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Comparison of traditional and modern approaches to soil conservation in a changing climate: a review

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Abstract

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Soil is the most age-long indispensable rudiment in sustainable crop production in Nigeria. Successful crop production lies in the soil conservation practice in use. Some traditional and modern soil conservation practices in Nigeria were reviewed from available literatures (1937-2015) to determine the extent of their usage and sectoral applicability. The literatures surveyed included scientific and legislative publications. The findings revealed that the efficacy of most traditional systems (stone lines, planting pits, and shifting cultivation) of soil conservation in Nigeria is yet to be verified by research. Be it as it may, local farmers have continued their use because it's working for them. Some of the modern approaches (agroforestry, plastic mulching, modern tillage and improved fallow) whose effects are well documented and positively reported are rather too expensive for farmer's adoption. Adoption is also hampered when the modern approaches are grossly unfamiliar to local farmers, arising from their not been synthesized from the traditional techniques. The modern approaches, particularly when home grown has shown proven positive effects on local soils, consequently has become widely adopted. All the traditional and modern soil conservation approaches showed the highest sectoral applicability in agriculture whereas the least was in forest resource management. With projected future adverse effects of climate change, practices that are inimical to soil conservation like sand mining and paving should be regulated by legislation whereas dredging of waterways, practices that increase soil infiltration capacities and dune stabilization and protection should be adopted.

Key words: Approach rating; sectoral applicability; land-use; environmental friendliness; Agriculture

Introduction

In Sub-Sahara Africa, soil conservation has a long tradition. Indigenous techniques like ridging, mulching, constructing earth bunds and terraces, multiple cropping, fallowing, and the planting of trees; from the pre-colonial era were focused on erosion control in combination with water conservation (Igbokwe, 1996; Scoones et al., 1996).

In colonial times, the British Government worked on natural resource management as interest was high in expanding commercial farming enterprises. Longtau et al. (2002) recorded the implementation of terraces in several areas on the Jos Plateau in former times. Large-scale projects on soil loss control were started, especially in areas of high agricultural potential, but many of them failed as the imported technologies had little relevance in the tropics and were not adopted later by local farmers. Farmers in Nigeria had their local technologies working for them and often imported technologies fail for not been comparatively effective and sometimes for absolute negligence to local farmer's technologies developed over years of experience. Research on soil conservation has been conducted for many years in Sub-Saharan Africa (e.g., Fournier, 1967; Greenland & Lal, 1977; Quansah, 1990; Kayombo & Mrema 1998; Ehrenstein, 2002) and in Nigeria (Lal 1976a, 1990). These Initiatives have resulted in various so-called on-farm strategies including agronomic measures, soil management, and mechanical methods, as well as off-farm strategies, including mechanical or biological soil conservation technologies. Therefore, this review is aimed at bringing to light indigenous and modern techniques of soil conservation as practiced in Nigeria.

Materials and Methods

Previously published studies on agronomic approaches to soil conservation in Nigeria like that of Junge et al. (2008) and some more recently international and local journal publications (scientific and legislative) were surveyed and summarized to synthesize the present state of understanding. Traditional (shifting cultivation, natural mulching, stone-lines, planting pits, strip cropping, traditional tillage, terracing, waterways and intercropping/multiple cropping) and modern (cover cropping, agroforestry, plastic mulching, modern tillage and improved fallow) approaches of soil conservation were compared to determine farmer responses and sectoral applicability.

2.1. Traditional Methods of Soil Conservation in Nigeria

Some traditional methods adopted in line with soil conservation practices in Nigeria are subsequently discussed.

2.1.1 Shifting Cultivation

Shifting cultivation is defined very broadly as any system under which food is produced for less than 10 years from one area of land, after which that area is abandoned temporarily and another area cultivated. About 30% of the world's exploitable land in 1973 was under shifting cultivation. Although precise figures were not available, it was estimated that in Africa the area under shifting cultivation represented a larger proportion of the total exploitable area than was the world figure of 30%. The development of shifting cultivation as defined here was a natural and normal response to need to produce food, without the continuing benefit of soil replenishment by manures, fertilizers and alluvial deposition.

Some of the reasons given for shifting cultivation in Africa (inclusive of Nigeria) are:

Cropping system: The practice of shifting cultivation was largely determined by the cropping systems practiced in forest areas of most tropical environments. For instance, a freshly opened forest for maize may be intercropped with plantain, cocoyam and eventually cassava. Sole cropping was never common. After the first harvest of maize, the shade established by the semi-perennials would be excessive to replant the main crop (maize). The farmer, in this case, maybe forced to shift to another site since the associated crops take a longer time to mature.

Soil erosion: In the savanna zones with less dense vegetation, erosion hazards are more serious especially with shallow soils. On such soils, concretions lie quietly close to the surface. Also, bush burning which usually precedes cropping in savanna areas leaves the land bare hence erosion sets in at the beginning of rains before the crops form the canopy. The exposure of the infertile subsoil results in farmers' abandonment of one site for another.

Land tenure system: The system by which land ownership was vested on farmers for the period their crops were on it; encouraged farmers to cultivate as many patches of land as their family labor can manage.

Soil fertility: Heavy rainfall and consequent excessive leaching in tropical forest regions and long drought coupled with annual bush burning in the savanna regions allow for the minimal accumulation of organic matter. The nutrient content of these soils become low. This results in abandoning of farmlands after a couple of years.

Shifting cultivation is reported to increase soil organic matter, improve soil structure and soil water regime, minimize soil erosion, moderate soil temperature and increase the total nutrients on the topsoil.

2.1.2 Natural Mulching

Different types of material such as residues from the previous crop, brought-in mulch including grass, perennial shrubs, farmyard manure, compost, byproducts of agro-based industries, or inorganic materials and synthetic products can be used for mulching (Lal, 1990). Natural mulches such as leaf, straw, dead leaves, stems, and compost have been used for centuries in Nigeria to cover the soil in which the farmers planted as this was believed to reduce the effect of the heat from the sun most especially in the dry seasons. Mulching was majorly used for crops which had higher water content such as tuber crops (e.g. yam, cassava etc.), rice etc. to slow down evaporation of water from the soil so that the just planted seeds would have enough water and avoid drying up.

The high amount of mulching materials might be available in the humid and semi-humid agro-ecological zones but not in the semi-arid regions of Nigeria where climatic conditions restrict the production of sufficient mulching material (Kayombo & Lal, 1993). Other reasons that reduce the amount of residues are bush fire (Okigbo, 1977) or termites (Maurya, 1988a). The complete removal of crop residues from the field for use as animal fodder, firewood, or as construction material is another factor that makes this soil conservation technology less applicable (Kirchhof & Odunze, 2003). A possible solution might be mulching with brought-in organic material. In Kaduna and Kano states of Nigeria for example, household waste was transported from the cities to rural areas and distributed on farmland (Junge et al., 2008). This is generally expensive, due to costs encored in the acquisition and transport of the material as well as the increased labor demand. Hence, this practice can only be economical and more appealing for small scale farmers mostly focusing on subsistence farming. The effect of natural mulch on the soil has been reported to include weed control, temperature moderation, improvement of soil moisture content and structure, increased soil biological activity and nutrient use efficiency (Mbagwu, 1991; Lal, 2000; Ahamefule & Mbagwu, 2007; Ahamefule & Peter, 2014; Ahamefule et al., 2015)

2.1.3 Stone lines

Northern regions such as Jos Plateau have developed different ways of conserving soil and water. This region is characterized by the presence of major fertile valleys and large barren plateaus. Rainfall in the area varies from 250-450 mm.

The stone-line (fig. 1) is built by collecting lots of stones, both small and large. The stones are then piled in a line of about 20 cm wide and 20-30 cm high. On flat land, the stone lines are placed about 30 m apart whereas on slopes the arrangement is closer. The stones are placed as closely as possible to the contour line of the slope; this is important because the stone lines slow the movement of water and thus keep the water on the land (field). Rainstorms can be intense sometimes, and when the rain falls hard, the water runs off the field instead of soaking into the soil. When this happens, rich topsoil is washed away as well.

Stone lines (Hausa term: gandari) have been laid out mainly by the people living on the plateaus to conserve water and trap windblown sand. They are often laid out in straight lines (grid pattern), but in some cases, efforts are made to follow a Contour line. Once laid out, farmers wait till the harmattan has deposited sufficient sand to permit cultivation. They usually have to wait 5 or 6 years before the land treated with gandari can be cultivated. It is not possible to estimate how many hectares have been treated with gandari as they are dispersed over a large area. The size of the fields treated varies from a few hectares to several hundreds of hectares-for example on the Plateau Wandali not far from Koura Abdou in the Badeguichéri valley. The gandari seem to be used mainly for the rehabilitation of barren degraded lands with a hard impenetrable crust (Hausa term: fako). These fakos have sandy-clayey soils.

Different ways of conserving soils varied concerning the particular situation. For example, hillside terracing is used only on the stony slopes, whereas stone lines are built where the land is flatter. Some techniques were later used in combination. For example, earth mounding, which is very common, is often combined with stone lines or stone bunds but where they got the idea from was unknown. It is believed that stone line techniques had been in existence even before the colonial era, thus the year of adoption is still unknown.

Although numerous fields have been abandoned, in some areas, stone lines continue to be maintained and fields can be found where stone lines have recently been laid out. The construction is done by individual farmers voluntarily without any project support. Farmers cover part of the soil with millet stalks, some manure, which, according to them, helps trap sand.

Stone bunds are larger structures than the stone lines, and less common. More labor is involved. They are preferred to stone lines where the land is sloppier, erosion is worse and where there is a good supply of stone. As with stone lines, these bunds are built across the slope, and the idea is again to slow runoff and reduce erosion. But again they would be more effective if they were built more carefully, and if they followed the contour.

2.1.4 Planting pits

In 1988, farmers in Plateau (Northern Nigeria) region suddenly started making planting pits (fig. 2) (tassa) to rehabilitate degraded land. It is not yet clear where they got the idea from though some say it is a revival of indigenous techniques, according to others, Hausa migrants from Niger who travelled to the Jos Plateau in Nigeria brought the idea there. An International Fund for Agricultural Development (IFAD) which funds soil and water conservation projects is now assisting these farmers with technical advice (on increasing dimensions of the pits and using organic matter although applied now on a small-scale).

Planting pits (tassa), typically measure 20-30 cm width, and 10-20 cm deep and spaced 6080 cm apart. It is an ancestral practice to regenerate degraded and crusted soils by breaking up the surface crust to improve water infiltration.

Planting pits involves digging, in the dry season; it consists of dug holes excavated in grids with a diameter of 20-30 cm and a depth of 10-20 cm filled with manure. They are spaced 60-80 cm apart, resulting in around 10,000 pits per ha. Staggered rows of holes are dug perpendicularly to the slope. The excavated earth is formed into a small ridge down the slope of the pit for maximum back capture of rainfall and runoff. Manure is added to each pit, through this, organic matter attracts termites and form pockets of water shielded from direct evaporation and other microbes which play a crucial role in improving soil structure. Row crops are then planted in the pits which can hold water over 500% of the water holding capacity of the soil.

According to Ayers (1989), 12% of the farmers she interviewed practiced pitting to retain more water. Some farmers mentioned that they had observed the technique in other villages in the region, but others claimed that pitting was an ancient technique which had been superseded by the plough. Traditional pitting practices on the Jos Plateau, Nigeria, are used as the source of inspiration for the development of modern variants of pitting to assist in the rehabilitation and revegetation of eroded grasslands (Jones et al., 1989). Population groups seeking refuge in

Fig. 1. Plate 1: Stone line. (Source): IIED GATEKEEPER SERIES NO.SA27

plateau regions often had to survive on limited land resources and therefore had to introduce intensive land management practices. Increasing problems of crusting and compaction made the farmers start using pitting.

2.1.5 Strip cropping

Strip cropping simply put, is growing crops in a systematic arrangement on strips across a field. It is a method of farming which involves cultivating a field partitioned into long, narrow strips which are alternated in a crop rotation system. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion. The most common crop choices for strip cropping are closely sown crops such as wheat, or other forages which are alternated with strips of row crops, such as corn, soybeans, cotton, or sugar beets. The forages serve primarily as cover crops. In certain systems, strips in particularly eroded areas are used to grow permanent protective vegetation; in most systems, however, all strips are alternated on an annual basis. The growing of a cultivated crop (as corn) in strips alternating with strips of a sod-forming crop (as wheat) should be arranged to follow an approximate contour of the land and minimize erosion.

Widths of strips are determined by several factors, with the two most important being the average wind velocity in a specific site and the features of the slope, particularly the gradient. Each strip typically ranges from 25 feet (7.6 m) to 75 feet (23 m) in width, but certain conditions may necessitate widths outside of this range. Minimum width of 50 feet (15 m) is ideal for the use of most farm equipment.

The term strip cropping also refers to a method of dry farming sometimes used in areas such as arid regions to accumulate moisture in these dry areas, cropland is periodically left fallow. Typically, the fallow and planted areas are organized in parallel long, narrow strips that are oriented normal to the prevailing winds, to minimize the erosion of soil from the bare fields. Strip farming helps to prevent mass erosion by having the roots of crops hold on to the soil to prevent it from being washed away. The major purpose for strip cropping include

• Reduce soil erosion from water

• Reduce the transport of sediment and other waterborne contaminants

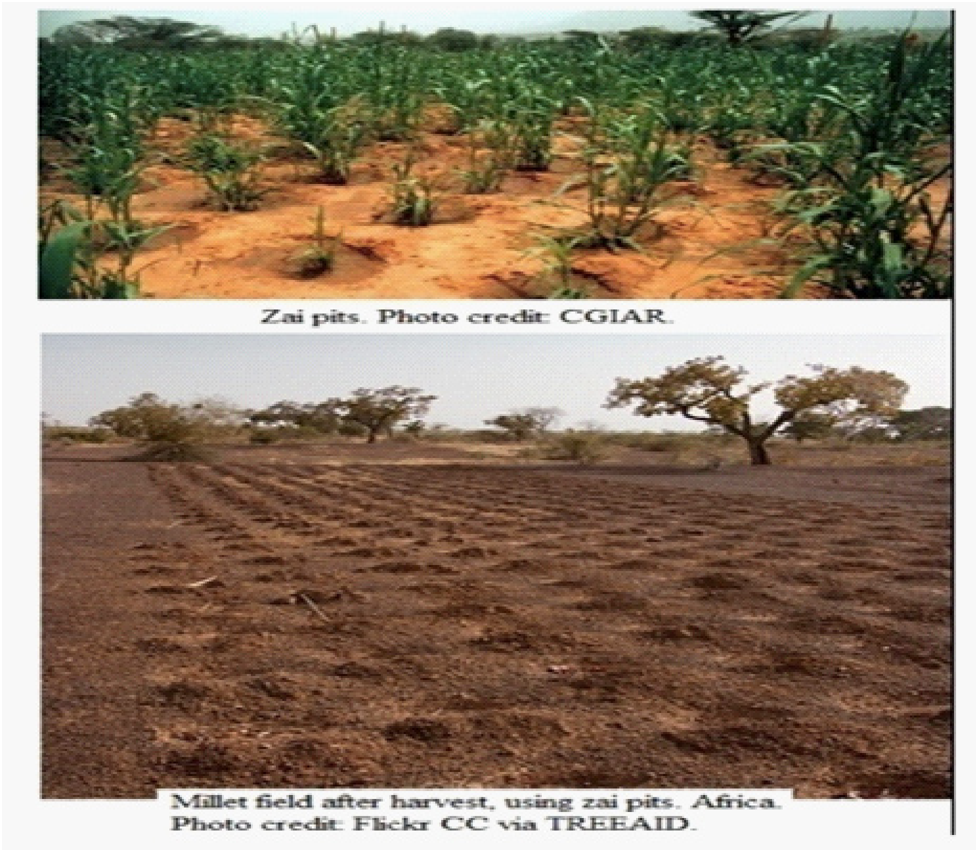

Fig. 2. Plate 2: Planting pits. (Source): IIED GATEKEEPER SERIES NO.SA27

• Reduce soil erosion from wind
• Protect growing crops from damage by windborne soil particles
• Improve water quality

Strip cropping is effective due to the precise arrangement of the alternating stripes in the field. The crops are arranged so that a strip of grass or close-growing crop is alternated with a clean-tilled strip or a strip with less protective cover. Generally, the strip widths are equal across the field. Where sheet and rill erosion is a concern on sloping land, the strips are laid out on the contour or across the general slope. Where wind erosion is a concern, the strips are laid out as closely perpendicular to the prevailing erosive wind direction as possible.

Strip cropping helps to stop soil erosion by creating natural dams for water, helping to preserve the strength of the soil.

2.1.6 Tillage (traditional approach)

Tillage practices started from the pre-colonial era with the use of simple farm tools such as hoe in tilling the ground. Simple farm tools are commonly used to cultivate the land as a form of tillage practice. Nigerian traditional agriculture is dominated by what is termed “hoe and cutlass” farming. It is widely used and still in use by small scale farmers who cannot afford the use of conventional tillage. The use of hoes was gradually replaced by conventional tillage due to the adverse effect of the use of hoes. Part of the adverse effect of the use of hoes is that it is labor intensive and requires a lot of time (Ahaneku, 1997).

2.1.7 Terracing

Terraces were traditionally built in Mokwa

(Palmer, 1958), in the Pankshin area on the Jos Plateau (Longtau et al., 2002), and at Maku near Udi-Nsukka (Igbokwe, 1996). Modern terraces consist of an excavated channel and a bank or ridge on the downhill side for cultivating crops and are permanent erosion control technologies (Morgan, 1995, Lal, 1995). The first is installed across slopes of low gradients, the latter at right angles to the steepest slope in hilly areas. Field trials on terraces made by Lal (1995) in Ibadan showed that the mean soil loss from a catchment without any erosion control measures was 2.3 t ha^{-1} and from a terraced catchment, 0.7 t ha^{-1}. The records state that permanent structures of these kinds are effective soil conservation technologies as excessive soil loss and silting up of the fields are reduced. However, high labor intensity, time-consuming regular inspections, high consumption of scarce farmland, and the large amounts of construction material required are factors that stop farmers from installing or maintaining terraces (Igbokwe, 1996).

2.1.8 Waterways (drainage)

Waterways such as cut-off drainage are permanent structures that aim to collect and guide excess runoff to suitable disposal points. They are constructed along the slope, often covered with grass to prevent destruction, and primarily installed in areas with high rainfall rates (Morgan, 1995). The literature on investigations into drainage systems is rare in Nigeria. The implementation probably needs special knowledge of the water regime of the area and the construction of waterways (Lal, 1995).

2.1.9 Intercropping and multiple cropping

The simultaneous cultivation of different crops on the same piece of land has been described interchangeably as mixed cropping or intercropping by Webster and Wilson (1966) and Norman (1974). Ruthenberg (1976), however, distinguishes between mixed cropping and intercropping based on the pattern of the intermixture.

The term intercropping has been used rather generally in the literature as referring to the practice of growing two or more crops simultaneously in different but proximate stands (Okigbo, 1975). Row intercropping is common in filled areas, annuals often being planted under perennials. For instance, tall-growing crops such as cassava or bananas are planted in young coffee, cocoa, or rubber plantations (Sanchez, 1979).

In multiple cropping, Herrera & Harwood (1973) indicated that each of the crop mixture patterns has different physiological characteristics and different advantages. For example, Norman (1974) showed that although there were at least 156 crop mixtures and many different spatial arrangements among Hausa farmers near Zaria (Nigeria), the most popular arrangement was a systematic spatial pattern on ridges. With the intensification of cropping, interactions among plants become critical. The most widespread multiple cropping systems practiced in the humid tropics are mixed intercropping and relay intercropping.

Mixed intercropping is common when cereals, grain legumes, and root crops are grown together and when little or no-tillage is practice ed. For example, farmers in southern Nigeria plant simultaneously maize, cassava, vegetables, and cocoyam. In Abakaliki, Nigeria, mixed cropping is practiced in mounds or ridges of soil constructed with hoes. Several crops are planted on different parts of the mounds. For example, an Abakaliki farmer plants yams on the mound, rice in the furrow, and maize, okra, melon, and cassava on the lower parts of the mound. Mounding is beneficial because it increases the volume of soil available to root crops.

2.2 Modern Approaches to Soil Conservation in Nigeria

Several methods have been recommended to farmers for the conservation of their soils. These include the planting of vetiver grass to reduce erosion, zero tillage and minimum tillage. Farmers in their effort to make their farmlands continue to sustain their activities have adopted conservation methods that are not labor intensive, highly cost-effective, compatible with the existing farming system, cheap and easy to install and maintain. These practices which include mulching, cover cropping and contour tillage are considered as sustainable soil Conservation practices.

After independence in 1960, more emphasis was put on soil fertility issues. Decreasing funds at the end of the oil boom in the 1980s additionally restricted the performance of soil conservation schemes (Slaymaker & Blench, 2002). Today, the seriousness of this environmental problem still exists and is also recognized by the Federal Government of Nigeria that planned to spend about half a million US dollars on soil erosion projects all over the country in 2007 (Federal Government of Nigeria, 2007).

2.2.1. Cover cropping

A cover crop is a crop planted primarily to manage soil erosion, soil fertility, soil quality, water, weeds, pest, diseases, biodiversity and wildlife in an agroecosystem (Lu et al., 2000). Erosion under cereals can be greatly reduced by intercropping with leguminous cover plants such as Stylosanthes or Desmodium (El-Swaify et al., 1988). The contrast in protective cover between well and poorly managed crops is seen in tea; a crop with close spacing, good growth and correct pruning provides a canopy cover of close to 100%, whereas poorly managed tea often leads to severe erosion; soil loss has been found to fall too low values where the canopy exceeds 65% (Othieno, 1975; Othieno & Laycock, 1975). In oil palm plantations, erosion is prevented when the palms are young by a dense cover crop, often Pueraria sp. The nearly closed canopy of mature palms, however, shades them out. In western Nigeria, maize was found to reduce erosion by more than was predicted from canopy cover; it seems likely that the additional factor was crop residues on the surface (Wilkinson, 1975). Residue from killed cover crops increases water infiltration and reduces evaporation, resulting in less moisture stress during drought. Lightly incorporated cover crops serve dual roles. They trap surface water and add organic matter to increase infiltration to the root zone.

The use of cover crops improves soil structure, increases nitrogen level, and acts as weed smothers. Examples of cover crops include Pueraria and Mucuna. They can be planted in pure stands on an uncultivated piece of degraded land or in the association as a relay with an annual crop such as maize. Tarawali et al. (2002) cited additional advantages of Mucuna to include increased crop yield, the ability to suppress weeds such as spear grass (Imperata cylindrica), thus reducing the arduous task of weeding, provide livestock feed and income for adopters through the sale of seeds. Farmers benefit from cultivating cover crops as soil loss is reduced and physicochemical soil properties are improved. However, a problem can be the intensive growth of several cover crop species that might result in competition with food crops for growth factors. Tian et al. (1999) recorded no significant competitive effects from P. phaseoloides to maize but reduced yields of cassava. This problem can be combated by choosing compatible crops and by controlling the cover crop by timely cutting.

2.2.2 Agroforestry (alley cropping)

Since the 1970s, the International Institute of Tropical Agriculture (IITA) has researched various options for sustaining crop production. Investigations initially involved the introduction and evaluation of the potential of integrating woody species with food crops as a land-use system for managing fragile lands. The encouraging results of these trials led to the development of alley farming in the early 1980s as one agroforestry system with great promise for the sustainability of small scale farming system (Kang et al., 1991; Kang, 1996).

Agroforestry is a collective name for the land use system in which woody perennials are integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal unit sequence (Rudebjer et al., 2001). There must be both ecological and economic interactions between the woody and non-woody components to qualify as agroforestry (Rocheleau, 1989).

More simply put, agroforestry is any land-use involving the planting of trees or deliberate retention of trees by farmers within the farm or homestead for a variety of purposes which include wood, fodder, fruits, medicine, shade, soil improvement, water conservation etc. (Rocheleau, 1989). Agroforestry can help mitigate deforestation because it addresses in general, the issues of tree planting; combat land depletion because of its potential for soil conservation and as a result contribute to the alleviation of rural poverty (ICRAF, 1993).

Alley cropping is an agroforestry system that involves continuous cultivation of food crops between hedgerows of multipurpose trees on the same land. It refers to the planting of trees or shrubs in two or more sets of single or multiple rows with agronomic, horticultural, or forage crops cultivated in the alleys between the rows of woody plants. It is an improved modification of agroforestry practice whereby the integration of trees and agronomic crops is done in a more structured manner. Its purpose is to enhance or diversify a farm enterprise by adding trees/shrubs product, reduce surface water runoff and soil erosion, alter water table depths, improve utilization and reduce offsite movement of nutrients, modify the microclimate for improved crop production, provide habitat for wildlife and beneficial insects, enhance the aesthetics of the areas, and increase net carbon storage. The ultimate objective was not tree production but food production as observed in southern Nigeria where yams, maize, pumpkins and beans were typically grown together under a cover of scattered trees (Forde, 1937). By the end of the nineteenth century, however, the establishment of forest plantations had become the dominant objective wherever agroforestry was being utilized as a system of land management.

The challenge to develop agroforestry to solve apparent problems in land degradation led to the conception of alley cropping. As a soil water conservation (SWC) technique, alley cropping has evolved. Its practice in Nigeria date back to the pre-colonial era, at that time it was known that a great variety of integrated land-use systems had already been practiced throughout semi-arid Africa since times immemorial. They had been empirically evolved and adapted to different environments as well as various ethnic groups. Ojo (1966) accounted that the Yoruba of western Nigeria, who have long practiced an intensive system of mixed herbaceous shrubs and tree cropping, he further explained that the system is a means of conserving human energy by making full use of the limited space laboriously won from the dense forest.

Between 1986 and 1992, a national program aimed at helping the agricultural sector was set up. However, the dependence on massive imports of fertilizers and pesticides, coupled with the devaluation of the naira, has led in most cases to failures. Farmers reduce fallow periods to increase production leading to increased soil erosion and are then obliged to destroy forests to gain new arable land. The inevitable result is a reduction of water resources, malnutrition and drift of rural populations to the big cities. This, in turn, has led to increasing social tensions.

Agroforestry was seen as an appropriate solution to the situation. Because agroforestry can combine trees, crop cultivation and livestock breeding, land utilization can be diversified, soil fertility conserved and soil productivity increased. It thereby serves as a means of halting the vicious circle of deforestation, soil erosion and reduced fallow periods. It is the main reason why FAO encourages agroforestry in its “Special Program for Food Safety.”

Agroforestry practices at present in Nigeria can be described in two broad categories: farm-based and forest-based. The farm-based practices deal with tree planting on and around agricultural fields, tree wood lots and commercial crop under shade trees or food crops inter-planted with commercial trees (Akinnifesi et al., 2006). The forest-based practices involve specific agricultural practices associated with forests where farmers collect food, fruits and gums (Tejwani & Lai, 1992). The recent benefits that led to agroforestry being viewed as a viable technique to be employed in SWC are: it helps to address complex and challenging environmental problems such as marginal economics of rural resource management, disruption of the soil and hydrologic cycles, air quality problems, loss of rare and endangered ecosystems, species and populations, and health issues. As a result, research has been intensified on domestication strategies: a selection of priority species, germplasm collection and tree genetic improvement, propagation systems and field management, harvesting and post-harvest technology, economic analysis and market research (Akinnifesi et al., 2006, 2008). Agroforestry tree domestication is aimed at promoting the cultivation of indigenous trees with economic potential as new cash crops, promote the environment and help mitigate factors contributing to land degradation.

Many farmers perceive the need for regular pruning of hedgerows as one of the main disadvantages of alley farming. Some have therefore used wider spacing, both to reduce the amount of pruning necessary as well as facilitating ploughing within the crop alleys. The extent to which this modification enhances soil fertility is uncertain but would merit research. Alley grazing was tested and abandoned by ILCA in early trials in Nigeria because of poor hedgerow performance. However, the use of fodder alleys is reported to have met with success in different farming contexts.

2.2.3 Plastic mulching

Plastic mulch is a product used similarly to mulch and suppress weeds, conserve water and soil in crop production and landscaping. Plastic mulch is often used with drip irrigation which provides a uniform supply of water that keeps the soil moist under the plastic. Some research has been done using different colors of plastic mulch. This method is predominant in large-scale vegetable growing with millions of acres cultivated under plastic mulch each year. Disposal of plastic mulch is cited as an environmental problem; however, technologies exist to provide for the recycling of used/disposed of plastic mulch into viable plastic resins for re-use in the plastic manufacturing industry. Plastics are available in different colors but black has so far been the major mulch used in agriculture especially in regions with a temperate climate (Subrahmaniyan & Mathieu, 2012).

Aniekwe et al. (2004) established black plastic mulching in cassava field, as an improvement technique, which is both environmentally friendly and a very effective means of modulating crop environment. However, the only snag about this report is that the plastic mulch used is non- biodegradable which presents disposal problem in the farm at the end of the crop growth. When biodegradable types become common and affordable, their use is expected to increase. Nairaland interested Nigerians have been seeking for how to get plastic mulches installed on their various farmland. The plastic mulch according to Nairaland goes for N3000 per roll (100 × 1.2 m) in the factory at Onitsha in Nigeria, this can last for – 4 months.

2.2.4 Tillage (modern approach)

Minimum tillage or zero tillage is an appropriate soil conservation technology in Nigeria as it reduces erodibility (Braide, 1986). This form of conservation tillage results in the long-term maintenance of the soil structure and an increase in water retention and hydraulic conductivity. Minimum tillage was found to reduce water erosion, long-term maintenance of the soil structure, increased stability of fine pores, increased aggregate stability, reduction of bulk density (Onwualu & Anazodo, 1989; Olaniyan 1988; Agele et al. 2005 and Lal 1984). Lal (1984) reported that soil loss was 42 times higher from a plowed watershed (5.5 t ha^{-1}) than from a no-till watershed (0.1 t ha^{-1}), similar observations were reported by Couper et al. (1979), Olaniyan, (1988), and Kirchhof & Salako (2000). Investigations focusing on the influence of different tillage methodologies performed manually or mechanically on soil properties and crop yields are numerous in Nigeria. In particular, Lal (1982, 1983) following field experiments in Ibadan, Nigeria stated that soil surface management is the key for solving problems associated with the transition from traditional farming to more productive land-use systems in the tropics. A tillage guide based on factors, such as soil moisture regime and texture, to assess the applicability of tillage and no-till practices for different tropical soils was developed by Lal (1982) which specified tillage-based technological packages for sustainable soil management on small-scale and medium-sized farms in the tropics (Lal, 1991). According to these studies, no-till and mulch farming are sustainable management technologies for the humid and sub-humid tropics, whereas rough plowing, tied ridging, and mulching are appropriate techniques for the semi-arid area.

Several studies showed that reduced and zero-tillage systems contribute to long-term maintenance of the soil structure as pores from root growth and the activity of the soil fauna and the soil aggregates from the previous years are less or not at all disturbed (Lal, 1993b; Franzen et al., 1994).

Studies on the bulk density of surface soil layers showed differences according to the tillage methods. Armon (1980) reported that the bulk density of the surface (0 to 5 cm) was significantly higher in conventionally tilled plots (1.35 g cm^{-3}) than in no-till plots (1.16 g cm^{-3}). Bulk density was reduced due to the loosening effect of tillage and increased again later as a result of the gradual compaction of soil particles resettling after soil preparation (Onwualu & Anazodo, 1989). Lal (1997) observed the highest infiltration rate for no-till treatments (32 to 40 cm h^{-1}) and lower rates for plowing (22 cm h^{-1}). Comparable results were observed by Aina et al. (1991) and Kayombo & Lal (1993). The saturated hydraulic conductivity of the 0 to 5 cm layers in the no-till plots was also higher than in the conventionally treated plots (Maurya & Lal, 1980; Ogunremi et al., 1986). Studies on the influence of different tillage methodologies on the soil moisture content were made by Lal (1976b, 1986b), Ojeniyi (1986), Opara-Nadi & Lal (1987), and Amezquita et al., (1993). These studies all reported that moisture content was higher in the surface soil of no-till plots than in treatments prepared with tillage machines. For example, Lal (1986b) measured soil moisture content of 15.4 % to 17.5% in the top 10 cm of soil on plots with no-tillage and 10.9-15.5% on tilled plots 58 days after the seeding of maize. Studies on the influence of different kinds of tillage operations on the soil temperature showed contrasting results. Obi & Nnabude (1988) stated that soil temperatures did not differ significantly on plots with different treatments, whereas Lal (1995) found reduced soil temperatures on the field with conservation tillage. Also, the content of organic carbon and nitrogen was maintained at significantly higher levels in the surface soil of untilled systems than in tilled systems. For example, Armon (1980) measured organic carbon content of 1.7% in no-till and 1.1% in conventionally tilled treatments and attributed this to the slow decomposition rate of the mulch left on the soil surface compared to the crop residues incorporated by tillage operations. The maintenance or increase of the organic matter by conservation tillage is a basic ingredient in maintaining soil productivity and the stability of systems according to Lal (1982). In a study in Western Nigeria, Osuji (1984) observed that water-use efficiency and maize grain yields during the early season of 1978-80 were significantly higher under zero tillage than under other tillage treatments whereas in Southeastern Nigeria Ahamefule & Peter (2014) reported higher returns per unit investment on cowpea grown in untilled compared to plants in tilled plots. Lal (1985) showed that soil physical properties and chemical fertility were substantially worse in ploughed watersheds after six years of continuous mechanized farming and twelve crops of maize, while the decline in the soil properties was less in the no-tillage watershed. In the same vein, Ahamefule & Mbagwu (2007) working in eastern Nigeria observed significantly higher amounts of available Phosphorus in untilled compared to tilled plots when mulched.

Conservation tillage is therefore considered as advancement in conserving the soil and helps to correct the disadvantages of conventional tillage and use of hoes. However, zero-tillage practices are not applicable to stem tubers and root crops which are usually planted on ridges. Conservation tillage practices can be adopted on any type of soil. However, there are some constraints which prevent adoption by farmers (the high cost of the no-till planter and high weed infestation). High weed infestation can be controlled by the use of herbicides or planting of weed resistant crop varieties.

2.2.5 Improved fallow

Natural fallow is land resting from cultivation, usually used for grazing or left to natural vegetation for a long period to restore soil fertility lost from growing crops. Improved fallow is also land resting from cultivation but the vegetation comprises planted and managed species of leguminous trees, shrubs and herbaceous cover crops. These cover crops rapidly replenish soil fertility in one or at most two growing seasons. They shorten the time required to restore soil fertility; they help to improve farmland productivity because the plant vegetation that follows them is superior in quality, and they increase the range of outputs because the woody fallow species can also produce fuelwood and stakes.

Improved fallows of short periods with the selected tree or herbaceous species remain important as the long fallow periods that were part of the traditional shifting cultivation system for encouraging soil regeneration are no longer possible in most Nigerian locations. Improved fallows are the deliberate planting of fast-growing species, usually legumes, for rapid replenishment of soil fertility. Improved fallow, as an alternative to natural or bush fallow, can increase soil fertility and at the same time does justice to some extent to other functions of bush fallow but does all within a shorter period as on a smaller area than in the case with spontaneous regrowth. This opens an opportunity to increase agricultural productivity and to decrease the pressure on land use. Improved fallows are rapidly spreading in several regions of the tropics as a sensible way for in situ accumulation of large quantities of N in vegetation and soil, as well as for providing sustainability enhancing services. Research on improved fallows increased after the mid-1980s with the development of what is known as the second soil fertility paradigm, which is based on sustainability considerations (Lal, 1995). Many lessons have emerged from short-term improved fallows (<5 years duration). These include the diversity of farm sizes where improved fallows are used, the advantage of sequential versus simultaneous systems, the utilization of dry seasons unfavorable for crop production, the comparative advantages of woody versus herbaceous leguminous fallows, the magnitude of N accumulation, the strategic use of N fertilizers, and the importance of P. Other key services provided by fallows include fuelwood production, recycling of nutrients besides N, provision of a C supply to soil microorganisms, weed suppression, Striga control, and improved soil water storage.

The distinction can be made between:

1. The intensification of successive fallow (replacing or complementing natural fallow vegetation by selected fallow plants that are particularly effective);

2. The setting up of a simultaneous fallow, where fallow and food plants are grown simultaneously in the more or less sharply distinguished spatial association.

For example, Juo & Lal (1977) showed that fallows with Guinea grass (Panicum maximum) provide much organic matter to the soil. Shrubs of woody plants such as pigeon pea (Cajanus cajan) are advantageous in improving the physical soil conditions due to the penetration of their rootlets into deeper soil layers (Juo et al., 1995; Owoeye, 1997; Salako, 1997; Jaiyeoba, 2003, Salako & Kirchhof, 2003). Leguminous fallows with Leucaena leucocephala, Mucuna pruriens or Pureria phaseoloides are known especially for increasing the N content and changing the number of available P fractions in the soil (Tian et al., 1999, 2001,; Okpara & Njoku, 2002; Salako & Tian, 2003; Ekeleme et al., 2004; Kolawole et al., 2004). Wick et al. (1998) stated the benefits of improved fallows on soil microbiological parameters whereas Akobundu et al. (1999), Hauser et al. (2006), and Ikuenobe & Anoliefo, (2003) on weed control. Hence, improved fallow is an alternative to natural or bush fallow as it has a high potential for soil and water conservation especially in farming systems without fertilizer input.

3.0. The Future (Tailored Approaches in Response to Effects of Climate Change in Nigeria)

Ethan (2015) observed that between 1914 and 1970, only patches of Nigeria (a typical tropical environment), around Sokoto and Maiduguri and in the Southeast, experienced the late onset of rains. However, from 1971 to 2000 late onset of rains had spread to most parts, leaving only a narrow band in the middle of the country with normal conditions. Similarly, only a small patch of the country in the Southwest recorded early cessation of rains between 1914 and 1970, while from 1971 to 2000 early cessation of rains had covered most parts of the country. The combination of late-onset and early cessation of rains decreased annual rainfall by 2-8 mm across most of the country but increased by 2-4 mm in a few places, most significantly around Port Harcourt.

Available evidence of climatic change has been earlier reported in Nigeria by Odjugo (2009) who observed that the areas experiencing bi-modal rainfall (Savannah) are shifting southward, whereas the short dry spell (August break) is been experienced more in July as against its normal occurrence in August before the 1970s. In the same vein, in the Northern and Niger-delta Coastal areas of Nigeria, the number of rain days dropped by 53% and 14% respectively. It has been reported that the erratic rainfall pattern coupled with increasing temperatures in Katsina, Maiduguri, Kano, Sokoto and Nguru (semi-arid agro-ecological zones of Nigeria) could cause increase in evapotranspiration, drought and desertification which will result to decline in water tables or complete dry up of some rivers, especially Lake Chad, with attendant consequences on agriculture, forestry and biodiversity (Chindo & Nyelong, 2004; Adefolalu, 2007). Persistent increase in rainfall in Nigerian coastal cities of Lagos, Calabar, Port Harcourt and Warri has led to the flooding of cultivated lands and huge loss of agricultural farmlands and produce (Ikhile, 2007; Nwafor, 2007; Odjugo, 2009).

Mean air temperature from 1901-1970 was 26.3 ^{0}C and increased to 27.8^{0}C from 1971 to 2005. This is greater than the global mean temperature with the increase of 0.74° C since recordings commenced in 1860 (IPCC, 2007). If this trend persists, Nigeria could experience between 1.6 ^{0}C and 4.5° C temperature increase risk by 2100 (Odjugo, 2009). Bello et al. (2012) noted that the period of the drastic rise in temperature from the early 1970s corresponds with a period of erratic and decreased rainfall. The most significant temperature increase in Nigeria was recorded in the extreme- northeast, northwest and southwest where the annual average temperature rose by 1.49^{0}C (Ethan, 2015). Chikezie et al., (2015) reported reduced output in the production of yam and maize in the periods 1984 – 2014 due to the effect of climate change in Nigeria. Estimation by FAO (2005) is that by 2100, Nigeria and other West African countries are likely to have agricultural losses up to 4% due to climate change. Agboola & Ojeleye (2007) revealed that there is already an observed decline in crop yield and food crops production due to reduction in rainfall and relative humidity and an increase in temperature in Nigeria. It is projected that starting from 2025; climate change will cause a decrease in crop production, GDP losses, increase in crop produce prices, and a higher food dependency on imports (Bosello et al., 2013). By 2050 it is likewise predicted, that crop production will decline by between 4.8% and 7.4%, the prices of crops will increase between 17-32% and agricultural imports will increase between 13-23% (Bosello et al., 2013).

3.1 Tailored Approaches

Most of the present approaches of soil conservation in Nigeria may suffice for the future since they were developed at a time when the effect of climate change was becoming pronounced. Nevertheless, since future projections indicate worse case scenarios, practices that increase soil infiltration capacity of the soil without compromising aggregate stability should be encouraged for areas south of Nigeria recording increased rainfall. The increased infiltration capacity of soils will ensure more percolation and less runoff, hence minimal soil and nutrient loss. The volume capacity of local water bodies/waterways should be monitored to determine appropriate dredging periods. Dredging of waterways will increase runoff water carrying capacity, thereby minimizing flooding of farmlands. There are practices in Nigeria that are inimical to soil conservation; they include paving (impervious) of surfaces which is assuming an alarming dimension in commercial and private premises and indiscriminate and illegal sand mining. These practices have been reported to accelerate erosion and therefore should be regulated by legislation.

On the other hand, in addition to the present techniques for soil conservation in use north of Nigeria (drier areas), there should be deliberate efforts from government, non-governmental agencies and individuals to revive numerous moribund irrigation projects domiciled in this area. These projects include Middle Rima Irrigation Project located in Sokoto State, Bakolori Irrigation Scheme located in Zamfara State, Kano River Irrigation Scheme located within the Kano-Zaria Plains, Hadejia Valley Irrigation Scheme in Jigawa State and the Dadinkowa-Guyuk Irrigation Scheme located in the mid-lower Gongola basin. The revitalization of these irrigation projects will enhance biomass production. Improved biomass production will boost soil organic carbon and consequently soil physical, chemical and biological properties. Measures to stabilize and protect desert dunes should be adopted as this will deter further encroachment (Gomez-Pina, 2002).

Generally, the processes that increase carbon sequestration in the soil should be encouraged while moving away from fossil fuels to renewable sources to meet growing energy demands.

Results and Discussion

The result in Table 1 indicate that the research attention given to most traditional approaches to soil conservation is low (except natural mulching), similarly low were their operational cost and expertise requirement. The research attention given to natural mulch may be connected to its regulatory effect on soil temperature and moisture (Eruola et al., 2012; Ahamefule et al., 2015). Soil temperature and moisture are among the soil properties adversely affected by changing climate (Ethan, 2015). The acceptability and environmental friendliness of traditional approaches were found to be generally high. All the traditional and modern soil conservation approaches were found applicable in agriculture whereas the least sectoral applicability of these approaches was in forest resource management (Table 2). Natural mulching, stone lines, terracing, waterways (drainage), plastic mulching and improved fallow had the highest multi-sectoral applicability whereas planting pits, traditional tillage, intercropping and multiple cropping had the least.

Table 1. Rating of inherent challenges in soil conservation approaches concerning farmer adoption in Nigeria

Soil conservation approach	Research attention	Operational cost	Expertise requirement	Acceptability	Environmental friendliness
Shifting cultivation	*	*	*	***	***
Natural mulching	***	*	*	***	***
Stone lines	*	*	*	***	***
Planting pits	*	*	*	***	***

Table 2. Sectoral applicability of soil and water management approaches in Nigeria

Soil conservation approach	Agriculture	Water resources management	Watershed management	Forest resources management	Engineering
Shifting cultivation	*	*	*	-	-
Natural mulching	*	*	*	-	*
Stone lines	*	*	*	-	*
Planting pits	*	-	*	-	-
Strip cropping	*	*	*	-	-
Tillage(traditional approach)	*	-	*	-	-
Terracing	*	*	*	-	*
Waterways (drainage)	*	*	-	*	*
Intercropping and multiple cropping	*	-	*	-	-
Cover cropping	*	*	*	-	-
Agroforestry (alley cropping)	*	-	*	*	-
Plastic mulching	*	*	*	-	*
Tillage (modern approach)	*	-	*	-	*
Improved fallow	*	*	*	*	-

* suggest applicable whereas - non-applicable

Conclusion

The efficacies of most traditional systems of soil conservation in Nigeria are yet to be verified by research; nevertheless, local farmers have continued their use because it's working for them.

All the traditional and modern soil conservation approaches showed the highest sectoral applicability in agriculture whereas the least was in forest resource management. Therefore, this review makes a case for scientific inquests in Nigeria and similar environments into the effects of the identified traditional techniques of soil conservation for documentation and adoption where necessary.

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