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THE EFFECTS OF CONSERVATION TILLAGE ON SOIL PROPERTIES AND CROP YIELD

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ABSTRACT

Tillage operation plays a vital role in seedbed preparation, weed control, management of crop residues, mixing fertilizer in the soil, improving soil aeration, alleviating compaction, optimizing soil temperature and moisture regimes. During field operation the ways of implementing traditional tillage operations affect the soil properties such as temperature, moisture, bulk density, aggregation, organic matter content, and plant properties such as root density, which in turn affect plant growth. Hence, the proper tillage practices are required to avoid degradation of soil properties, crop yield variation and effects of ecosystem stability. The main objective of this review is to understand the effect of conservation tillage on soil properties and crop yield because conservation tillage is a crop production system which involves management of surface residues, prevents soil degradation, restores and improves soil fertility and increase crop yield during the crop cultivation.

KEYWORDS: Conservation tillage – soil properties - Crop yield

INTRODUCTION

Tillage has been an important aspect of technological development in the evolution of agriculture. Tillage aims to create a soil environment favorable to plant growth (Klute 1982). Lal (1983) defined tillage as a physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. The main objectives of tilling the soil include seedbed preparation, water and soil conservation and weed control. Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on the appropriateness or based on the methods adopted. The physical effects of tillage such as aggregate-stability, infiltration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability. Tillage practices with heavy machinery physically break macro aggregates into smaller units, leading to new surfaces. These changes in soil structure acts on the pore-size distribution and thus influence drainage or plant-available water content. Pore-size distribution is a sensitive soil physical property that can be used to evaluate the influence of tillage on the physical condition of the soil because it regulates the rate of water entry into the soil. It also influences soil, water fluxes, which affect plant nutrient availability and plant growth. Three important phenomena related to plant nutrition, which are negatively affected by reduction in macropores, are: root growth-nutrient interception by roots, soil drainage and aeration (Preciado et al., 1998). Tillage of soil by machinery leads to a constant breakdown and reduction in soil aggregates. The action of rainfall and gravity results in a re-packing of these aggregates and consequently reduce the total soil porosity and pore-sizes. The resulting changes in macro porosity affect water flow, which in turn affects nutrient availability and thus impact negatively on the productive capacity of the soil (Preciado et al., 1998). The repeated use of inadequate tillage systems in soils with slopes, the high concentration and intensity of precipitation are key factors for the occurrence of the erosion process (Ramos and Martínez-Casasnovas, 2006). Erosion is one of the main factors for land degradation and low yields in many areas of the world, because water erosion removes topsoil (horizon A) resulting in highly compacted soils with poor fertility, low infiltration, and water holding capacity (Palau et al., 2007). These negative impact results in an increase in the bulk density decreased aeration and increased penetration resistance, which results in impeding root development (Letey, 1985; Batey, 2009). In addition, tillage operations in loosening, granular, crush or compact soil structure, changing soil properties such as bulk density, pore size distribution and composition of the soil atmosphere, affect plant growth. Therefore, appropriate tillage practices are those that avoid the degradation of soil properties but maintain crop yields as well as ecosystem stability (Greenland 1981). The effects of tillage on soils are closely related to the management of crop residues in and on the surface of the soil. Unger et al., (1991) pointed out the two practices which have a major impact on soil conservation are crop residue management and tillage. Tillage systems included under crop residue management are no-till, ridge-till, mulch-till, and reduced-till. The conservation tillage is defined by the Conservation Tillage Information Center (CTIC) 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 and wind. With conventional tillage (complete turning over of the soil), the bare soil is exposed to the erosive action of water, which, in many areas is the major route of soil loss.

Fabrizzi et al., (2005) evaluated the effect of conservation tillage on soil temperature, compaction, water content, and crop yield and reported that soil has higher water retention during the critical growth stage of corn in no-till method. West and Marland (2002) showed that, zero tillage method released less CO_2 from agricultural operations, compared to the conventional tillage. They also concluded that, changing from conventional tillage to zero tillage increased carbon sequestration and decreased CO_2 emissions. Baker et al., (2007) found that, conservation tillage had the advantage of no carbon sequestration, compared to the conventional tillage method.

Under conservation tillage, the crop residue buffers the raindrop energy, so water has less erosive force when it reaches the soil. This protection by residue, along with the rough surface provided by the residue facilitates infiltration and decreases runoff that carries soil and nutrients with it. Peruzzi et al., (1996) found that conservation tillage reduced fuel and energy consumption and increased system field efficiency compared to the conventional tillage method. Rusu (2005) reported that, minimum tillage reduced fuel consumption for 12.4 to 25.3 liter per hectare and power requirement from 23.6 to 42.8 %, compared to the conventional tillage method.

In addition, macropores, which are the major route for water movement through soil, get disrupted in the soil surface at a depth of 15-20 cm by conventional tillage, but remain intact under conservation tillage. The improved macropore development also enhances water infiltration and decreases water runoff. Conservation tillage can also conserve water and fertilizers.

This study is based on the effects of conventional tillage as compared to conservation tillage on both soil properties and crop growth

Effect of Conservation Tillage on Soil Properties

When implemented for long term conservation tillage practices which can change many soil properties. Changes in soil properties change the way in which crops respond to nutrient management practices. Continuous tillage practice affects soil properties such as temperature, moisture, bulk density, aggregation, organic matter content, and plant properties such as root density which mostly influences crop growth. Griffith et al., (1977) observed soil temperature variation due to different tillage practices as shown in Table 1. Soil temperatures are comparatively less in conservation tillage systems than other tillage systems, which are attained by residue cover on top soil. Residues reflect a portion of the solar energy that would otherwise reach the soil surface. In addition, residues delay soil drying. Conservation tillage results in higher soil moisture retention because wetter soils require more energy to warmer than do drier soils due to residue left over the topsoil.

Table 1: Effects of Tillage on Soil Temperature

Tillage System	Average Daily Maximum Soil Temperature (˚C) At 10 Cm, 8 Weeks After Planting
Plow, disk twice Chisel	21.9
Field cultivation	19.8
Ridge- till	21.0
No-till	18.4

Rockwood and Lal (1974) reported that, a thin layer of dead crop residue 1-2 cm thick on the soil surface of no-till plots decreases the minimum soil temperature and improves soil moisture conditions. Following results are obtained from field studies, no- till tillage practices shows decreased soil temperature of 31.6, 32.4, 32.4 and 33.8 ˚C than 41.4, 40.0, 41.1 and 41.8 ˚C of conventional tillage and similarly improves soil moisture conditions as 13.3, 12.1, 10.6 and 15.4 percent than 9.7, 10.8 7.3 and 12.3 percent of conventional tillage. Casanova et al., (1989) reported that soil loss from wind and water erosion occurs at a rate of 73.8 t/ha, 17.3 t/ha and 2.1 t/ha in bare plot, plots practicing conventional tillage and plots practicing conservation tillage.

Scott Murrel (2013) reported that, soils in conservation tillage systems generally have higher bulk densities than tilled soils. Bulk density is the mass of soil within a given volume. Soils with higher bulk densities usually have less pore space. This condition can lead to a decreased amount of root growth. In an intensively tilled system, higher bulk densities would result in decreased root growth. However, in conservation tillage systems, higher bulk densities do not necessarily result in reduced root growth. Soils in conservation tillage systems exhibit increased aggregation and higher numbers of root and worm channels than other tillage systems. These channels provide paths for root growth. If the channels are open to the soil surface, water infiltration increases. The differences in bulk density between conservation tillage systems and other tillage systems usually disappears at the end of the growing season, because tilled soils become more dense throughout the season from compaction by rainfall. Soil compaction (measured by cone Penetrometer) was higher for no-till than for other systems, in a study conducted in Illinois as shown in Fig 1. Source: Illinois, USA, Cited in IPIN. Fertilizer management, for today's tillage systems.

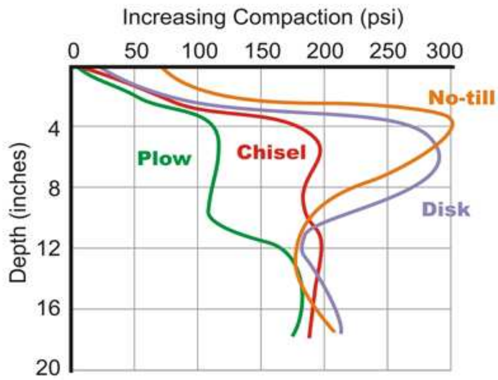

Figure 1: Soil Compaction Due to Different Tillage Systems

Griffith (1977) reported that conservation tillage practices increases organic matter levels at various depths comparing to conventional tillage practices as shown in Table 2

Table 2: Percent Organic Matter in Various Tillage Systems

Percent organic Matter in Various Tillage System		
Depth (cm)	**Mould board plough**	**No-till**
0-10	4.1	4.8
10-20	4.1	4.2
20-30	3.7	3.8

Lal (1986) studied the effects of mechanized tillage methods on soil chemical properties for 6 years, after imposing different tillage treatments as shown in Table 3.

Table 3: Effects of Mechanized Tillage Methods on Soil Chemical Properties

Soil property	Conventional tillage	No-tillage
PH (1:1 in water	4.7	5.3
Organic carbon (%)	1.35	1.48
Total nitrogen	0.195	0.191

Hoeft et al., (1985) reported that, the roots of plants growing in conservation tillage systems are more concentrated at shallower depths than plant roots grown in other tillage systems as shown in Fig 2

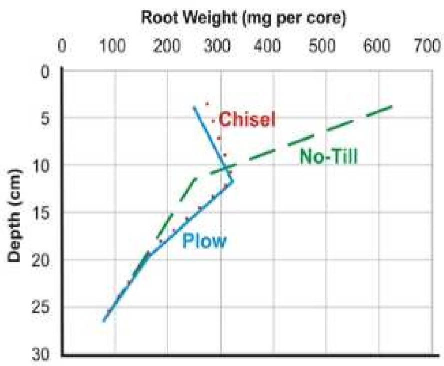

Figure 2: Root Growth Affected by Different Tillage Practices

In conservation tillage higher soil moisture levels near the surface and nutrients concentrated near the soil surface allows more root depth to grow compared to conventional tillage.

Effect of Tillage on Crop Yield

Many researchers studied the 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 the water infiltration rate and water storage capacity, or indirectly related to soil and water conservation. Moisture conservation is particularly important in semi-arid conditions. Conservation tillage is commonly accepted to reduce soil erosion and facilitate water storage. It is especially important in semi-arid climate regions where the correct management of crop residues is essential to achieve sustainable yields (Du Preez et al., 2001). More authors have demonstrated that, different climatic conditions for conservation tillage (reduced tillage). It can improve the water storage capacity in the soil profile (Pelegrín et al., 1990; Moreno et al., 1997, 2001). Under these conditions, improvements were also obtained in crop development and yield, especially in very dry years (Pelegrín et al., 1990; Murillo et al., 1998, 2001). The effect of tillage systems on crop yield are not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice. The results presented by Nicou and Charreau (1985) in Table 4, which show the effect of tillage on yields of various crops in the West African semi-arid tropics. Cotton showed the smallest yield increase, with tillage within the range of crops tested.

Table 4: Effect of Tillage on crop Yields in the west African Semiarid Tropics

Crop	Number of annual results	Yield (kg/ha)		Yield increase (%)
		Control	With tillage	
Millet	38	1558	1894	22
Sorghum	86	1691	2118	25
Maize	31	1893	2791	50
Rice	20	1164	2367	103
Cotton	28	1322	1550	17
Groundnut	46	1259	1556	24

Tillage effects in semi-arid zones are closely linked to moisture conservation and hence the management of crop residues. Unger et al, 1991, Larson 1979, Brown et al., 1989, Thomas et al., 1990 and other researchers emphasize the link between crop residue management and tillage and recognize them as the two practices with major impact on soil conservation in the semi-arid zones. Residue retention in a cropping system in Burkina Faso significantly increased the yield of cowpeas as shown in Table 5.

Table 5: Effect of Cropping Sequence and Residue Management on Cowpea (IITA/SAFGRAD 1985)

Preceding crop	Residue management system[1]	Date of flowering[2]	Date of maturity[2]	Yield (kg/ha)
Maize	Residues removed	48.7	71.2	436
Crotalaria	Residues retained	46.6	69.2	918
Maize	Residues retained	45.7	68.5	921

[1]No tillage in all treatments

[2] Number of days after planting

Conservation tillage is often less likely to result in corn yields equal to those with conventional tillage (whether moldboard or chisel plowing) on fine-textured and (or) poorly drained soils (Griffith et al., 1992; Opoku et al., 1997).Conservation tillage usually has positive effect on soil quality and crop yield, mainly due to the improvements achieved in soil water storage, especially in regions where this parameter is often limiting under conditions of drought.

CONCLUSIONS

Repeated cultivation, without any effort to redress the decline of soil structure, will lead to decrease microbial activity, nutrition transforms, residues decomposition rate, soil fertility and crop yield. Therefore, suitable tillage practices which help to avoid the degradation of soil, maintain crop yield and ecosystem stability should be followed. The conservation tillage is one of the superior tillage practices than conventional tillage which provides the best opportunity for halting degradation, restoring, improving soil and crop yield.

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