adequately.
2. Shifting from rain-fed agriculture to dry season farming becomes necessary to avoid tillage of soils during the rains which predisposes them to the impact of raindrops and runoff that detaches and transports soil particles respectively in the rain splash-sheet-rill-gully erosion processes.
3. Both the affected people and the landholders should be empowered through grants from governments, donor agencies and non-governmental organization (NGOs) to manage soil erosion using adaptive measures at an early stage in the development of soil erosion. This will ensure their participation as major stakeholders in their soil erosion management process.
4. Creation of awareness generally among the populace on human actions and inactions that trigger soil erosion and the consequences of their activities is a veritable tool to the management of the menace. Training and sensitization in soil erosion management should include agricultural practices that uncover the soil and expose it to the erosive power of rainfall.

VII. CONCLUSION

From the review of many studies on adaptations to soil erosion across the globe, the study concludes that the management of soil erosion should be driven by the affected people and the landholders who know when the menace starts developing on their lands and at such can easily apply the indigenous knowledge to stem the occurrence of the phenomenon. To achieve this, there major stakeholders should be given grants and be made to pay a little counterpart funds as part of their commitment.

VIII. ACKNOWLEDGEMENT

We appreciate the grace and empowerment of God Almighty who has been our source of strength from beginning to completion of this work. We also commend the effort of the relations, friends and well- wishers of the authors who contributed both financially and otherwise for making this review a success. Our gratitude extends to the Vice chancellor and the entire stakeholders of Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria for providing a platform for the study of Environmental Management. To all the lecturers, head of department and dean of the Environmental Sciences, we appreciate their collective efforts in making sure that the goal of environmental management is achieved in the institution. We are highly indebted to the chief author, Mr. Igwe, P.U. for his tireless effort towards an extensive research on the materials used for the review. We cannot fail to commend and appreciate the works of various authors used for the review. Finally, we thank the entire students of Environmental Management especially her final year students for their support throughout the review.

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