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# Soil tillage: The implications on soil properties and maize production in Nigeria

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**Abstract:** There is an urgent need to match food production with increasing world population through identification of sustainable land management strategies. However, the struggle to achieve food security should be carried out keeping in mind the soil where the crops are grown and the environment in which the living things survive. Soil Tillage, the most important aspect of conservation agriculture, is thought to take care of the soil health, plant growth and the environment. This paper aims to review the work done on soil tillage in different agro-ecological regions so as to understand its impact from the perspectives of the soil and how it affects the maize production. Research reports have identified several benefits of soil tillage on maize production with respect to soil physical, chemical and biological properties as well as crop yields. Therefore, soil tillage involving different methods has potential to break the surface compact zone in soil with reduced soil disturbance offers to lead to a better soil environment and crop yield with minimal impact on the environment.

**Keywords:** Soil, Tillage, Properties, Maize, Production, Nigeria Etc.

## Introduction

Low maize yields are a major concern for West African farmers and Nigeria in particular. Maize is the main cereal crop in Nigeria and is eaten by people with no socio-economic history in the country (Badu-Apraku et al., 2011). In Nigeria, maize is mainly cultivated by small-scale farmers under rainy conditions. These farmers use a range of agricultural practices in crop processing. Many farmers use disk plough and disk harrow before planting while some farmers intend maize after disc ploughing without disc harrowing. Some farmers are harrowing disc without ploughing disks before planting. Some farmers "slash and burn" while others don't use tillage until maize is planted. Many farmers conduct tillage operations without knowing how these activities affect soil physical characteristics and crop reactions (Ozpinar and Isik 2004).

Tillage is a method of modifying the state of the soil, so as to create favorable conditions for cultivation (Culpin, 1981). In the growth of crops such as maize, tillage plays a key role. Tillage can affect crop growth in a positive or negative manner. The effects on soil physical, chemical and biologic properties that affect crop productivity in turn influence soil quality (Anikwe and Ubochi, 2007).

Disk ploughing is one of the most important conventional tilling operations. The modern tillage practices change the soil structure by modifying its physical characteristics, including soil bulking density, soiled penetration resistance, soil moisture content, soil porosity and soil air, according to Rashidi and Keshavarzpour (2007). Papworth (2010) also stated that tillage affects crop growth and output through changes in soil structure and humidity removal patterns during the growing season.

Tillage conservation plays a major role in reducing soil erosion and improving soil quality (Uri et al., 1999) and could offer farmers an alternative to conventional tillage because of its potential to reduce work and fuel consumption and the total costs of production (Uri, 2000). No tillage is a system in which crops in previously unsettled soil are cultivated on narrow slots or tilled strips. There is no tillage for lower soil compaction, lower fuel and labor costs.

Tillage provides a number of other advantages, such as wind and water erosion controls, soil humidity loss and emissions of greenhouse gases (Chen et al., 2005). However, no laying is mainly disadvantageous by soil compaction, which can increase mechanical strength and thus hamper

Arvidsson's (1998) root growth. Continuous soil cultivation contributes to low maize yields due to soil nutrient extraction. In order to reverse nutrient loss and maintain productivity, external inputs are necessary (Agbede, 2010). The addition of fertilizers could help to refill nutrients and improve the quality of tropical soils (Shangakkara et al., 2004).

The climate in numerous Nigerian farming systems is severely degraded as a result of soil degradation and lower fertility, but the increased nutrient use is seldom monitored by soil guidelines which lead to misuse and related economic and environmental hazards (Chase et al. 1991) (Bundy et al., 2001). Knowledge about the requirements for maize labour and the effects of the maize yield combination are scarce in Nigeria. Therefore it was necessary to carry out this research as insufficient information is available regarding the effect of reducing the type of tillage and fertilizer in soil properties during maize production.

## Maize: Origin, Classification and Botany

Maize is an annual monocotyledon from the Poaceae family and the Maydean tribe, of whom taxonomists have identified eight separate generations (Raemaekers, 2001). Teosinte is generally accepted as an ancestor of maize, although there are varying views as to whether maize is a tanned version of teosinte (Galinat, 1988).

Maize is a high, monoecious annual grass with overlapping sheaths and wide, distinctive dissectional blades. Plants have long, spikelike stamina spikes that form wide, spread terminal panicles and pistillate inflorescence on the axils of the leaves, in which the spikelets appear on a thick, almost woody axis (coB) in 8 to 16 rows about 30 cm in length. (PDF) The entire structure (silks), enclosed in numerous large bracts and a weight of long styles (silks), is a mass of silkscreen threads protruding from the tip (Hitchcock and Chase 1971). Pollen is made completely in the stamina and in the cob, completely in the inflorescence of pistillate. Maize is pollinated by wind and auto-pollination and usually cross-pollination is possible. Maize is grown around the world and for a large share of the world's population it is a staple food. No significant indigenous toxins associated with Zea genes have been reported (International Food Biotechnology Council, 1990).

## The Physiology of Maize

Maize stems look like bamboo came, and the joints (nodes) are roughly 40-50cm apart. The stalks are straight and the height is between 1 and 3m. The bottom leaves are like large flags, are 50-

100cm long and 5-10cm widespread. The leaves consisted of a sheath of leaves holding the stem and a long, slender, conical blade and ligule. The ligula marks the point where the blade of the leaf stretches from the foundation. There's a leaf in every node.

The leaves are opposite to each other. Depending on its maturity and growth a mature maize plant produces 20 to 24 leaves (Twumasi-Afriyie and Sallah 1994). A prominent mid-rib supports the leaf along its length. The cobs grow beneath the leaves and near the stalk. There are female inflorescences which are closely hidden by many layers of leaves and are so confined to the stem that they do not appear quickly until the light yellow silk is drawn from the blade at the end of the cob. Silks are thick, tufts-like stigmas, first white, then red or yellow. The stem's apex ends with the male flora, the tassel. For each silk on which pollen from the tassel lands a kernel of maize is produced. As the plant matures, the cob gets harder and the silk gets dryer. Dry your kernels and make it hard to chew without first cooking them in boiling water. The grains are about the size of the peas and they stick around the white pithy substance that makes the cob in regular rows. The root network is fibrous and spreads throughout. The primary roots emerge from the germination seed and in the first few weeks have the most nutrient. Once the seedling grows up, permanent or coronal roots emerge from the crown just below the surface of the earth. More adventurous roots then develop from above and grow into the soil to anchor and support the plant upright Raemaekers, 2001).

## Importance and Uses of Maize in Nigeria

The maize supplies 50% of basic calories to an estimated 50 percent of the population of sub-Saharan Africa (Ofori and Kyei-Baffour, 2006). It is a big source of carbohydrates, sugar, phosphorus, vitamin B and minerals. The nutritional value of the maize grains is high, with a total of 72% starch, 10% protein, 4.8% fat, 8.5% fiber, 3.0% sugar and 1.7% ash (Chaudhary, 1983). Maize is the most important grain and cereal feed crop in semiarid and arid tropical irrigated and rainfall agriculture (Hussan et al. 2003). In Nigeria, the projected capital consumption of maize in 2000 was 42.5kg (MoFA, 2000).

Maize, due to its worldwide distribution and lower cost relative to other grains, has a wider variety of uses and ranks second only to wheat in terms of overall production in the world than any other grain. It is the largest food crop and the base of most rural diets and cash crops. It is the main source


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of calories and protein and primary food weaning in poor communities for infants (Mashingaidze, 2004).

Maize is eaten directly in developing countries such as Nigeria and is a staple diet for many people. Nigeria consumes maize in a wide variety of porridges, noodles, beans, and beers as a starchy base. The parched, fried, toasted, or cooked green maize is an important part of the dry season in filling the hunger gap (Ofori and Kyei-Baffour, 2006). Every country has one or more corn plates unique to its own culture. Ogi (Nigeria), Kenkey (Nigeria), Koga (Cameroon), To (Mali), Injera (Ethiopia), Ugali (Kenya), among others. Most of these products are still processed traditionally (Okoruwa, 1997). The economic value of any portion of the maize plant can be used to manufacture a wide variety of food and non-food items (Raemaekers, 2001), cited by Gomez (2010).

## Climatic Requirements for Maize Production

Maize thrives well in a variety of environments, but grows best with sufficient humidity in dry, sunny climates (Purseglove, 1992). The crop is grown in temperate to tropical climates, with daily average temperatures above $15^{o}$C. The minimum germination temperature is approximately 10oC. At soil temperatures above 16oC germination and, in particular, germination would be much more rapid and even. Maize usually develops 5-6 days after sowing at about 20oC (Raemaekers, 2001). 21-30oC is ideal for cultivating maize (Adjetey, 1994). The critical temperature, however, that damages maize yields is around 32oC (du Plessis, 2003).

## Water Requirements for the Production of Maize

Maize is an efficient water user in terms of total production of dry matter. The crop needs a regular supply of water and is severely affected by drought. Depending on the environment, maize needs between 600 and 1200 mm of water each year and must be well distributed during the growing season (Awuku et al., 1991). Maize requires maximum moisture during tasselling and silking periods. The availability of soil moisture during tasselling is therefore essential for the production of high yields (Tweneboah, 2000). In drought conditions, the growth rate is declining, the silking period is delayed, and grain filling and grain formation is significantly reduced, resulting in a reduction in yield (Raemaekers, 2001).

## Requirements for the Cultivation of Maize Soil

Maize is good in most soils and can be grown continuously as long as soil fertility is maintained. Soils with good effective depth, favorable morphological properties, good internal drainage, optimal moisture regime, sufficient and balanced amounts of plant nutrients and chemical properties are best suited to maize production (du Plessis, 2003). Maize is suited to a wide variety of tropical soils, from sandy to heavy clay soils. However, most maize is grown on well-structured medium-sized soils (sandy loam to clay loams) because they provide adequate soil water, aeration and penetrability.

## Maize Harvesting and Storage

Maize thrives well in a variety of environments, but grows best with sufficient humidity in dry , sunny climates (Purseglove, 1992). The crop is grown in temperate to tropical climates, with daily average temperatures above 15 ° C. The minimum germination temperature is approximately 10oC. At soil temperatures above 16°C germination and, in particular, germination would be much more rapid and even. Maize usually develops 5-6 days after sowing at about 20 ° C (Raemaekers, 2001). 21-30 ° C is ideal for cultivating maize (Adjetey, 1994). The critical temperature, however, that damages maize yields is around 32 ° C (du Plessis, 2003).

## Pests and Diseases Control in Maize Production

The incidence of several pests, including stalk borers and army worms, affects maize cultivation. The economic losses incurred by stalk borers may be very large because the damage done at first is not evident and many plants could have been killed and many others may have been damaged after recovery as a result of a serious attack. Infected plants found, spotted or white leaves, delayed growth, impaired growth of plants, and gradual death (Fr. Aichlich and Rodrwald 1970).

Many grasshopper species are known to feed on the foliage of maize plants. They attack and devor large plants; they only leave bare stalks or stubs in the field sometimes. Insects that are preferably used in hatching areas when the nymphs are young may be used to control grasshoppers (Martin et al., 2006). Birds, cane rabbits, squirrels, rabbits, monks and insects often cause various damage to the corn plant, particularly husks, which provide room for secondary pathogenic diseases. Squirrels and crows remove seeds from the ground and seedlings; cane rats kick stalks and cobs; birds and monkeys destroy cobs and grains. Birds and animals can be handled through threats, capture or terror.

Common maize conditions include smuts, rust, bacterial fog, and stripes. The use of pesticides, selection of seed, crop rotation and use of resistance varieties and the removal of alternative hosts will control these diseases. In addition, all diseased plants, husks and cobs should be destroyed by burning during harvest in order to prevent the transport of pathogens to crops of the next year.

## Understanding Soil Tillage

Soil tillage is a physical, chemical or biological manipulation of the soil to optimize the conditions for germination, seedling and crop growth. However, Ahn and Hintze (1990) defined it as any physical loosening of the soil carried out in a variety of cultivation operations, either by hand or mechanized. The choice of a tillage activity for any given area would depend on one or more of the following factors (Lal 1980; Unger 1984): always Soil characteristics, including relaxation, erodibility, erosivity, rooting depth, texture and structure, organic matter quality and mineralogy; Climatic factors, including amount of rainfall and distribution, water balance, length of growing season, temperature (environment and soil), duration of the rainy season; Crop factors, including growing length, rooting characteristics, water requirements, seeds and plants, Socio-economic factors, including farm size, availability of power, family structure and composition, employment situation.

Tillage is a labour-intensive activity in low-resource agriculture practiced by smallholders and a capital and energy-intensive activity in large-scale mechanized agriculture (Lal, 1991). In some situations, continuous soil inversion can lead to degradation of the soil structure leading to a compacted soil composed of fine particles with a low level of soil organic matter. These soils are more vulnerable to soil loss due to water and wind erosion, ultimately leading to desertification, as observed in the USA in the 1930s (Biswas, 1984).

This process can trigger a wide range of environmental problems, both directly and indirectly. Conventional soil management practices have resulted in losses of soil, water and nutrients in the field and have degraded soils with low organic matter content and a fragile physical structure which, in turn, have led to low crop yields and low water efficiency and fertilization (Wang et al., 2007). For this reason, scientists and policy makers have put emphasis on conservation tillage systems.

Compared to conventional tillage, there are several benefits from conservation of tillage, such as economic benefits for labour, cost and time savings, erosion protection, soil and water conservation, and increased soil fertility (Wang and Gao, 2004). Conservation of tillage (reduced tillage) can lead to significant improvements in water storage in the soil profile (Pelegrín et al., 1990). Tillage operations generally loosen the soil, decrease soil bulk density and penetration resistance by increasing soil macro porosity. Under conventional tillage conditions, improvements were also obtained in crop development and yield, especially in very dry years (Murillo et al., 2001).

Studies comparing no-tillage with conventional tillage systems have yielded different results for soil bulk density. Osunbitan et al. (2005) found that soil bulk density was greater in no-till in the 5 to 10 cm soil depth. Appropriate tillage practices are those that avoid the degradation of soil properties but maintain crop yields as well as ecosystem stability.

## Importance of Tillage

Effective laying systems provide a good seedbed condition for plant emergence, plant development and unimpeded root growth (i.e. soil humidity, temperature and resistance to penetration) (Licht and al-Kaisi 2005). Soil cultivation can also dramatically alter fertility status, and changes in crop output can occur in good or bad crops (Ohiri and Ezumah, 1991).Tillage aims at creating a soil condition conducive to plant growth. It is conducted in order to alter the physical properties of the soil and to allow plants to demonstrate their full potential. Soil ploughing techniques are used to provide good seed and rooting, to manage weeds, crop residues, reducing erosion and soil level for planting, irrigation, drainage, fertiliser or pesticide integration and picking operations. Soil ploughing techniques are used. The supply and absorption of water and nutrients by subsoil compaction can thereby reduce crop yield (Khurshid et al . , ( 2006).

## Tillage Treatment for Maize Production

Tillage treatment is known to affect maize and soil growth and yield parameters. It has been documented that tillage contributes up to about 20 percent of crop production factors (Khurshid et al., 2006). The method chosen for tillage depends on the cover of vegetation and the way the soil surface is exposed to seeds, which in turn is determined by the density of weeds. The main treatments for the manufacture and maintenance of maize are conventional tillage (plough and harrow).

Conventional tillage requires intense soil work to yield a fine tilth. In mechanised cultivation, the soil is ploughed into pieces and harrowed to break up large clods of soil that result from ploughing before the ridges are formed. Vegetation in such tillage will normally be cleared and partially decomposed or burned to enable digging during which residue is extracted in the soil (Youdeowei et al., 1986).

Conservation tillage is an operation which is designed to preserve the ruggedness of the field surface , leaving surface residues for most of the preceding crops while ensuring sufficient seed and weed protection for the next crop. These ruggedness decreases water flow and soil erosion (Ikisan, 2000). The use of cutlass, hedge, pickax, herbicide or mulch tillage is required. Mulch tillage leaves plant residue for rapid germination and adequate yield on the soil surface. The use of conventional laying operations is detrimental to soil, and therefore the move to conservation laying and no-tillage methods for controlling soil erosion is of considerable interest and emphasis (Iqbal et al. 2005). Conservation agriculture has led to higher yields of maize crops and higher profitability with lower production costs (CKB, 2009).

## Tillage Effects on Soil Degradation

Soil erosion is traditionally seen as one of the main causes of land loss and as a major explanation for declining returns in tropical regions. High or insufficient labouring was a significant contributor to land degradation. Over the last four decades, industrial agriculture has expanded considerably to feed the population of the world more effectively than ever before. This intensification of agriculture has led to the use of increasingly heavy machinery, deforestation and change of land use in favor of farming in many countries, and particularly in the more developed countries. This has contributed to various problems such as organic matter degradation, soil compaction and soil physical damage.

Soil tillage breaks down aggregates, breaks down organic soil material, pulvers soil, breaks the consistency of pore and forms robust pans that restrict the flow of water , air and root production. On the ground surface, the powdered soil is more likely to be sealed, crusted, and eroded. The enhancement of soil physical fertility means reducing soil laying and increasing organic soil quality. Tillage induced soil erosion can result in a loss of soil of more than 150 tons per hectare per year in developing countries. Wind-and-water accelerated soil erosion is responsible for 40 % of global land degradation. A number of more recent studies have shown that no crop residue mulch planting systems can increase nutrient use efficiency (Lal, 1979). The no-till method seems to be commonly applicable in humid and sub-humid areas, where 4-6 t / ha of residual mulch appear optimal (Lal, 1975). Studies performed by ICRISAT (1988) and Mensah Bonsu and Obeng (1979) show the beneficial effect of tillage management systems on the depletion of soil and runoff.

## Tillage effects of soil water quality

The effects of tillage differ between agro-ecological areas. In semi-arid areas, moisture conservation is one of the main considerations. Nicou and Chopart (1979) have shown that the management of weeding and residue has increased the soil profile's water content. Sharma et al ( 2011) demonstrated that no-till soils retained their highest humidity and, in semi-arid regions of India, limited tillage, higher bed and conventional tillage in inceptisols. Tillage treatments affected the intake rate and water absorption. Also showing the value of tillage to soil moisture were several studies (Norwood et al., 1990). Tillage increases the conservation of soil water by increasing roughness of ground surfaces and controlling weeds in the fallow season. This stored water can boost crop production by adding to the growing plumage season (Unger and Baumhardt, 1999). Several studies have shown that Schillinger (2001) has enormous water conservation and enhanced cultivation ability.

## Impact of Tillage on Porosity

The characteristics of soil porosity are closely related to soil physical behaviour, root penetration and movement of water (Pagliai and Vignozzi, 2002, Sasal et al., 2006) and vary between tillage systems (Benjamin, 1993). Lal et al. (1980) found that the return of straw could increase the total soil porosity while minimal and no tillage would reduce soil porosity for aeration, but increase capillary porosity; as a result, it increases soil water capacity along with weak soil aeration (Glab and Kulig, 2008). However, Borresen (1999) found that the effects of tillage and straw treatment on total porosity and porosity distribution were not important. Allen et al. (1997) indicated that minimal tillage could increase the quantity of large porosity. Tangyuan et al. (2009) showed that the overall soil porosity of the 0–10 cm soil depth layer was mostly affected; traditional tillage may increase the capillary soil porosity and the porosity was C > H > S but the non-capillary porosity (S) was the maximum. The return of straw can increase the porosity of the soil.

## Tillage Consequences of Soil Bulk Density

The most frequently calculated soil physical properties affecting hydraulic conductivity are soil bulk density and effective porosity, both of which are central to soil compaction and related agricultural management issues (Strudley et al., 2008). Studies comparing no-tillage with traditional tillage systems have yielded different results for soil bulk density. Several studies have shown that no-till soil bulk density is higher in soil depths of 5 to 10 cm (Osunbitan et al., 2005). However, Tripathi et al. (2005) found an increase in bulk density with conventional tillage in silky loam soil. In addition, few studies have examined changes in soil physical properties in response to long-term tillage and frequency management (> 20 y) in the northern Great Plains. Rashidi and Keshavarzpour (2008) reported that the maximum bulk soil density of 1.52 g cm-3 was achieved for No Tillage treatment and the lowest (1.41 g cm-3) for traditional tillage treatment. The highest soil penetration resistance of 1250 kPa was achieved for No Tillage treatment and the lowest (560 kPa) for conventional tillage treatment. The highest soil moisture content was 19.6 percent for conventional tillage treatment and the lowest (16.8 percent) for No tillage treatment.

## Effect of tillage on the environment

Conservation of tillage may affect the production of nitrous oxide by affecting the structural quality and water content of the soil (Ball et al., 1999). Conservation tillage may prevent the loss of nutrients (Jordan et al . 2000). Comparison of herbicide and nutrient emissions in silky clay loam soil from 1991 to 1993. Plots 12 m wide were established and planted with winter oats in 1991, followed by winter wheat and winter beans. De-nitrification in anaerobic soil and nitrification in aerobic soil produces nitrous oxide, the former being more essential. As soil structure improves, the potential for anaerobic conditions and nitrogen oxide emissions is reduced (Arah et al . , 1991). Intensive soil cultivation breaks down the CO2-producing SOM, thereby reducing the total C sequestration retained within the soil. Building SOM, the use of conservation tillage, especially when combined with the return of crop residues, can significantly reduce CO2 emissions (West and Maryland, 2002).

## Tillage effect on Crop Yield

The effect of tillage systems on crop yield is not consistent with all crop species, in the same way those different soils that react differently to the same tillage method. Murillo et al., (2004) compared the traditional tillage, (the soil was ploughed by the mold board, to a depth of 30 cm, after burning the straw of the preceding crop) and the conservation tillage, the conservation tillage (the residues of the previous crop were left on the soil surface, as mulch, and the minimum vertical tillage (chiselling, depth of 25 cm) and the disk harrowing (5 cm depth) were carried out. Results have shown that the yield of crops in conservation tillage is higher. The results presented by Nicou and Charreau (1985) showed the effect of tillage on yields of various crops in the semi-arid tropics of West Africa. Cotton showed the smallest increase in yield with tillage in the range of crops measured. Tillage results in semi-arid areas are closely linked to the conservation of moisture and therefore to the management of crop residues.

## Conclusion

Empirical and literature reviews indicate that tillage improves soil health and increases production of maize production in Nigeria, however; large-scale adoption of soil tillage will require addressing multiple social and economic factors. The need for education and demonstration of tillage practices on soil health and economic viability is crucial to increase production of maize.

## Recommendations

At the end of the study, the following recommendations have been made:

1. There is the need to determine the long-term effect of tillage rates on maize growth yield and on soil properties.
2. Field experiments should be conducted to determine the suitable tillage treatment for different maize varieties and other crops.
3. Economic analysis should also be undertaken to determine costs and benefits of the effects of tillage on maize yield and soil properties.

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