

SOIL EROSION AND SOIL DEGRADATION: CONCEPTUAL, THEORETICAL AND PANACEA STUDY

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Abstract

Soil-land environmental security is a risk to human security, a security problem common to all states and a threat to national security requiring collective action. Soil-land environmental insecurity cum global change needs updated reviews, readings and focus given; increasing social request for resources, ecosystem services, and environmental goods identified as a possible cause of increased violent conflict – a risk too, to human-health and security. This study on soil-land environmental degradation and security concerns used the desktop critical research method to conceptualize and theorize; accurately estimate global environmental change and; the challenge focus of inter-playing interactions between ecosystems and mankind impacting the environment, productive agriculture and security. The study recommends environmental rationality through the use of conceptual, theoretical and soil-degradation panacea studies; collective action for; the security of the soil and, absence of threats on its physical, biological and chemical components and systems.

Keywords: *Soil erosion, Land conservation, Environmental degradation, Environmental change*

Introduction

Despite the key and enormous capacity of the soil, land and environment in the maintenance of the physical surroundings of society,

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fortification of natural environment and vital interests of citizens, society, and the state from internal and external impacts, there are concerns about natural soil and land diminishing stock and adverse processes/trends in lieu of advancement of human happiness and satisfaction that is causing increased soil and land degradation and erosion – environmental fortification threats impacting human health, biodiversity and sustainable functioning of ecosystems, and survival of human-kind resulting from anthropogenic and natural impacts on the land and soil cum overall environment (Eneh, 2021; Giessen, 2011; Worrall and Little, 2011). Despite this, soil and land degradation studies especially with focus on divulging through conceptualization and theory for better, innovative panacea and consistency in panacea maintenance and use remains an understudied topic (Trombetta, 2009). In lieu, soil degradation and her consequent threats to environmental security which is concurrently impacting the resilience capacity of the environment; health; responsiveness of environmental systems (land and soil) to agricultural processes are often silenced by more urgent human-environmental threats in studies (Trombetta, 2009)

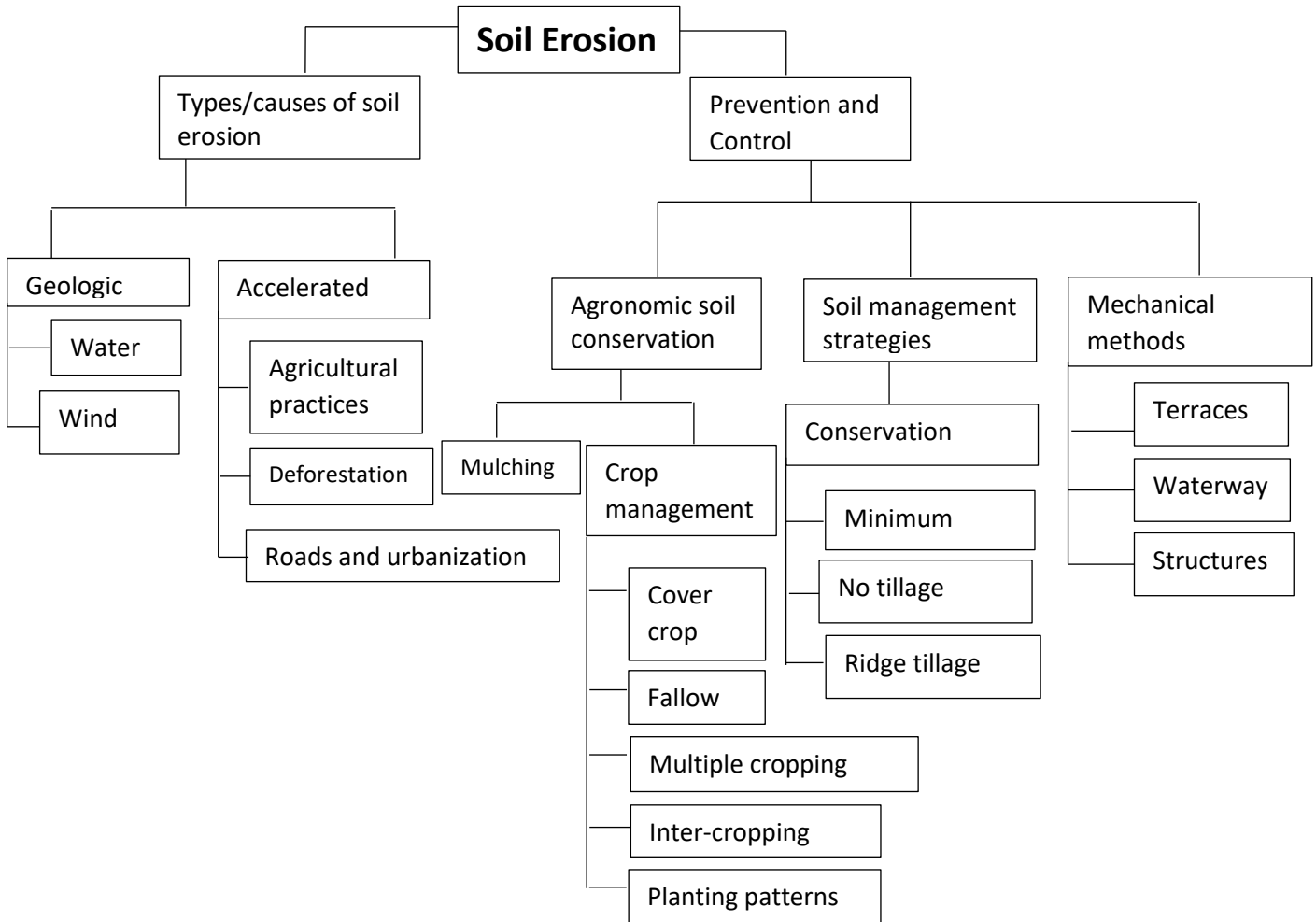
Yet, the paucity of readings especially emphasizing soil-land-environmental degradation and offering the very opportunity of considering soil and land degradation as a human-environment-threat makes it a challenge to accurately estimate the responsiveness of land and soil to agricultural processes. This problem may have force-induced increased herders-farmers' clash in Nigeria – a security concern requiring focus (Trombetta, 2009) especially for its long-term dynamic effects linked to agricultural GDP, human-health shocks and environmental security threats. Understanding this interplay is sine qua none to elucidate the role agriculture and human-health differences play in determining why some countries have grown more rapidly than others and as well inform on the critical role of good soil environmental health to both national and continental quest for greatness (Eneh, 2021). Thus, this study will drive

further facilitating macroeconomic policy on overall magnitude of agricultural output and human productivity losses, resource allocation and their distribution, and setting priority to efficient micro-ecosystem health maintenance since better soil-environment health contributes to increasing output growth

Conceptual framework

Soil erosion is the wearing away of the land surface by physical forces such as rainfall, runoff water, wind, ice, temperature change, gravity or other natural or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth's surface to be deposited elsewhere (Jones, 2007). Thomas et al. (2003) further explained that erosion can be "geologic" or "accelerated". Geologic erosion is the type of erosion that is naturally on-going within the earth crust such that the erosion rate is very slow and its effect is of less importance to human beings. But accelerated erosion is the type caused by human-beings. The erosion rate is very high that it has resulted in different focuses by soil scientists, environmentalists and scholars in related disciplines.

Figure 1: Soil conservation conceptual framework for erosion prevention and control. *Source: El-Swaify et al, 1982; Ofomata, 1984; Lal, 2001; [As authors' Modified].*



Types and forms of soil erosion

According to Thomas et al (2003), there are two main types of soil erosion; geological soil erosion and accelerated soil erosion. Accelerated soil erosion is induced by human activities such as agricultural activities, deforestation, road construction and development and urbanization amongst others. Accelerated soil erosion is one of the major threats to sustainable agricultural production in many parts of Africa.

Geological soil erosion is the gradual removal of soil by natural processes acting over a very long time (Thomas et al., 2003). Major agents of geological soil erosion are rainfall and wind. Geological soil erosion by rainfall occurs in humid areas where rainfall exceeds infiltration capacity of the soil (Ning, 2004) while wind erosion is a major geomorphological force especially in, arid and semi-arid regions. It is also a major source of land degradation, evaporation, desertification, harmful airborne dust, and crop damage especially after being increased far above natural rates by human activities such as deforestation, urbanization, and agriculture (Zheng and Huang 2009).

Wind erosion is of two primary varieties: deflation, where the wind picks up and carries away loose particles; and abrasion, where surfaces are worn down as they are struck by airborne particles carried by wind. Deflation is divided into three categories: (1) surface creep, where larger, heavier particles slide or roll along the ground; (2) saltation, where particles are lifted a short height into the air and bounce and satiate across the surface of the soil and (3) suspension, where very small and light particles are lifted into the air by the wind amidst often carried for long distances. Saltation is responsible for the majority (50 to 70%) of wind erosion followed by, suspension (30 to 40%) and then surface creep (5 to 25%) (Blanco and Lal, 2010). In addition, wind erosion is much more severe in arid areas and during times of drought. For example, in the Great Plains, it is estimated that soil loss due to wind erosion can be as much as 6100 times greater in drought years than in wet years (Wiggs, 2011).

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Water is the main agent of soil erosion in the humid areas where rainfall exceeds infiltration capacity of the soil (Ning, 2004). On the other hand, the water that does not infiltrate the soil starts to accumulate on the surface and moves down the slope carrying soil particles. Subsequently, top fertile soils rich in, plant nutrients and organic matter are eroded leaving behind infertile sub-soils. Aside the resulting plant nutrient degraded soil is important organic matter also eroded via the top soil during erosion. Negative to know is that this eroded organic matter maintains plant nutrients in the form that is fairly readily available to plants (Kaihura and Stocking, 2003). Also, organic matter maintains soil structure, stabilizing soil aggregates. Further, organic matter promotes infiltration hence, reduces the potential for erosion (Gachimbi, 2002). In lieu therefore, soil conservation must aim at maintaining soil organic matter. Deposition of soil material occurs when the force of striking and moving water diminishes due to either reduced volume of water or change of the topography.

In addition, the severity of soil erosion depends upon intensity, amount and quality of detachment eroding-agent, eroding-agent applied force and the capacity of the eroding agents to transport the soil (Suresh, 2000). There are five forms of soil erosion by water. These include; sheet erosion, rill erosion, gully erosion, slip erosion, stream bank erosion and sea shore erosion. Sheet erosion is essentially the uniform removal of a thin layer or sheet of soil from a given area of land after the soil has been detached by the impact of falling raindrops (Nyathi et al., 2003). Thus, water which carried soil particles move uniformly down the slope. This the type of erosion is suffered mostly by Nigerian small farmers (Okoye, 2001).

Rill erosion is the detachment and removal of soil from well-defined small channels which are few centimeters wide and deep (Nearing, Norton, Bulgakov, Larionov, West, Donstova, 1997). Rill erosion results from a concentration of surface flow. As the volume of run-off water increases, the rills grow into gullies. Gully erosion occurs when runoff water accumulates and rapidly flows in narrow channels during or immediately after heavy

rains or melting snow, removing soil to a considerable depth (Poesen et al., 2007; Borah et al., 2008). It is the channel erosion that washes so deep into the subsoil that the ground cannot be easily smoothed by ordinary tillage methods (Thomas et al., 2003).

Slip erosion sometimes known as land slide occurs due to instability formed in large masses of soil as a result of saturation and moisture pressure aided by gravitational pull-causing big mass of soil and rock slips down slope. Stream bank erosion occurs when rivers and streams meander and change their courses by cutting the banks and depositing the soil elsewhere (Abrol and Oman, 2002). This type of erosion becomes more serious during heavy rains and when river-floods and stream-floods move faster due to rain water. On the other hand, sea shore erosion is caused by striking action of strong waves.

Soil degradation-anthropogenic causes: case of agricultural practices

Unsustainable agricultural practices are the single greatest contributor to the global increase in soil degradation and erosion rates (CCSA, 2010). The tillage of agricultural lands which, breaks up soil into finer particles is, one of the primary factors of soil degradation. In modern times, the agricultural tillage practice-inducing soil degradation problem has been exacerbated due to, mechanized agricultural equipment that allows for deep plowing which, severely increases the amount of soil that is available for transport by water erosion. Other agricultural practices inducing soil degradation include; mono-cropping, farming on steep slopes, pesticide and chemical fertilizer usage which, kill organisms that bind soil together; row-cropping and the use of surface irrigation (Lobb, 2009; Blanco and Lal, 2010). A complex overall situation deepening soil degradation after these agricultural practices in lieu with respect to nutrient losses from soils could further arise as a result of the size selective nature of soil erosion events. Loss of total phosphorus, for instance, in the finer eroded fraction of degraded soils is usually greater relative to the whole soil (Poirier et al., 2012). Extrapolating

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this evidence to predict subsequent behavior within receiving aquatic systems has continued to gain increasing focus for the reason that total phosphorus loss in finer eroded fraction of degraded soil is a more easily transported material and may support a lower solution phosphorus concentration compared to coarser sized fractions (Scalnghe et al., 2007).

Further agricultural tillage-practice inducing soil degradation also increases wind erosion rates of soils by, dehydrating the soil and breaking it up into smaller particles that can be picked up by the wind. Exacerbating, this soil-degradation inducing agricultural practice is the reason most trees are generally removed from agricultural fields to, allow winds have long, open runs for travel even at high speeds (Whitford, 2002).

Heavy grazing-agricultural practice inducing soil degradation reduces vegetative cover and causes severe soil compaction. In addition, both the, reduced vegetative cover and the resulting severely compacted soil increases erosion rates (Imeson, 2012).

Increasing undisturbed forests for reduced soil degradation and increased ecosystem services

Forests provide essential ecosystem services such as soil erosion control, ecosystem stabilization, and moderation of micro/macro-climate and energy fluxes. Excessive logging and forest-clear-cutting, expansion of agriculture to marginal lands, frequent fires, construction and development of roads and highways cum urbanization are the main causes of denudation (Glover, 2006). In an undisturbed forest, the mineral soil is protected by a layer of leaf litter and humus that covers the forest floor. These two layers form a protective mat over the soil that absorbs the impact of rain drops. They are porous and highly permeable to rainfall and, allow rainwater to slowly percolate into the soil below instead of, flowing over the surface as runoff (Sands, 2005).

Further, the roots of the trees and plants hold together soil particles preventing them from being washed away (Sands, 2005). The vegetative

cover on the other hand acts to, reduce the velocity of the raindrops that strike the foliage and stems before hitting the ground. Thus, reducing the kinetic energy of the falling rain (Goudie, 2000). However, whilst the forest floor and the canopy structures prevent surface erosion the, forest floor structure-control acts more in soil erosion control. In lieu, because forest canopies are usually higher than about 8 metres (26 feet) – height at which terminal velocity of rain drops is reached, the intact forest floor, with its layers of leaf litter and organic matter could sagaciously absorb the impact of the rain drops or falling rain more than the forest canopy structures below whose heights the, terminal velocity of falling rain can be regained even after the initial strike on the canopy (Goudie, 2000; Stuart and Edwards, 2006).

Thus, deforestation causes increased erosion rates from exposure of mineral soil to agents of erosion either by removing the humus and litter layers from the soil surface or, removing the vegetative cover that binds soil together and/or causing heavy soil compaction from logging equipment. Hence, once trees have been removed by fire or logging, infiltration rates may become high and consequently significant severe fires may lead to increased erosion following heavy rainfall (Goudie, 2000).

Soil degrading roads development and urbanization factor

Denuding the land of vegetative cover, altering drainage patterns, and compacting the soil during road development and construction and, covering the land with an impermeable layer of concrete that increases the amount of surface runoff and increases surface wind speeds induces major soil erosion effects (Nir, 1983). Further, much of the sediment carried in runoff from urban areas (especially roads) is highly contaminated with fuel, oil, and other chemicals (Randhir, 2007). This increased runoff in addition to eroding and degrading the land that it flows over also causes major disruption to surrounding watersheds by altering the volume and rate of water that flows through them especially, filling them with chemically

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polluted sedimentation. The resulting increased flow of water through such local waterways also causes a large increase in the rate of bank erosion (Williams, 1995).

Effects of soil degradation

Loss of soil and nutrients limiting factor affecting food security

Soil degradation has in many years resulted into depletion of the top fertile soil, reduction or loss of the biological and economic productivity and complexity of terrestrial ecosystems including, soil nutrients, vegetation, other biota, and the ecological processes that operate therein (Claassen, 2004). This situation increases production costs for agricultural crops. Worldwide it is estimated that soil degradation has affected 1,966 million hectares. This represents 15% of the total land area and 38% of the agricultural land (Hellin, 2006). Furthermore, approximately 12 million hectares of arable land are destroyed and abandoned annually because of unsustainable farming practices (Hellin, 2006). Nitrogen (N) and phosphorus (P) are the main limiting nutrients in crop production. Reyes et al. (2006) reported that about half of the N, P and K losses in Africa are due to erosion and leaching.

Soil fertility depletion is considered as a biophysical limiting factor affecting food security. Resource poor farmers are the most affected ones since most of them depend on annual crops that succumb more to soil erosion than perennial crops. In Anambra state, the study area, effects of indiscriminate cultivation started becoming evident in the 1930's during which soil degradation impact consciously became a major problem in the area. As a result, soil conservation schemes were established. The schemes aimed at introducing various conservation practices. Nevertheless, the important issue of addressing soil degradation effects on crop yields and its consequent income-effects on farmers has not achieved varied soil conservation practices to, prevent/reduce soil degradation in order to ensure

increased crop production, improved farmers income amongst others (Nnenwa, 2018).

Effects of soil erosion: case of decrease in crop yields

Soil degradation caused by soil erosion is the major contributor to nutrient losses because most of the scarce soil nutrients are in the top 5-10 cm of the soil (Nkonya et al., 2004). Crop production is expected to decline due to decreased levels of soil nutrients caused by erosion. Approximately 50% of the earth's land area is devoted to agriculture. About one-third is utilized for crop planting and two-thirds currently utilized for grazing (Pimentel, 2006). Among these areas, cropland is most susceptible to erosion because of the frequent cultivation of soils requires that vegetation is often removed before the crops are planted thus, exposing the soil to wind and rainfall energy. In addition, cropland is often left without vegetative cover between the fallow-gaps between planting seasons which, intensifies erosion on such agricultural lands at, erosion rates that are estimated to be 75 times greater than erosion in natural forest areas (Pimentel, 2006).

Currently, about 80% of the world's agricultural land suffers moderate to severe erosion, while 10% experiences slight erosion (Speth, 1994; Nkonya et al., 2004). Worldwide, soil erosion losses are highest in agro-ecosystems of Asia, Africa and South America averaging, 30 to 40 tons/ha/year (Pimentel, 2006). In developing countries including Nigeria, soil erosion is particularly severe on small farms that are often located on marginal lands where, the soil quality is poor with commonly steep topography. In addition, poor farmers tend to raise row crops such as corn and beans. These row crops are highly susceptible to erosion because the crop vegetation does not cover the entire tilled soil surface.

In the past – worrying and unfortunate for the African continent – soil erosion has caused an average annual crop yield decline of 8.2% and 6.2% for the African continent as a whole and sub-Saharan Africa respectively forecasted to reach an average annual crop yield decline of

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16.5% and 14.5% for the African continent as a whole and sub-Saharan Africa respectively possible if, higher soil erosion rates continue unabated (Lal, 1995). Adjourning the ill-fate at stake with soil degradation and erosion especially for many farmers is that soil degradation and erosion exacerbates an already precarious struggle for food security achievement globally and particularly in Africa (FAO, 2006).

Erosion prevention and control measures

Agronomic measures of soil conservation such as mulching and crop management practices of, cover cropping, fallowing, multiple cropping, intercropping and planting pattern use effect of surface covers reduce, erosion by water and wind in order to conserve the soil (Junge et al., 2009). These agronomic soil conservation strategies are important and require focus. However, there are many prevention and control practices that can curtail or limit erosion of soils especially vulnerable soils.

Agronomic soil conservation strategies

Mulching: Mulching is the covering of the soil with crop residues such as straw, maize stalks, palm frond or standing stubble. Mulches are used to protect soil surfaces from erosion agents of rainfall, runoff and wind (Odunze, 2002; Adekalu et al., 2006; Salako et al., 2006). They also help to reduce intense solar radiation, suppress extreme fluctuations of soil temperatures, reduces water loss through evaporation and increase soil moisture which can assist in creating ideal conditions for plant growth in many circumstances. Mulching reduces the deterioration of soil by way of preventing the runoff and soil loss and, minimize weed infestation. Thus, it facilitates retention of soil moisture and helps in control of temperature fluctuations, improve physical, chemical and biological properties of soil as it adds nutrients to the soil and ultimately enhances the growth and yield of crops.

Other gains in mulching includes, suppression of weeds thereby, saving weeding costs, increase in, soil organic matter, increasing infiltration rate and maintaining the exchange capacity of the soil at a level where nutrient leaching losses are minimized and hydrogen saturation is kept within bounds (Morgan and Rickson, 1995; Chude, 2005).

Cover crops: Soil loss can also be prevented or reduced by appropriate crop management of, cover cropping, multiple cropping, and high-density planting. Cover cropping is an agricultural practice and an erosion prevention/control measure in which crops with good canopy formation are planted with other crops so that their canopy formation can shield the soil from the effect of soil erosion causing agents (Akamigbo, 1998). Canopy of some crops such as melon, groundnut and cowpea prevent rain drops from detaching soil particles and thus keeping soil loss at tolerable limits. In lieu, cover crop soil conservation practice plays an important role in reducing soil erosion hazard, improving environmental conservation for improved crop management and crop degradation prevention and control (Chude, 2005).

Cover crops also positively influence physical soil properties such as the infiltration rate, moisture content/retention and bulk density and, consequently increases the organic matter content and nitrogen levels by the use of Nitrogen-fixing legumes, the cation exchange capacity and, hence in so doing increase crop yields (Ibewiro et al., 2000; Salako and Tian, 2003). Another benefit of cover crop is the suppression of weeds such as spear grass (*Imperata cylindrica*) or witch-weed (*Striga hermonthica*) which are common in Nigeria (Chikoye et al., 2002; Ekeleme et al., 2003). Farmers benefit from cultivating cover crops for reduced soil loss and improved physio-chemical soil properties.

Fallow: Improved fallows of short periods with selected tree or herbaceous species remain important as the long fallow periods that were part of the

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traditional shifting cultivation system for encouraging soil regeneration are almost non-feasible in most Nigerian locations. For example, Chianu et al. (2002) reported that fallows with Guinea grass (*Panicum maximum*) provide much organic matter to the soil thus helping the soil to improve on its quality and reducing the effects of soil-erosion agents. Shrubs of woody plants such as pigeon pea (*Cajanus cajan*) are advantageous as fallows in improving the physical soil conditions sine qua non to the penetration of crop rootlets generally into deeper soil layers thereby making it possible to withstand erosion (Chianu et al., 2002; Salako and Kirchhof, 2003). Fallowing with leguminous plants such as, *Leucaena leucocephala*, *M. pruriens* or *P. phaseoloides* as reported by Okpara and Njoku (2002), Salako and Tian (2003), Ekeleme et al. (2004) and Salako (2006) are known especially for increasing the nitrogen content and changing the quantity of available Phosphorus fractions in the soil. Hence, improved fallows have a high potential for soil conservation especially in farming systems without fertilizer input.

Multiple cropping: Multiple cropping is a form of ecological intensification that is potentially highly sustainable when two or more crops are grown at the same time or in a sequence (Agriculture for Impact, 2013). It does this by balancing three key ecological processes: competition, on the one hand, commensalism (one plant gaining benefits from the other) or mutualism (both plants benefitting each other) on the other. Typically, farmers will plant crops as close together as possible to utilize all the available land. When different crop species or varieties are grown together the competition may be disastrous and; trees grown in a maize farm for example may, deny the maize crops access to adequate sunlight which conversely affects photosynthesis. However this can be compensated for by determining the optimal spacing and by exploiting various forms of commensalism or mutualism thus, for example where the multiple-tree is a legume nitrogen is provided for the crop plant beneath.

Multiple cropping involves different kinds of systems depending on the temporal and spatial arrangement of different crops on the same field (Morgan, 1995). It has been traditionally practiced and is still very common in Nigeria (Olukosi et al., 1991).

In addition, annual herbaceous crops are grown interspersed with perennial trees or shrubs. These deeper-rooted trees can often exploit water and nutrients otherwise unavailable to the plant crops. Thus, the trees may also provide shade and mulch creating a microenvironment whilst the ground cover of crops reduces weeds and prevents erosion. Thus, agroforestry of multiple cropping is a 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 sequence (Rudebjer et al., 2001).

Intercropping: Intercropping systems includes different kinds of annual crops planted in alternating rows. It reduces soil erosion risk by providing better canopy cover than sole crops (Morgan, 1995). In Nigeria, numerous investigations have been conducted on intercropping of cereals such as maize (*Zea mays*), sorghum (*Sorghum bicolor*) or millet (*Pennisetum glaucum*) with herbaceous grain legumes or root and tuber crops with other annual crops to improve soil productivity and crop yields. For example, Odunze et al. (2004) determined the effect of grain legumes in legume/cereal treatments on soil properties in the arid ecosystem of northern Nigeria. The results showed that sole groundnut improved the soils' bulk density. Further, the cultivation of legumes also resulted in better stability of soil aggregates in the topsoil which, generally reduces the rate of erosion.

Investigations on the effect of intercropped root and tuber crops with cereals on soil properties were conducted by Ghuman and Lal (1991). The maximum soil temperature in the topsoil was also affected by intercropping as it was reduced by about 2°C to 9°C compared with temperature under

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sole maize. The increased moisture and reduced temperature in the topsoil of the intercropping system was attributed to the shading effect of the different crop species which, reduced water evaporation from the soil surface.

Hulugalle and Ezumah (1991) and Olasantan et al. (1996) analyzed the effects of cassava-based cropping systems on earthworms. These studies concluded that these earthworm macro-organisms were more active in intercropping than in mono-cropping systems.

Summarily thus, studies on intercropping systems reveal that intercropping increased coverage of the soil surface and enhanced stability of soil aggregate; reduce the erosivity of the soil by rain and the erodibility of the soil by other eroding agents. Thus, to increase soil productivity, cultivating soils with different crop species is important and essential to not just also increase resilience of the soil to erosion but also, as a soil conservation technology measure suitable for adoption in the tropics.

Planting pattern/time: Planting pattern and time of planting also play an important role in soil conservation. Crops planted at close spacing or at a certain time provide a higher canopy during periods with higher rainfall intensities and hence protect the soil from the direct effects of rainfall. Literature on cropping pattern and planting schedules with regard to erosion prevention and control is rare. Craufurd (2000), Yusuf et al. (2004), and Udealor and Aseigbu (2005) reported that when planted in sequence cereals, grain legumes and root and tubers helps in soil conservation.

Yusuf et al. (2004) in investigating the time of seeding and planting found that simultaneously seeding of sorghum and soybean led to optimum resource utilization and yield by both crops whilst planting at different times might intensify the competition for the growth resources of, light, water and nutrients. In addition, this study posited that plant densities also affect soil loss by influencing the height of crops and extent of surface coverage. It can thus be concluded that, diverse crop management practices have various

beneficial effects of reduced erosion, improved physical, chemical, and biological soil properties amidst improved crop production and crop production increase.

Additional advantages of planting pattern/time are a, decreased risk of total crop failure and the suppression of weeds. Thus, since product diversification and higher crop yields help to ensure both subsistence and disposable income, poly-culture is of huge economic value for farmers especially highly-prone soil erosion areas (Kang, 1993a). Consequently, Carsky et al. (2001) recommended cowpea-maize intercropping system as a panacea to reducing soil erosion and for the advantage of relatively being productive even in low-input crop production system especially for the savanna zone.

In lieu, special knowledge on the selection of species and good crop management is needed when annual crops are planted between hedgerows of woody perennials. Otherwise, this may make the resulting alley-cropping less attractive to farmers (Hauser et al., 2006).

Soil Management Strategies

Conservation tillage: Conservation tillage leaves is utilized for her about 30% crop residue remains promulgated on the soil surface and at least, small grain residue on the surface during the critical soil erosion period. This slows water movement which, reduces the amount of soil erosion. Additionally, conservation tillage has been found to benefit in control of predatory arthropods that could enhance pest control (Tamburini et al., 2016). Conservation tillage also benefits farmers by reducing fuel consumption and soil compaction. Thus, by reducing the number of times the farmer travels over the field, farmers realize significant savings in fuel and labor.

However, on the other hand, conservation tillage delays warming of the soil due to the reduction of dark earth exposure to the warmth of the

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spring sun thus, delaying the planting of the succeeding year's spring crop corn (Tamburini et al., 2016).

Conservation tillage defines the method of seedbed preparation that includes the presence of residue mulch and an increase in surface roughness as key criteria. The practices therefore range from reduced or no-till to more intensive tillage depending on several factors such as, climate, soil properties, crop characteristics and socioeconomic factors (Tamburini et al., 2016).

Minimum tillage: Minimum tillage describes a practice where soil preparation is reduced to the minimum necessary for crop production and where 15% to 25% of crop and plant residues remain on the soil surface (Morgan, 1995).

No-till or zero-tillage: is characterized by the elimination of all mechanical seed bed preparation except for the opening of a narrow strip or hole in the ground for seed placement. The surface of the soil is covered by crop residue mulch or killed-sod (Lal, 2006).

Ridge tillage: Ridge tillage is the practice of planting or seeding crops in rows on the top, along both sides or in the furrows between the ridges which are prepared at the beginning of every cropping season. Tied ridging or furrow diking includes the construction of additional cross-ties in the furrows between neighboring contour ridges (Lal, 2001).

Most smallholders in Nigeria still perform soil preparation manually by using hoes. Larger farms use plows and harrows pulled by tractors to achieve an almost complete inversion of the top 20 to 30 cm of the soil. Hence, ridging is very common all over Nigeria, whereas tied ridging is primarily conducted in the semi-arid northern part of the country to conserve both soil and water in individual basins (Chiroma et al., 2006c).

Research on quantifying the effects of different tillage operations on runoff and erosion were conducted by Lal (2001). He recorded that soil loss was 42 times higher from the plowed watershed than from the no-till watershed. Other erosion effect-measures causing soil loss was made by

Kirchhof and Salako (2000). In their study, they reported the suitability of conservation tillage as an effective soil erosion control measure through the protective effect of residue mulch.

Soils with reduced tillage are characterized by less total pore space but have more stable fine pores and fewer air-filled pores than tilled farmland soils (Osunbitan et al., 2005). Analyses on soil aggregates further under different tillage operations were made by Adesodun et al. (2007) who showed that cultivation significantly reduced the macro-aggregate fractions to smaller diameters. Agele et al. (2005) published comparable results which measure the contribution of reduced tillage to the maintenance of the soil structure.

Studies on the bulk density of surface soil layers showed differences according to the tillage methods. Tillage operations also affect the infiltration capacity and hydraulic conductivity of soils which has an impact on the amount of runoff and, hence, of soil loss. Lal (1997) observed the highest infiltration rate for no-till treatments (32 to 40 cmha⁻¹) and lower rates for plowing (22 cmha⁻¹).

Studies on the influence of different tillage methodologies on the soil moisture content was performed by Amezcua et al. (1993). They recorded that the moisture content was higher in the surface soil of no-till plots than in treatments prepared with tillage machines. For example, Lal (1995) measured soil moisture content of 15.4% to 17.5% in the top 10 cm of the soil on plots with no-tillage and 10.9% to 15.5% on tilled plots 58 days after the seeding of maize.

The more favorable moisture and temperature conditions in plots with reduced or no tillage also have beneficial effects on the activity of the soil fauna, such as earthworms. These soil organisms reduce compaction and crust formation, construct macropores, and contribute to an improved soil structure by the formation of stable aggregates. These processes improve the infiltration rate for rainwater and reduce the erodibility and hence, the eroding-vulnerability of the soil. In addition, the content of

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organic carbon and nitrogen was maintained at significant higher levels in the surface soil of untilled systems than in tilled systems. 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 (2000).

However, as mentioned above, different tillage operations are necessary in locations with unfavorable climatic conditions or problematic soils. Overall, water harvesting is important in arid and semi-arid areas with erratic and small rainfalls to dis-necessitate wind erosion, construction of ridges or tied ridges with a series of small basins for the collection and storage of rainwater is a useful indigenous technology in dry areas (Chiroma et al., 2006c).

Mechanical Methods

Mechanical methods including, terraces, waterways, and structures such as vegetative barriers or stone lines installed on farm also can break the force of winds or decrease the velocity of runoff to reduce soil erosion (Morgan, 1995).

Terraces: Contour bunds made of earth or stones or terraces that consist of an excavated channel and a bank or ridge on the downhill side for cultivating crops are permanent erosion control technologies (Morgan, 1995; Lal, 1995a).

The first are installed across slopes of low gradients while the latter at right angles to the steepest slope in hilly areas. Research on contour banks was conducted by Couper (1995) who considered these measures to be useful to prevent gully erosion – the most spectacular type of erosion in his study area. He also prepared an implementation guide for farmers including the description of the design and construction of graded contour banks. Field trials on terraces include that made by Lal (1995a) in Ibadan. The study showed that the mean soil loss from a catchment without any erosion control measure was 2.3tonha⁻¹ and from a terraced catchment, 0.7tonha⁻¹.

Thus, permanent structures of terrace 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).

Waterways: 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 implementation probably needs special knowledge of the water regime of the area and the construction of waterways (Lal, 1995a).

Structures: Structural barriers made of stones or vegetation installed along contour lines are another mechanical erosion prevention and control measure (Morgan, 1995). As they operate as filters, they may not reduce the runoff amount but retard its velocity and hence encourage sedimentation, increase infiltration, and facilitate the formation of natural terraces (Lal, 1990).

Vegetative barriers are usually constructed as single lines or in the form of strips of several meters wide. Malgwi (2000a; 2000b) in investigating the effectiveness of vetiver (*Vetiver zizanioides*), a perennial grass with a deep and fibrous root system, in northern Nigeria as an appropriate vegetative soil erosion barrier recommended this grass as an appropriate soil conservation technology for semiarid zones advantage for withstanding denudation, fire, drought, and flood.

Records on on-farm trials with vetiver in the derived savanna were also made by Kolade (2006) who emphasised the beneficial effects on soil conservation and economic advantages. Further, Lal (1995) published a list of grass species commonly used for establishing vegetative hedges in the humid tropics and stated the thick root system-grasses to, prevent riling, gullyng, and tunnelng. In general, mechanical measures are effective soil

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conservation technologies as they reduce soil loss. However, its installation and maintenance is usually labor-intensive thus, these structures are not likely to be adopted by farmers.

Theoretical framework

The loss of soil from land surfaces by erosion is widespread and reduces the productivity of all-natural ecosystems as well as agricultural environments, forest and pasture ecosystems (Troeh et al., 2004). Concurrent with the growing human population, soil erosion, water availability, climate change due to fossil fuel consumption, eutrophication of inland and coastal marine bodies of water, and loss of biodiversity soil erosion rank as one prime environmental problem throughout the world. Conservation agriculture according to United Nations Food and Agricultural Organization is a concept introduced for resource-saving agricultural crop production that and strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment (FAO, 2006). Conservation is the use of resources in a manner that safely maintains a resource used by humans. Conservation has become critical because the global population has increased over the years and more food needs to be produced every year (New Standard, 1992).

Theory of population

This was credited to Thomas Robert Malthus (1766-1834). He argued a dis-uniform world population-food production growth rate with world population growing geometrically while food production grows increasingly arithmetically. Thus, human populations grow exponentially (that is, doubling with each cycle) while food production grows at an arithmetic rate (that is, by the repeated addition of a uniform increment in each uniform interval of time). Thus, while food output increase is an arithmetic progression of, 1,2,3,4,5,6,7,8,9 and so on, population was capable of increasing geometrically progressively on

1,2,4,8,16,32,64,128,256 and so on. Thus, to sustain this growing population, more land has to be put into cultivation. Unfortunately, however over the years, these 'more' lands continue to be exposed to land degradation thus, destruction of the natural ecosystem. Thus, the theory of population is been used in the study of erosion. This is the case with Eze (2012) in his study of farmland erosion in Enugu state.

Ricardian theory of rent (1772-1823) argues that rent arises from the differences in the fertility of different plots of the land. First the more fertile lands are taken for cultivation but as the population rises continuously, the demand for food goes up. To meet the demand of food for the growing population, the land may be put under intensive cultivation or extensive cultivation or both simultaneously.

Conclusion

Soil-land security is environmental rationality cum viability for life support that can be enhanced through the use of conceptual, theoretical and soil-degradation panacea studies. Thus, the security of the soil and, absence of threats on its physical, biological and chemical components and systems that sustain life cum diverse array of disciplines and schools of thought that contribute to the study and/or dispute global soil-environmental change – a possible cause of violent conflict – calls for collective action given conceptualization and theory.

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