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Proceedings of the 44th Conference of Soil Science Society of Nigeria on Climate-smart soil management, soil health/quality and land management: synergies for sustainable ecosystem services

Restoring degraded soil through climate smart agriculture

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Abstract

Research has shown that the global population is increasing geometrically, and the soil pressure is increasing, leading to soil degradation. In Sub-Saharan Africa (SSA), soil degradation has led to the loss of about 615 million hectares while in Nigeria the effect is enormous, considering that Nigeria is the most populous nation in Africa and highly dependent on agriculture. To manage the soil better, there is a need for an approach that is sustainable, resilient, and can reduce Green House Gases. Such an approach is found in Climate-Smart Agriculture (CSA) which is one agricultural development approach aimed at a sustainable increase in productivity and resilience, while also reducing/removing emissions of greenhouse gases. The CSA practices are based on soil conservation that is suitable for a particular locality.

Keywords: Restoration, Soil Fertility, Degradation and Climate-Smart Agriculture

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1.0. Introduction

The world population is put at 7.3 billion in 2015 and projected to increase to 9.7 billion by 2050, an increase in agricultural production of about 70% between 2005 and 2050 is therefore vital (Lal 2015; Dyborn, 2016). It has been estimated that in 2014, there were 5.5 billion people in developing countries (Van and Smith, 2014). Out of this, a large proportion of them depends on agriculture for their livelihood. One billion of these people are small landholders who cultivate less than 2 ha of land (IFAD, 2011).

Nigeria, with a population of 167 million persons ranks first in Africa and the sixth most populated nation in the world (NPC, 2016). Agriculture is the economic mainstay of the majority of households in Nigeria (Udoh, 2000) and is a significant sector in Nigeria's economy. Ahungwa et al. (2014) noted that agriculture contributes more to the nation's GDP with 66.40% than any other individual sector. .

Agricultural production is based mainly on soil, for large-scale and low-cost crop production; there is no substitute for natural soils as a substrate for crops in the foreseeable future. Soil, the most basic of all resources, is the essence of all terrestrial life and cultural heritage (Bini and Zilioli, 2015). Yet, the soil is finite in extent, prone to degradation by natural and anthropogenic factors, and is non-renewable over the human timescale (decades).

Soil degradation, which is defined as the inability of the soil to maintain its fertility has profound consequences for food and water security, poverty, mass migrations, and increased vulnerability of affected areas to climate change. Meeting the present and future needs of the population in terms of food, fiber, shelter, etc. without destroying the soil and the environment remains a significant concern. Management of soil, therefore becomes essential.

Soil degradation is a 21st century and a global problem that is very severe in the tropics and sub-tropics. It currently affects 1.5 billion people (Braimoh, 2015). Every year, 12 million hectares of arable land are lost to land degradation globally (UNCDD, 2012). Accelerated soil degradation has reportedly affected as much as 500 million hectares (Mha) in the tropics (Lamb *et al.,* 2005), and globally 33% of the earth's soil surface is affected by some soil degradation (Lal, 2015).

It is estimated that out of 923,678 km^2 total geographical area of Nigeria, 83.67% area under agriculture (World Bank, 2011). The land area is degrading at 3.5% annually (Osei et al., 2006), an issue that should pose great worry considering the impacts of soil degradation. The degradation is affecting the country's productive resource base. It is given this that this study aimed at reviewing the cost of soil degradation in Africa, particularly in Nigeria and Climate Smart Agriculture as a means of restoring degraded soils.

2.0 Soil degradation

Soil degradation is a serious global environmental problem and may be exacerbated by climate change. It describes ongoing processes that generally limit agronomic productivity, result in undesirable or deteriorating physical, chemical, or biological properties, enhance soil displacement due to wind or water-driven erosion (Baumhardt *et al.,* 2015), and require reassignment of land resources. Soil degradation is defined as a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Degraded soil has a health status such that it do not provide the standard goods and services of the particular soil in its ecosystem (FAO, 2015). According to Adams (2009), soil degradation is often used interchangeably with land degradation. It often interacts with terrain and climatic factors in an ecosystem to reduce sustainable productivity, which eventually threatens food security.

Soil is a vital resource for the future of humanity and needs to be protected and enhanced, more than half (52%) of all abundant food-producing soils globally are now classified as degraded, many of them severely degraded (UNCCD 2015). Soil degradation has been described as a critical global problem (Lal, 2015), with implications for several key policy areas, including food security, climate change, flood risk management, drought tolerance, drinking water quality, agricultural resilience in the face of new crop diseases, biodiversity and future genetic resources.

It was estimated in 2015 that soil degradation cost was between $6.3 and 10.6 trillion dollars per year globally (Richard *et al*., 2015). These costs could be reduced by enhancing soil carbon stocks and adopting more sustainable farming methods. Soil degradation adds carbon (C) and reactive nitrogen (N) to the atmosphere, increasing global warming, which in turn accelerates degradation processes (Lal 2004). Moreover, the soil contains over 98% of the genetic diversity in terrestrial ecosystems (Fierer *et al.,* 2007), and any adverse effect will result in the depletion of this critical ecosystem.

Sub-Saharan Africa (SSA) has experienced the most severe land degradation in the world (Nkonya *et al.,* 2016). According to Le *et al.* (2014), between 1982 and 2006, SSA accounts for 17% of the global 3.623 billion hectares that experienced soil degradation. Richard *et al*., 2015, estimated that 24 billion tonnes of fertile soil are irretrievably washed or blown away (3.4 tonnes for every human on the planet), while UNCCD (2015) projected that this would lead to a 12% decline in global food production over the next 25 years, resulting in a 30% increase in world food prices. African countries are likely to be the worst hit, while Nigeria will be positively affected in the West African region considering its population and landmass.

Soil degradation involves both physical loss and the reduction in quality of topsoil and nutrient decline (Karkee, 2004; Nkonya *et al.,* 2016). The main types of soil degradation include physical, chemical, and biological degrada-

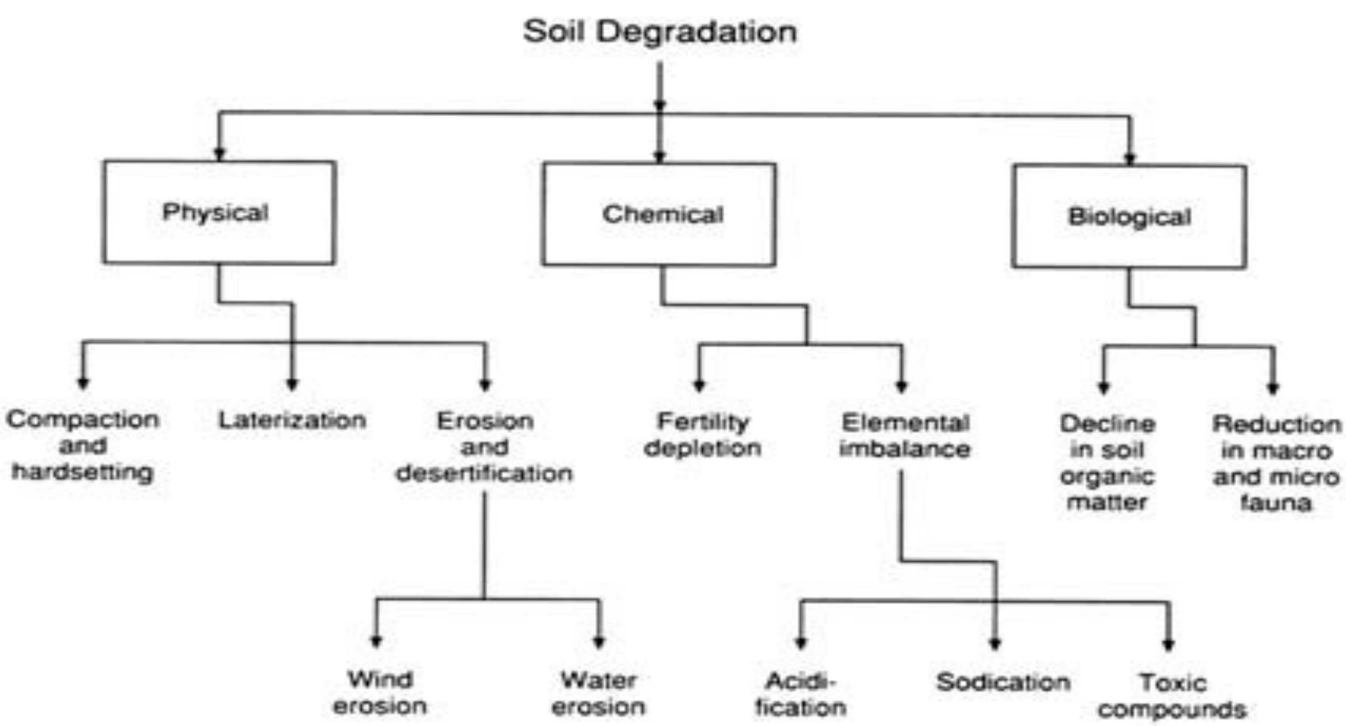

Figure 1: Types of soil degradation and its effect

Source: Soil and water quality: An agenda for Agriculture (1993) tion. Each type of soil degradation is closely related to its cause, as can be seen in figure 1.

The cost of soil degradation worldwide has reached an estimated US$490 billion, according to the United Nations Convention to Combat Desertification (UNCCD, 2015), far higher than the cost of reversing it (Bossio and Zanstra, 2016). The only reasonable response now is investing in land restoration and soil rehabilitation, which have the potential to benefit millions of rural households in developing countries and all who rely on the ecosystem services that farm families help in maintaining.

According to Humberto and Lal, (2010), restoring degraded soil is an absolute necessity for;

meeting the increasing demand for food, reducing the increasing adverse pressure on prime agricultural soils, recovering the value of the degraded soils and enhance wildlife habitats, reducing the pollution of surface and groundwater resources, enhancing economic growth and agricultural sustainability, and avoiding the risk of irreversible soil degradation.

There are no universally applicable techniques for managing degraded soils, but there are several approaches for ensuring sustainable soil management depending on the location and existing policy. The ideal strategy is to meet increasing global food demands while simultaneously restoring soil quality, improving the environment, and minimizing the trade-offs.

One of the strategies that were recognized by FAO (2011) at the first Conference on Agriculture, Food Security, and Climate Change held in Hague was Climate-Smart Agriculture (CSA). It is believed that CSA has the ability for increasing food production and farmer's income under the present climate change without destroying the soil but restores the degraded soil.

2.1 Climate smart agriculture

Climate-Smart Agriculture (CSA) addresses the challenge of meeting the growing demand for food, fiber and fuel, through the restoration of degraded soil despite the changing climate and fewer opportunities for agricultural expansion on additional lands. CSA focuses on contributing to economic development, poverty reduction, and food security; maintaining and enhancing the productivity and resilience of natural and agricultural ecosystem functions, thus building natural capital; and reducing trade-offs involved in meeting these goals. The objectives of CSA, according to FAO (2011), are to:

- Increase agricultural productivity and farming incomes sustainably
- Increase farm resiliency to extreme weather and climate variability through the adoption of best management practices for climate change adaptation
- Reduce greenhouse gas emissions from agricultural production through the adoption of best management practices, and increased energy efficiency and use of renewable energyIncreased energy efficiency and use of renewable energy

CSA practices are not new in Nigeria. Virtually any agricultural practice that improves productivity or the efficient use of scarce resources can be considered climate-smart because of the potential benefits concerning food security, and even if no direct measures are taken, it has no counter detrimental climate effects (Neufeldt *et al.,* 2013). The

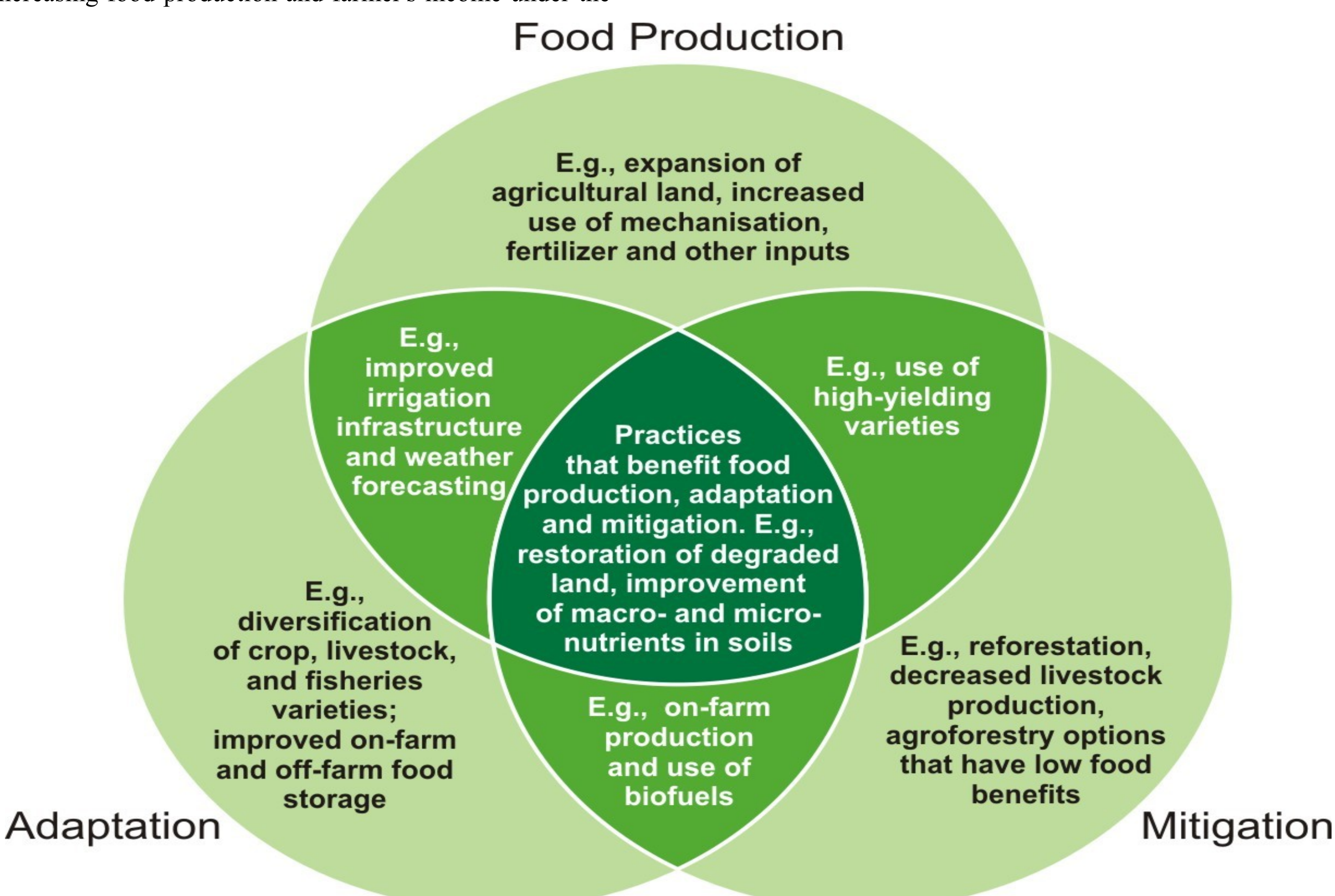

Figure 2: Climate-Smart Agriculture Practices
Source: Adapted from Sanjok (2014)

practices are as illustrated in Figure 2.
Some of the CSA practiced in Nigeria are

1. agroforestry; an integrated land-use system that combines trees and shrubs, with crops and livestock; and,
2. conservation agriculture, a system based on minimum soil disturbance through mechanical tillage, permanent soil cover through residue management, and
3. crop rotation and diversification using legumes and green manure or cover crops.

2.2 How do climate smart agriculture restore degraded soils?

2.2.1 Reduction in Agricultural Emissions

Land use represents the most considerable climate mitigation potential in many countries. Indeed, only soil-based carbon sequestration efforts currently offer the possibility of large-scale removal of greenhouse gases (GHG) from the atmosphere, through photosynthesis and carbon sequestration in soils and perennial plants (Lal, 2004). Agricultural soil carbon accounts for 89% of the technical sequestration potential, representing an estimated potential of between 5.5 and 6 gigatons of CO_2 emissions per year, which roughly equals agriculture's total yearly contribution to global emissions. Significant sources of emissions reductions include improved feed systems and manure management, more efficient fertilizer use, reducing deforestation and wetland conversion, and restoring degraded lands (Smith *et al.,* 2007). Changes in soil management and land use may also moderate local and regional climate through changes in evapotranspiration, soil moisture, and temperature (Desjardins *et al.,* 2006). Moreover, within agriculture, many adaptation measures have significant mitigation co-benefits. For example, increasing soil organic matter improves adaptive capacity by increasing soil water holding capacity and soil fertility, while also sequestering carbon (Falloon and Betts, 2010).

2.2.2 Sequestration of carbon

Carbon sequestration is a process where CO_2 is pulled from the atmosphere and stored for an extended period in the soil. One of the carbon sequestration methods is through agroforestry practices. Agroforestry is an African traditional practice whereby crops, tree crops, and forest plants or animals are simultaneously combined. (Hamma and Ibrahim, 2013). Forests store large amounts of carbon. Globally, forests makeup 90% of the carbon sink and sequester about 10-15% of CO_2 emissions. According to Alao and Shaibu (2013), agroforestry is a dynamic ecological based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels. Agroforestry may also represent a cost-effective and sustainable complement, or in some cases a substitute, to the use of inorganic fertilizer, significantly if fertilizer costs rise in the future (Ajayi *et al.,* 2008). In Nigeria, Currently, fertilizer price appears to be beyond the reach of the small scale farmer, it, therefore, implies that one of the ways to salvage food production in by agroforestry practices. Under an agroforestry system, carbon can be stored in the leaves, stems, roots, soils, In an attempt to reduce the emission of CO_2, the soil structure and fertility are improved thereby leading to smart practices.

2.2.3 Soil Moisture conservation

These measures are a totality of all techniques that operate on the principle of modifying the physical condition of the soil and constituting a physical barrier/impedance to minimize any runoff, evaporation, seepage, and deep percolation (Obalum *et al.,* 2011). Any practice that addresses the condition mentioned above is smart agriculture because such also address soil degradation. Some of the practices under soil moisture conservation include minimum tillage, mulching, and conservation practices. The choice of an appropriate method to be adopted depends on the soil texture and ability of the farmer to manage the method. These practices are climate-smart because they enhance farmers' ability to cope with extreme weather by reducing exposure, sensitivity, or vulnerability to climate variability or change.

2.2.4 Improvement in Resource use Efficiency

Efficient management of available resources with variable weather conditions is essential to increase the productivity of agriculture. In addition to this, the focus on agricultural production is changing from quantity to quality in recent years in the context of climate change. This management will depend on the ability of research to come up with higher productivity crop and livestock breeds, improved crop management, and animal husbandry. The idea of facilitating the supply of chemical fertilizer and genetically improved seeds to farmers and enhancing their access to output markets is giving way to an approach that is centered on developing smallholders' ability to help themselves (Braimoh, 2015). Globally, water is the most critical factor limiting crop production. It is vital to develop crop varieties that can use the available water more efficiently so that crop production can be maintained while leaving sufficient water for domestic and industrial users and the environment (Gifford, 2012).

3.0 Conclusion

Climate Smart Agricultural (CSA) practices are generating significant benefits while farmers face substantial socioeconomic barriers to their adoption. Climate-Smart Agriculture (CSA) is an alternative approach to managing soil sustainably while increasing agricultural productivity. The techniques developed over the past few years are already transforming the way the world thinks about agricultural assistance. Degraded croplands and grazing lands can be restored through farmer-managed natural regeneration of trees and shrubs from tree stumps, roots, and seeds. Rainwater can be harvested; alternate wet and dry rice production systems can be employed that use flush irrigation to supplement rainfall for parts of the growing season strategically. For livestock, improved pasture management, such as rotational grazing, can make a huge difference.

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