A Review on the Effects of Conservation Tillage on Soil Loss and Physico-Chemical Properties

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Abstract
The populations of semiarid regions have doubled in the past three decades and are still growing rapidly. These increases have not been accompanied by similar rises in food production. The pressing need to assure an adequate and reliable food supply is obvious. Tillage has been an important aspect of technological development in the evolution of agriculture, in particular in food production. Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods. This paper aims to review different conservation tillage practices with their effects on physico-chemical properties of soil and soil loss. Research reports have identified several effects of conservation tillage over conventional tillage (CT) with respect to soil physical, chemical properties and soil loss as well as crop yields. The values eroded materials from the drainage scale were significantly less in the no-till system compared to the inversion tillage system where, more runoff (over 12 times) and more eroded material (54 times) were produced. Soil chemical properties of the surface layer are generally more favorable under the no till method than under the tilled soil. conservation tillage effects on crop yields is related to its effects on root growth water and nutrient use efficiencies.

Key words: Soil loss, Conservation tillage, Soil properties

Introduction
As many as 500 million people live in the semi-arid regions of the world, and most of them depend on agriculture for their livelihood. The populations of many of the countries in such regions have doubled in the past three decades and are still growing rapidly. These increases have not been accompanied by similar rises in food production. The pressing need to assure an adequate and reliable food supply is obvious.

Farming systems today have more obvious and detectable social, ecological, economic, and environmental implications than ever before because of the growing concerns about agricultural sustainability and the environment (Shrestha and Clements, 2003). Agricultural sustainability implies an increasing trend in per capita productivity to meet the present needs without jeopardizing the future potential. This demands appropriate methods of land stewardship for the development of sustainable agricultural systems. An important aspect of land stewardship is tillage, the mechanical manipulation or preparation of soil employed in crop production. Soil tillage influences agricultural sustainability through its effects on soil processes, soil properties, and crop growth.

Tillage has been an important aspect of technological development in the evolution of agriculture, in particular in food production. Tillage is defined as mechanical manipulation of soil to provide a favorable environment for good germination of seeds and crop growth, to control the weeds, and to maintain infiltration capacity and soil aeration. In addition, it also protects and maintains a strong soil structure to reduce erosion. Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on the appropriateness or otherwise of the methods used. The physical effects such as aggregates stability, infiltration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability.

An important effect of soil tillage on sustainability is through its impact on the environment e.g. soil degradation, water quality, emission of greenhouse gases from soil-related processes, etc. As a subsystem of a crop production system, tillage can be used to achieve many agronomic objectives, including soil conditioning (modification of soil structure to favor agronomic processes such as soil...
seed contact, root proliferation, water infiltration, soil temperature control, etc.), weed/pest suppression (direct termination or disruption of weed/pest life cycles), residue management (movement, orientation or sizing of residues to minimize negative effects of crop/cover crop residues and promote beneficial effects), incorporation/mixing (placement or redistribution of substances such as fertilizers, manures, seeds, residues, sometimes from a less favorable location to a more favorable spatial distribution), segregation (consolidation of rocks, root crops, soil crumb sizes), land forming (changing the shape of the soil surface e.g. ridging, roughening and furrowing).

However, tillage may have negative impacts on soil and crop production, when excessive or inappropriate. Among the disadvantages are land degradation, compaction of soil below the depth of tillage (i.e., formation of a tillage pan), increased susceptibility to water and wind erosion, accelerated decomposition of soil organic matter (negative from a long term perspective), high energy cost of tillage operations, and labor and temporal obligations. The impact of tillage depends on the combination of tillage operations and their timing that is the tillage system, to provide specific functions in given situations. The ways in which these operations are implemented affect the physical and chemical properties of the soil, which in turn affect plant growth and crop yield potential. Therefore, the first step in making sustainable production management decisions is to understand the practices associated with each tillage system.

Among the crop production factors, tillage contributes up to 20% (Khurshidet al., 2006). Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel 1989). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal et al., 2005).

Conservation tillage (CT) is defined by the Conservation Tillage Information Center (CTIC, 2004) as any tillage and planting system that covers 30 percent or more of the soil surface with crop residue after planting, to reduce soil erosion by water. Throughout much of the US, the definition of conservation tillage has been maintenance of a minimum of 30% soil cover with crop residues after planting. Conservation tillage (no till and reduced tillage) practices simultaneously conserve soil and water resources, reduce farm energy and increase or stabilize crop production.

Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before and after planting the next crop, to reduce soil erosion and runoff. Other definitions have arisen for special circumstances such as 1,120 kg ha$^{-1}$ of flat, small grain residue equivalents on the soil surface in areas with wind erosion potential. In Australia, conservation tillage refers to systems that reduce tillage operations, but not necessarily preserve stubble or residues due to problems with establishing crops in high stubble loads resulting from slow residue breakdown during dry summers (Lyon et al., 2004).

There are many variations of conservation tillage systems covering a broad spectrum of farming methods primarily based on reducing soil disturbance, conserving and managing crop residue to reduce erosion. They include no-till, ridge-till, mulch-till or strip-till. However, in Ethiopian conservation tillage practices are minimum as compared to other countries. Therefore, there is a need to review to provide some information about conservation tillage and its importance particularly on soil loss and soil properties to increase yield.

Research reports have identified several benefits of conservation tillage over conventional tillage (CT) with respect to soil physical, chemical and biological properties as well as crop yields. Not less than 25% of the greenhouse gas effluxes to the atmosphere are attributed to agriculture. Processes of climate change mitigation and adaptation found zero tillage (ZT) to be the most environmental friendly among different tillage techniques. Therefore, conservation tillage involving ZT and minimum tillage which 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 (M. Abolanle Busari 2015).
Based on the above rationale and facts of conservation tillage this review has the following objectives:

To review different conservation tillage practices with their effects on physico-chemical properties of soil and soil loss.

To overview the benefits of conservation tillage over conventional tillage.

**Discussions of Reviewed Literatures**

**No-Tillage (need latest review)**

No-tillage involves a method of seeding through crop residue mulch by opening a narrow slot in the soil for seed placement without mechanical or secondary tillage operations. Chemical weed control is used. The beneficial effects of no-tillage in soil and water conservation are widely recognized in humid and sub-humid climates where the system seems to have a broad application. The benefits include soil moisture conservation due to reduction in storm runoff, improved infiltration capacity, enhanced earthworm activity, and reduced evaporation loss. It also reduces soil erosion and maintains organic matter content at high levels. As much as a 5-fold reduction in runoff has been reported under no-tillage compared to conventional tillage (Lal 1976). The effectiveness of no-tillage farming in soil and water conservation is improved when used in association with planted cover crop.

The no-till system is a specialized type of conservation tillage consisting of a one-pass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed (Parr et al. 1990). The surface residues of such a system are of critical importance for soil and water conservation. Weed control is generally achieved with herbicides or in some cases with crop rotation. According to Lal (1983), no-tillage systems eliminate all pre-planting mechanical seedbed preparation except for the opening of a narrow (2-3 cm wide) strip or small hole in the ground for seed placement to ensure adequate seed/soil contact. The entire soil surface is covered by crop residue mulch or killed sod. A review of tillage studies in Nigeria (Opara-Nadi 1990) shows that no-tillage with residue mulch is appropriate for Luvisols in the humid tropics.

No-till farming (also called zero tillage or direct planting or pasture cropping) is a way of growing crops from year to year without disturbing the soil through tillage. No-till is an agricultural technique which increases the amount of water and organic matter (nutrients) in the soil and decreases erosion. It increases the amount and variety of life in and on the soil but may require herbicide usage (FAO 1988).

**Mulch Tillage**

Mulch Tillage is performed either by making the soil surface cloddy or mulched with the help of crop residues. Mulch tillage is happened to be an effective measure to minimize soil erosion and to conserve the moisture when it is combined with strip cropping system. This type of tillage is also practiced to utilize the crop residues as mulch and also performing farming operations simultaneously. It can be defined as a method which permits the crops to grow where all or most of the residues from previous crops are left on the soil surface.

**Mulching:**

It is defined as the application of any plant residues or other materials to cover the top soil surface for.

* Conserving the soil moisture
* Reducing the runoff and thereby to control soil erosion.
* Checking weed growth
* Protecting from winter climate?
* Improving the soil temperature?.
* Modifying the micro - environment of soil to meet the needs of seeds for their good germination and better growth of seedlings.

Mulching attribute the suppression of the weed growth, conservation of moisture by checking evaporation and runoff, protect the soil against erosion, increase infiltration of water, fluctuate the moderate soil temperature, enhance mineral nutrient availability, enhance nitrification, add nutrients...
and organic matters derived from decomposing of residues or other materials used as mulch to preserve or improve the soil structure. It also improves the soil aeration creates better biological activates and thus to make consequent beneficial effect on the soil fertility (Suresh.R 2000)

Strip Tillage or Zonal Tillage

The concept of strip or zonal tillage is described by Lal (1973, 1983). The seedbed is divided into a seedling zone and a soil management zone. The seedling zone (5 to 10 cm wide) is mechanically tilled to optimize the soil and micro-climate environment for germination and seedling establishment. The inter-row zone is left undisturbed and protected by mulch. Strip tillage can also be achieved by chiseling in the row zone to assist water infiltration and root proliferation.

Ridge till (Including No-Till on Ridges)

In this system, the soil is left undisturbed prior to planting but about one-third of the soil surface is tilled at planting with sweeps or row cleaners; planting of row crops is done on preformed cultivated ridges, while weeds are controlled by herbicides. Ridge till has been gaining popularity as a conservation practice for maize and soybean production in the USA (Parr et al. 1990).

Reduced or Minimum tillage

Minimum tillage is a soil conservation system like Strip-till with the goal of minimum soil manipulation necessary for a successful crop production. It is a tillage method that does not turn the soil over. It is contrary to intensive tillage, which changes the soil structure by Ploughs. Reduced tillage systems leave between 15 and 30% residue cover on the soil or 500 to 1000 pounds per acre (560 to 1100 kg/ha) of small grain residue during the critical erosion period. This may involve the use of a chisel plow, field cultivators, or other implements (FAO1988).

Conventional Tillage Systems

Conventional tillage is defined by the Conservation Tillage Information Center in West Lafayette, Indiana, USA (CTIC, 2004) as any tillage and plantingsystem that leaves less than 15 percent residue cover after planting, or less than 560kilograms per hectare of small grain residue equivalent throughout the critical wind erosionperiod. It is based on mechanical soil manipulation involving a sequence of soil tillage, suchas moldboard ploughing followed by one or two harrowings, to produce a fine seedbed andalso the removal of most of the plant residue from the previous crop. It embraces primarycultivation based on ploughing or soil inversion, secondary cultivation using discs, and tertiary working by cultivators and harrows, drawn by animals, tractors or any mechanically powered devices. Weeds are controlled by herbicides and cultivation. The mechanical soil disturbance involved increases the risk of erosion and dust emission (Baker et al, 2005)

Mechanized Systems

These involve the mechanical soil manipulation of an entire field, by ploughing followed by one or more harrowing. The degree of soil disturbance depends on the type of implement used, the number of passes, soil and intended crop type.

Traditional Tillage

In the humid and sub-humid regions of West Africa, and in some parts of South America, traditional tillage is practiced mostly by manual labour, using native tools which are generally few and simple, the most important being the cutlass and hoe which come in many designs depending on function (Morgan and Pugh 1969). To facilitate seedbed preparation and planting, forest undergrowth or grass is cleared with a cutlass and trees and shrubs left, but pruned. The cut biomass and residues are disposed of by burning in situ. This type of clearing is non-exhaustive, leaving both appreciable cover on the soil, and the root system which gives the topsoil structural stability for one or two years (Aina et al. 1991). This type of tillage practice is also used in Ethiopia.
Factors Affecting the Choice of Tillage Practices

Tillage is a labour-intensive activity in low-resource agriculture practiced by small landholders, and a capital and energy-intensive activity in large-scale mechanized farming (Lal 1991). For any given location, the choice of a tillage practice will depend on one or more of the following factors (Lal 1980; Unger 1984):

<table>
<thead>
<tr>
<th>Soil factors</th>
<th>Climatic factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relief (slope)</td>
<td>Rainfall amount and distribution</td>
</tr>
<tr>
<td>Erodibility</td>
<td>Water balance</td>
</tr>
<tr>
<td>Erosivity</td>
<td>Length of growing season</td>
</tr>
<tr>
<td>Rooting depth</td>
<td>Temperature (ambient and soil)</td>
</tr>
<tr>
<td>Texture and structure</td>
<td>Length of rainless period</td>
</tr>
<tr>
<td>Organic-matter content</td>
<td></td>
</tr>
<tr>
<td>Mineralogy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop factors</th>
<th>Socio-economic factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing duration</td>
<td>Farm size</td>
</tr>
<tr>
<td>Rooting characteristics</td>
<td>Availability of a power source</td>
</tr>
<tr>
<td>Water requirements</td>
<td>Family structure and composition</td>
</tr>
<tr>
<td>Seed</td>
<td>Labour situation</td>
</tr>
<tr>
<td></td>
<td>Access to cash and credit facilities</td>
</tr>
</tbody>
</table>

| Government policies             | Objectives and priorities            |

According to Unger et al. (1988) conservation tillage systems to protect the soil and water reserves often have limited appeal to producers unless they offer economic advantages. Economic factors contributing to interest in conservation tillage include:

- High costs of fuel, labour, tractors, and other equipment;
- High equipment inventories and maintenance costs;
- Ability to use land at risk of erosion for more intensive crop production (rather than for pastures or in long-term rotations);
- The opportunities offered for more intensive cropping, avoiding long fallow periods, because of greater water conservation; and in many instances, higher crop yields.

Conservation Tillage - Effects on Soil Properties, Soil Loss and Crop Yield

Conservation tillage leads to positive changes in the physical, chemical and biological properties of a soil (Bescanca et al., 2006). Soil physical properties that are influenced by conservation tillage include bulk density, infiltration and water retention (Osunbitan et al., 2004). Improved infiltration of rainwater into the soil increases water availability to plants, reduces surface runoff and improves groundwater recharge (Lipiec et al., 2005). Reduced soil cultivation reduces farm energy requirements and overall farming costs as less area has to be tilled (Monzon et al., 2006).

Several more recent studies have shown that no-till systems with crop residue mulch can:

- Maintain the productivity of upland soils by reducing erosion (Mensah-Bonsu and Obeng 1979; Lal 1981a, b, 1984a, b; Aina 1988);
- Maintain a favourable soil temperature (Hulgalle et al. 1985, Lal 1986a);
- Improve water-retention capacity (Aina 1979; Opara-Nadi and Lal 1986, 1987a, b, Hulgalle et al. 1990);
- Improve water use efficiency (Osuji 1984; Osuji et al. 1980), and
- Increase nutrient use efficiency (Lal 1979a, b, c; Hulgalle et al. 1985). The no-till system seems to have a broad application in humid and sub-humid regions, for which 4-6 tons ha⁻¹ of residue mulch appears optimal (Lal 1975; Aina et al. 1991). The beneficial effect of conservation tillage systems on soil loss and runoff have been demonstrated in Ghana (Table 4) and Chaguanamas, Venezuela (Table 5).
Effects on soil properties

Conservation tillage affects soil physical, chemical and biological properties. Research results have been widely reported on the effects of conservation tillage on soil aggregation, temperature, water infiltration and retention as the main physical parameters affected. The magnitude of the changes depends on soil types as well as soil composition. Changes in chemical properties are dependent mainly on the organic matter content of the soils. Tillage affects aeration and thus the rate of organic matter decomposition. Biological activities in the soil are vital to soil productivity through the activities of earthworms, termites and the many other living creatures in the soil. These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation.

Effect on physical properties

Effect on soil moisture availability and movement

Soils under no tillage had higher moisture retention than the conventional because evaporation losses decreased due to coverage of soil by plant residues or mulch and infiltration rates increased since soil structure was improved (Lal 1976, Osbrone et al 1986,).

Table 3.1

Effect of tillage on soil moisture retention at 0-10 cm depth under different crops two weeks after planting (Rockwood and Lal 1974)

<table>
<thead>
<tr>
<th>Moisture retention in soil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
</tr>
<tr>
<td>Ploughed</td>
</tr>
<tr>
<td>No-tillage</td>
</tr>
</tbody>
</table>

Table 3.2

Effect of tillage system on profile water content to a depth of 1 m at 2 weeks after planting (Nicou and Chopart 1979)

<table>
<thead>
<tr>
<th>Tillage system</th>
<th>Profile water content (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No till, residues burnt</td>
<td>49.4</td>
</tr>
<tr>
<td>Ploughing, residues incorporated</td>
<td>95.8</td>
</tr>
<tr>
<td>Ploughing, residues incorporated followed by addition of external mulch</td>
<td>103.7</td>
</tr>
</tbody>
</table>

Effects on soil structure and texture

Soil structure is the aggregation of primary soil particles into secondary units. A high level of aggregation is considered to be an indication of good structure and positive influence on plant growth (Griffith et al, 1986). Aina 1979 showed that the percentage of soil aggregates was substantially greater and the aggregates are more stable under fallow than under continuous cultivation and soil structure deterioration increased as the number of tillage operations increased. Under long term management practices, the particles size distributions of conventional tillage plots showed more sand and less silt in the top 15 cm than soils under no tillage (Aina 1979).

Effects on soil temperature

The maximum soil temperatures in the upper soil layer were higher for the conventional tillage plots than for the no tillage plots (Lal 1976, Wall and Stobbe 1983). This difference at 5 cm depth were as high as 11°C for maize, 9°C for soybean and 6°C for cowpea at two weeks after planting (Lal 1976). These differences were also related to the nature of crop canopy.
Table 3.3
Effect of tillage on maximum soil temperature at 5 cm depth under different crops two weeks after planting (1 May 1973) (Rockwood and Lal 1974)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Maize (°C)</th>
<th>Pigeon peas (°C)</th>
<th>Soy-beans (°C)</th>
<th>Cow-peas (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughed</td>
<td>41.4</td>
<td>40.0</td>
<td>41.4</td>
<td>41.8</td>
</tr>
<tr>
<td>No-tillage</td>
<td>31.6</td>
<td>32.4</td>
<td>32.4</td>
<td>33.4</td>
</tr>
<tr>
<td>Difference</td>
<td>9.8</td>
<td>7.6</td>
<td>9.0</td>
<td>8.4</td>
</tr>
</tbody>
</table>

Effects on soil aeration, bulk density and compaction

Soil aeration depends on porosity and water content. When a soil is water saturated to field capacity, the extent of the remaining filled with air may be critical for the maintenance of soil aeration (Baeumer and Bakermans, 1973). No tillage not only reduced total pore space but also radically changed pore space distribution: the larger pores disappeared and, therefore finer pores predominated (van Ooijerkerk and Boone, 1970).

When a soil is placed under zero tillage (ZT) management, the surface soil layers may become more compacted than under conventional tillage (Ehlers et al. 1983), particularly in coarse textured soils (Marshall and Holmes 1979). However, in the deeper soil zones, compaction is generally no greater under reduced than conventional tillage systems and may be lower (Gantzer and Blake 1978; Larney and Klavdikko 1989; Malhi and O’Sullivan 1990). Malhi and O’Sullivan (1990) observed higher penetration resistance in surface soils after 5 years under ZT as compared to conventional tillage on four soils in central Alberta. The depth of soil affected varied from 3.5 to 10.5 cm at the various sites. Malhi et al. (1992) determined, after 7 years of tillage treatments on a solonetzic loam soil in east-central Alberta that penetration resistance in the surface 10 cm of soil was higher under ZT and minimum tillage (MT) than conventional tillage, but did not differ in the 10- to 20-cm or 20- to 30-cm depths. Hammel (1989), working on silt loam soils in northern Idaho, observed that bulk densities in the surface 30 cm of soil were higher under ZT than under an MT or conventional tillage treatment. Tillage-induced high density layers occurred in the conventional tillage and MT treatments at the 10- to 15-cm depths, immediately below tillage depth. Penetration resistance was also higher in the surface 25 cm in the ZT and MT treatments than in the conventional tillage treatments. Mielke et al. (1986) collected information from a number of tillage trials in Nebraska, Minnesota, Kentucky and Illinois and determined that bulk density was generally higher in ZT than plowed systems. However, tillage does not consistently affect penetration resistance and bulk density, as soil texture, aggregation, organic matter content and moisture conditions can influence the sensitivity of the soil to compaction and the persistence of the effect (Marshall and Holmes 1979; Voorhees 1987). Hill and Cruse (1985), working on clay loam and loam soils in Iowa, observed increases in penetration resistance after 8 years under a ZT system as compared to a conventional tillage system, but bulk density was not affected. Carefoot et al. (1990), working in the semi-arid region of Alberta, observed that bulk density did not differ in loam and clay soils which had received 3-8 years of ZT as compared to conventional tillage. Chang and Lindwall (1989) reported no differences in bulk density among conventional tillage, MT and ZT systems after 20 years under a spring cereal-summer fallow rotation on a clay soil in the Brown soil zone of southern Alberta. Chang and Lindwall (1992) observed only minor differences in bulk density among conventional tillage (CT), MT and ZT systems after 8 years under continuous winter wheat, winter wheat summer fallow and winter wheat-barley summer fallow rotations on a loam soil in southern Alberta. Martino (1991) examined bulk density and penetration resistance under ZT and CT on heavy clay, a silt loam and loamy sand in Manitoba. He observed that in two of the three soils studied, the top 10-cm layer had a higher penetration resistance under ZT as compared to CT, while the reverse occurred at the lower depths. No effect was observed on the loamy sand, presumably because of its poor structure and the slow rates of natural aggregation and macro-pore formation.
Table 3.4  
Effect of different tillage treatments on soil bulk density, penetration resistance and moisture content (Majid Rashidi and Fereydoun Keshavarzpour 2006-2007)  

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Soil bulk density (g cm(^{-3}))</th>
<th>Soil penetration resistance (kPa)</th>
<th>Soil moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional tillage</td>
<td>1.41</td>
<td>560</td>
<td>19.6</td>
</tr>
<tr>
<td>Reduced tillage</td>
<td>1.47</td>
<td>815</td>
<td>18.4</td>
</tr>
<tr>
<td>Minimum tillage</td>
<td>1.50</td>
<td>1105</td>
<td>17.1</td>
</tr>
<tr>
<td>No-tillage</td>
<td>1.52</td>
<td>1250</td>
<td>16.8</td>
</tr>
</tbody>
</table>

Effect On chemical properties  
The most important soil chemical properties affected by tillage are: CEC, Exchangeable cations and soil total nitrogen, Organic matter (OM), Nutrient Concentration and Distribution (NPK) and soil PH

Table 3.5. Effect of tillage on soil chemical properties after maize harvest.  

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH (H(_2)O)</td>
<td>OC (g kg(^{-1}))</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>6.0</td>
<td>16.50</td>
</tr>
<tr>
<td>MT</td>
<td>6.2</td>
<td>19.80</td>
</tr>
<tr>
<td>ZT</td>
<td>6.1</td>
<td>21.20</td>
</tr>
<tr>
<td>LSD</td>
<td>0.05</td>
<td>2.20</td>
</tr>
</tbody>
</table>

(2\(^{2}\) ≤ 0.05)  
Source: Busari and Salako (2013).  
Exchangeable Ca, Mg, and K, were significantly higher in the surface soil under NT compared to the ploughed soil Ismail et al. (1994) and Rahman et al. (2008).The lowest values of soil OM, N, P, K, Ca and Mg were recorded in conventional till plots(Ali, Ayuba, and Ojeniyi (2006).

Effect on organic matter (OM)  
Soil organic matter content is directly related to soil moisture retention, evaporation, moisture availability, water infiltration, soil temperature, erosion, soil compaction and stability of soil structure (Phillips and Young, 1973). In long term management practices OM content of cultivated soil was 0.8% as compared to 2.5% under NT Aina, (1979) With NT, plant residues remained on the soil surface. Hence the level of soil OM in NT plots tended to increase or stabilize rather than decline, as was the case with continuous cultivation (Aulakh and Gill, 1988; Lal 1976)

Effects on Nutrient Concentration and Distribution  
According to Triplatte and Van Doren(1977) although mixing of fertilizer with the soil was absent in conservation tillage systems especially under NT, it was not a problem as far as the three major nutrients (Nitrogen(N), Phosphorus(P) and Potassium (K)), commonly applied for crops, were concerned.Deck (1983) reported that NT resulted in significantly higher N concentration than conventional tillage in the 0 to 15 cm but the opposite in the 15 to 30 cm soil depth. He also indicated that C: N, C:P and N:P ratios were higher in NT compared to conventional in the surface soil. Organic P concentrations under NT were significantly higher in the 0 to 7.5 cm depth of the soil and significantly lower in the 22.5 to 30 cm depth (Deck 1983). In the 0 to 10 cm layer, Lal (1976), obtained higher P concentration from the NT than from conventional tillage. Aina 1979, obtained lower exchangeable K from conventional field than from NT; but Unger (1991) reported the reverses for the surface soil layer. Thomas (1986) indicated that K, which is held relatively tightly by soil, did not tend to be lost more readily under NT than under conventional tillage.
Effect on soil reaction

The pH of the soil is an indicator of the acidity or alkalinity. Both higher and lower values are detrimental for crop growth. Soil pH rapidly dropped under no tillage compared to conventional tillage Deck (1983). The work of Thomas (19836) indicated soil acidity to be higher in the no tillage than conventional tillage, especially at the soil surface. According to Unger (1991) the difference in pH might be related to management practices and natural cultivation in the soil.

Table 3.5

Effects of mechanized tillage methods on soil chemical properties 6 years after imposing the tillage treatments (Lal 1985c)

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Conventional tillage</th>
<th>No-tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (1:1 in water)</td>
<td>4.7</td>
<td>5.3 (?)</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>1.35</td>
<td>1.48</td>
</tr>
<tr>
<td>Total nitrogen (%)</td>
<td>0.195</td>
<td>0.191</td>
</tr>
<tr>
<td>Bray-P (ppm)</td>
<td>42.8</td>
<td>25.0</td>
</tr>
</tbody>
</table>

effects on soil loss

Figure 1: Average values for runoff collected from 11 ft² plots on a 15-20 percent slope during crop year 2003 and 2004 (Brooke Rust and John D. Williams)

No-till is more effective than inversion tillage at reducing runoff and erosion on hill slopes and from watersheds. In the 11 ft² Erosion period (?) plots, the inversion tillage system produced significantly more runoff (over 2 times), and eroded material (47 times) than the no-till system

Figure 2: Average eroded materials collected from 11 ft² plots on a 15-20 percent slope during crop year 2003 and 2004. (Brooke Rust and John D. Williams)
The values from the drainage scale were significantly less in the no-till system compared to the inversion tillage system where, more runoff (over 12 times) and more eroded material (54 times) were produced.

The beneficial effect of conservation tillage systems on soil loss and runoff have been demonstrated in Ghana (Table 3.6) and Chaguaramas, Venezuela (Table 3.7) below.

### Table 3.6
Effects of conservation tillage systems on soil loss and runoff in Ghana (1976) (Mensah-Bonsu and Obeng 1979)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil loss (t ha(^{-1}) yr(^{-1}))</th>
<th>Runoff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kwadaso</td>
<td>Ejura</td>
</tr>
<tr>
<td>Bare fallow</td>
<td>313.0</td>
<td>18.3</td>
</tr>
<tr>
<td>No-tillage</td>
<td>1.96</td>
<td>9.2</td>
</tr>
<tr>
<td>Mulching</td>
<td>0.42</td>
<td>1.9</td>
</tr>
<tr>
<td>Ridging (across slope)</td>
<td>2.72</td>
<td>4.5</td>
</tr>
<tr>
<td>Minimum tillage</td>
<td>4.90</td>
<td>3.8</td>
</tr>
<tr>
<td>Traditional mixed cropping</td>
<td>33.6</td>
<td>2.5</td>
</tr>
</tbody>
</table>

### Table 3.7
Soil loss for three tillage systems on a Luvisol, Chaguaramas, Venezuela (Casanova et al. 1989)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil loss (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare plot</td>
<td>73.8</td>
</tr>
<tr>
<td>Conventional</td>
<td>17.3</td>
</tr>
<tr>
<td>Minimum tillage</td>
<td>2.1</td>
</tr>
</tbody>
</table>

### Table 3.8
Residue mulch effect on runoff and soil erosion

<table>
<thead>
<tr>
<th></th>
<th>Runoff (% rainfall)</th>
<th>Erosion (t ha(^{-1}) yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bare</td>
<td>Mulched</td>
</tr>
<tr>
<td>Ghana(^1)</td>
<td>49.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Côte d'Ivoire(^2)</td>
<td>36.4</td>
<td>0.33</td>
</tr>
<tr>
<td>Nigeria(^3)</td>
<td>29.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Nigeria(^4)</td>
<td>42.1</td>
<td>2.4</td>
</tr>
</tbody>
</table>

\(^1\) Mensah-Bonsu and Obeng (1979); \(^2\) Roose (1988); \(^3\) Lal (1976); \(^4\) Lawes (1966)

Ibadan, Nigeria, Lal (1976a) reported an annual saving of 32% of rainfall for crop residue mulch of 6 tons ha\(^{-1}\). In Côte d'Ivoire, Roose (1988) reported drastic reductions in runoff and soil erosion from a mulched pineapple field on a 20% slope. According to estimates by the CTIC, the average reduction in soil erosion for conservation tillage systems is about 50% of that for most conventional tillage practices.

The effectiveness of mulching in reducing erosion is demonstrated by the field experiments of Borst and Woodburn (1942) who found that, on a silt-loam soil on a 7% slope, annual soil loss was 2.46kgm\(^{-2}\) from uncultivated bare land and only 0.11kgm\(^{-2}\) on land covered with straw mulch applied at 0.5kgm\(^{-2}\). Lattanzi et al., (1974) obtained similar results in laboratory studies for the same soil, using the same slope and mulch condition. The study carried out by Mokhtaruddin and Maene (1979) on experimental farm of the University Pertanian Malaysia near Serdan, Selangor by applying a mulch of mLalang grass (imperatacylindrica) at a rate of 0.3kgm\(^{-2}\) to maize grown on a sandy loam soil on a 40% slope reduced the soil loss over the period from October 1978 to July 1979 to 0.75kgm\(^{-2}\) recorded for maize grown without a mulch and 1.95kgm\(^{-2}\) for bare soil. Using pruned fronds to cover harvesting paths in an oil palm plantation in Johor, Malaysia, reduced annual soils loss
to 0.42km\(^{-2}\) from 1.49kgm\(^{-2}\). Covering an alfisol on a 6% slope with 0.6kgm\(^{-2}\) of straw mulch results in an annual soil loss of 0.02kgm\(^{-2}\); a considerable reduction compared with 2.33kgm\(^{-2}\) recorded for bare soil.

**Effects on crop yield**

A large volume of experimental data has been published on conservation tillage effects on crop yields under various climates, agro-ecological conditions, soils, crops and residue management systems. Under some of these conditions, the tillage effect is either closely linked to soil aggregation, hence water infiltration rate and water storage capacity, or indirectly related to soil and water conservation. Moisture conservation is particularly important in semi-arid conditions.

Michels et al, (1998) reported that surface mulching, apart from its erosion preventing effects, also creates favorable microenvironments for better crop yields. Lal (1974b) obtained higher yields of maize from mulched than from unmulched plots for some Nigerian soils and attributed the higher yield to decreased soil temperature and improved soil moisture regime. Land and water management principles, used have great effect on the runoff yield (Suresh, 2008 and Isikwue, 2005).

Table 9

<table>
<thead>
<tr>
<th>Crop</th>
<th>No-till (t ha(^{-1}))</th>
<th>Conventional till (t ha(^{-1}))</th>
<th>Soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>3.64</td>
<td>2.58</td>
<td>Clay loam</td>
</tr>
<tr>
<td>Soybean</td>
<td>2.36</td>
<td>1.97</td>
<td>Clay loam</td>
</tr>
<tr>
<td>Sorghum</td>
<td>3.30</td>
<td>3.42</td>
<td>Sandy clay loam</td>
</tr>
<tr>
<td>Groundnut</td>
<td>4.66</td>
<td>4.61</td>
<td>Sandy clay loam</td>
</tr>
</tbody>
</table>

**Benefits of conservation tillage over conventional tillage**

A number of well documented benefits (Beck 1990; Freebairnet al. 1993, Reicosky 1997, Baker et al. 2005) have been associated with the practices of conservation tillage production systems which aim to maintain at least 30% of the soil surface covered by residue and reduce primary, intercrop tillage operations such as ploughing, disking, ripping and chiseling, using fewer tractor operations.

**Conclusion**

Tillage operations are needed for seedbed preparation, weed control, management of crop residues, mixing fertilizer in the soil, improving soil aeration, alleviating compaction and optimizing soil temperature and moisture regimes. The choice of tillage practice depends on soil, climatic, crop and socio-economic factors (Lal 1980; Unger 1984).

Tillage impact is noticeable on soil physical, chemical and biological properties though in different magnitudes. Tillage impact also includes the effect on the soil environment in the form of runoff and soil erosion (Bhatt & Khera, 2006).

Effects of conservation tillage on soil properties vary, and these variations depend on the particular system chosen. No-till (NT) systems, which maintain high surface soil coverage, have resulted in significant change in soil properties, especially in the upper few centimeters (Anikwe & Ubochi, 2007). According to Lal (1997a), soil physical properties are generally more favorable with no-till than tillage-based systems. Many researchers have found that NT significantly improved saturated and unsaturated hydraulic conductivity owing to either continuity of pores (Benjamin, 1993) or flow of water through very few large pores (Allmaras, Rickman, Ekin, & Kimball, 1977). According to Lal, Reicosky, and Hanson (2007) NT technologies are very effective in reducing soil and crop residue disturbance, moderating soil evaporation and minimizing erosion losses.

Soil chemical properties that are usually affected by tillage systems are pH, CEC, exchangeable cations and soil total nitrogen. According to Lal (1997b) soil chemical properties of the surface layer are generally more favorable under the no till method than under the tilled soil. Tillage impact on crop...
yield is related to its effects on root growth (Boone & Veen, 1994), water and nutrient use efficiencies (Davis, 1994) and ultimately the agronomic yield (Lal, 1993).

Conservation tillage, a crop production system involving the management of surface residues, prevents degradative processes and restores and improves soil productivity. The experimental data presented in this review show that conservation tillage has a wide application for sustainable crop production on a range of soils in the humid and sub-humid tropics. Major goals of conservation tillage are improved maintenance of surface residue for erosion control and efficient water conservation in the different agro-ecological regions. A limitation is its heavy dependence on herbicides and pesticides, which can lead to serious water pollution.

Conservation tillage leads to positive change on soil physico-chemical properties, soil loss and crop yield. It has also practical benefits such that fewer trips across the fields saves time and money (lowers fuel, labor and machinery maintenance costs) and reduces soil compaction that can interfere with plant growth and Optimizes soil moisture, enhancing crop growth in dry periods or on droughty soils.

Recommendation

Conservation tillage procedures must be related to the particular site. Their successful application and use over a wide range of soil conditions depends on matching the procedure to soil type, crop cultivar, climatic factors and other aspects of the environment.

Conservation tillage practices become more important now than ever and should be based on scientific data from well-designed and adequately equipped long-term experiments to achieve sustainable food production with minimal impact on the soil and the atmosphere.

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