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CONVENTIONAL TILLAGE VS CONSERVATION TILLAGE - A REVIEW

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ABSTRACT

Conservation tillage decreases soil erosion, leaching of fertilizer, pesticides and herbicides into the ground water. Conservation and conventional tillage greatly affect bulk density and soil aggregation. Conservation tillage improves activity of earth worm and other soil micro flora. Some studies showed that soil microbial activity was higher with conventional tillage due to better aeration. Numerous studies conducted in temperate climate zones showed that no-tillage resulted in acidification of surface layer when continued for several years compared to conventional tillage. Conservation tillage increases soil infiltration rate and reduces soil evaporation there by it increases soil water storage, while other studies stated that soil crusting at a slower rate on no-till surface than on the tilled reducing the infiltration rate. Due to higher residue in surface soil in conservation tillage, it will improve soil organic carbon content, while other work reported a decrease in soil organic matter compared to ploughed soil down to a depth of 10 cm after 3 years of study. Zero tillage gives smothering effect to weeds but some studies shows that, higher density of perennial grass weeds in reduced tillage systems compared to conventional tillage. Several studies have shown that crops grown under zero tillage have yielded as similar as or better than those grown under conventional tillage, while some workers revealed conventional tillage increased the yield of crops and other scientist reported there no yield difference between any tillage system.

1. The objective of seed bed preparation is to create stress free soil environment (water, mechanical impedance, aeration, nutrition etc.) to achieve optimum germination, proper seedling establishment and adequate plant population. Tillage is needed to make proper seed-bed, which varies with the crop to follow and largely depends upon soil types, nature of preceding crop and residue management systems. Seedling emergence is critical for better establishment of crop. Hence, it is important to ensure an adequate seed and soil contact to facilitate water movement into seed, which intern depends upon physical characters of seed bed, thus affect germination and plant stand (Bouaziz, 1987). Tillage helps in controlling weeds by burying weed seeds and emerged seedlings leaving a rough surface to hinder weed seed germination, expose underground parts of perennial weeds leading to their desiccation (Subbulakshmi, 2007).

Regardless of the ecological region, compaction and crusting are major production constraints to intensive agriculture. Some soils in arid/ semi arid regions of Africa and India are naturally compacted and restrict root growth. Mechanical loosening as a part of conservation tillage may be required to improve crop growth. Soil compaction is caused by wheel traffic at the soil surface and formation of a plow-pan in subsurface layers (Lal, 1985). Conservation tillage systems are systems of managing crop residues on the soil surface with minimum or no tillage. The systems are frequently referred to as stubble mulching, ecofallow, limited tillage, reduced tillage, minimum tillage, no-tillage and direct drill.

2. Purpose of review: The agricultural literature for the last several decades contains many reports pertaining to conventional and conservation tillage but the information is scattered. So a review of all such literature is necessary to bring all the information in one fold. In this chapter, selected references are used to illustrate actual and potential benefits and problems of using both the tillage for conserving soil and water resources.

3. Tillage and environment

3.1. Energy use: Conservation tillage, especially no-tillage, along with N fertilizer management, offers farmers one of their greatest opportunities to conserve energy in crop production. Moldboard plowing to 20 cm depth requires an estimated 17 liters ha ^{1} of diesel-fuel equivalents (DFE = 41 MJ per liter) of energy. In contrast, chisel –plowing to 20 cm requires 1.18 and disking requires 0.64 liters ha ^{1} DFE (Frye, 1984). In no-tillage, tillage is eliminated and this energy is conserved. Some, but not all, of the energy conservation is offset by slightly greater need for herbicides in no-tillage. Ozturn *et al*. (2006) found that zero tillage recorded lower energy consumption compared to ploughed soils. Subbulakshmi, (2007) in her study reported that energy consumption was higher with conventional tillage while, lowest total energy was used by zero tillage. Even though lower energy consumption was recorded by zero tillage, higher energy out put, net energy, energy use efficiency and energy productivity were higher with continuous conventional tillage due to increased crop productivity.

3.2. Soil Physical Properties

3.2.1. Bulk density and compaction

Studies conducted by Blevins and Frye, (1993) at Kentucky found, no significant effect on bulk density after 20 years of corn production compared no-tillage and moldboard-plow tillage. The surface 0-5 cm of the no-tillage soil had slightly lower bulk density than the surface of the moldboard-plow system. In contrast, Gantzer and Blake (1978) in Minnesota found significantly higher bulk densities (1.24 to 1.32 g cm^{-3}) of a clay loam soil in no-tillage than in plow tillage (1.05 to 1.12 g cm^{-3}). Hill and Cruse (1985) reported no significant effect of tillage methods (no-tillage, conventional tillage, and minimum tillage) on bulk density of a loess-derived Iowa soil. Rice yield reduction in zero tillage was observed due to higher strength and bulk density of surface soil layer (Sharma *et al.,* 1988). Pratibha *et al*. (1994) reported that ploughing once with tractor drawn mould board plough plus rotavator twice resulted in lower bulk density and higher moisture availability. Similarly, Cavalaris and Gemtos, (2002) mould board ploughing created great stresses during tillage that caused shear planes and resulted in soil loosening. Bulk density in both the depths (0-8 cm, 8-16 cm) was highest in zero tillage treatment and lowest in conventional tillage due to natural soil consolidation and minimum disturbance of soil by tillage operation in zero tillage (John Anurag and Singh, 2007).

3.2.2. Soil aggregation

Soil aggregation involves the binding together of several soil particles into secondary units (Unger and McCalla, 1980). Soil aggregates, especially water stable aggregates, are of special importance for high water infiltration and good soil structure. These properties help to determine soil quality and influence directly soil and water conservation. Plant emergence, water infiltration, and soil erosion are directly influenced by aggregate stability. Results from soil aggregation studies on four Indiana soil by Mannering *et al*. (1975) showed that as tillage intensity increased, soil aggregation decreased. Aggregation was highest in the 0-5 cm layer of no-tillage treated soil. Douglas and Goss (1982) found that after repeated direct seeding in Britain, aggregate stability of the topsoil was improved. Research on a poorly drained soil in Northern Ohia (Lal *et al*., 1989) showed that median aggregate size tended to be higher (about 22 %) for no-tillage treatments than for plow-till treatments. Edwards *et al*., (1988) concluded that no-tillage effectively preserved the macropores during the intercrop period, whereas tillage disrupted many of them. Similarly, Rao *et al.* (1995) found that seedling emergence was found to be the lowest when soil was tilled with mould board plough and disc plough, due to formation of bigger size clods. Borges *et al.* (1997) observed that zero till on sandy (>70 % sand) soil restored water aggregate stability to near 70% of original levels of undisturbed soil after 3 years.

3.2.3. Soil water conservation

The capacity of a soil to supply water to plants during periods of water stress is determined by the available water holding capacity, infiltration and percolation rates, evaporation rate, effective rooting depth, position of the landscape, and depth to the water table. Of these, tillage can significantly affect infiltration and evaporation in all soils and affects available water holding capacity and effective rooting depth in some soils.

3.2.3.1. Infiltration

Tillage studies on silty soils in Germany (Ehlers, 1979) showed that no tillage improved soil structure due to increased concentrations of organic matter in the surface, resulting in less slaking during heavy rains. Even though total porosity was increased by tillage, the macro pores connecting the soil surface to the subsoil were enhanced, thus improving infiltration. Water infiltration increases with increasing amounts of residue on the surface (Lang and Mallett, 1984). Surface residues, as with conservation tillage systems, reduce runoff (1.2 and 2.2 %) and increase infiltration than ploughed soil (8.3 and 21.5 %) at 1 and 15% slope respectively (Rockwood and Lal (1974). Zero tillage resulted in lower infiltration rate. Lindstrom *et al*. (1984) stated that, no till treatment is characterized by higher bulk density, greater penetrometer resistance, lower volume of macropores and reduced infiltration rate. They also observed detachment of soil particles from raindrop impact and subsequent soil crusting at a slower rate on no-tillage surface than on the tilled reducing the infiltration rate. Mc Garry (2003) and Scopel and Findeling (2001) reported that infiltration rates remain reasonable due to more favorable porosity, pores being continuous and vertical, postulate under zero tillage. Subbulakshmi (2007) stated that soil crusting at a slower rate on no-till surface than on the tilled reducing the infiltration rate.

3.2.3.2. Soil water storage

In an irrigated winter wheat-fallow-dryland sunflower system, average increases in soil water content during fallow after wheat were 38, 53, 61, and 71 mm with disk, sweep, limited (sweep tillage plus herbicides) and no-tillage treatments respectively (Unger, 1981). The study conducted by Unger (1984) showed that, soil water storage was 29, 34, 27, 36 and 45 % under mould board, disk, rotary, sweep and no-tillage treatment respectively. Carefoot *et al.,* (1990) observed greater grain yield of wheat and barley with no-tillage than with conventional tillage mainly due to improved plant emergence because of conserving both seed bed moisture and total soil water which had beneficial effects on crop yield in semi-arid region (Carefoot *et al.,* 1990).

3.2.3.3. Evaporation

The plant residues left on the soil surface reduces the rate of water evaporation under conservation tillage relative to conventional tillage. Mulch provides protection against short-term but not long-term droughts. According to Bond and Willis (1969), the protection against drought due to mulching lasts 7 to 14 days. Smika (1976) compared the effects of conventional, minimum and no-tillage treatments on soil water loss during a 34 day period following 165 mm of rainfall. At 34 days, soil with the conventional tillage treatment had dried to less than 0.1cm cm^{-1} to 12 cm depth and the minimum tillage soil had dried to that water content to 9 cm depth. In contrast, soil with the no-tillage treatment dried to the 0.1 cm cm^{-1} water content only to 5 cm depth. Utomo (1986) found that the effect of a mulch from a killed hairy vetch cover crop on soil water in the 0-15 cm depth was apparent virtually throughout the entire 1985 corn growing season and it was found that no-tillage was superior to conventional tillage. Zero tillage can be particularly effective in enhancing crop yield during years of relatively low precipitation due to reducing evaporation by surface mulch (Donovan and McAndrew, 2000).

3.3. Soil Chemical properties

3.3.1. Soil pH

Numerous studies conducted in temperate climate zones showed that no-tillage resulted in acidification of surface layer when continued for several years. Findings from a classic long –term tillage study in Ohio on Wooster silt loam indicated significant acidification of the surface 0-7.5 cm under no-tillage (Dick *et al*., 1986). Moschler *et al*. (1973) also reported increased acidification of surface layer under no-tillage. In Kentucky, Blevins *et al*. (1977) observed that soil pH was lower with no-till than plow-till due to decomposition of the concentrated layer of organic residues at the surface with subsequent leaching of resultant organic acids into mineral soil. Longterm tillage and crop rotation experiment on acidic soils in Brazil have indicated that zero –tillage may increase pH, KCL-exchangeable Ca and Mg, & Mehlich- 1P, and decreased KCL-exchangeable AL (Calegari, 1995) compared to conventional tillage (Machado and Gerzabek, 1993). Kaminski *et al*. (2000) proposed that crops grown on zero tillage land suffered less from Al toxicity as their roots often followed the channels produced by insects or the decay of previous roots in the soil profile, such channels having lower levels of Al, higher levels of exchangeable Ca, Mg, raised available P and K, more organic matter and higher pH than ploughed soil.

3.3.2. Distribution of nutrients in the soil

Rice and Smith (1982) observed higher soil moisture contents in no-till soils, rather than tilled soil are primarily responsible for higher denitrifying bacteria activity. Tracy *et al.* (1990) determined that no-tillage wheat plots after 16 year accumulated greater No_3-N, SO_4- S and PO_4-P in the 0 - 2.5 cm soil depth than plowed plots. Mineralization of organic N, P, and S can be a major source of plant-available nutrients near the surface of no-tilled soils. Exchangeable K was not significantly affected by N rates; however, it was greater in the 0-5 cm depth of no-tilled than conventional tilled soils. Without mechanical mixing, K continuously accumulated near the surface of no-tillage plots, whereas conventional tillage resulted in mixing of K in the surface 20 -25 cm depth depending on the depth of plowing (Blevins and Frye, 1993). Soil disturbance during the tillage process and incorporation of surface residue increased the soil aeration and rate of residue decomposition. This process influenced the soil organic N mineralization and made available N for plant use (Dinnes *et al.,* 2002). Conventional tillage systems mineralized more N at the soil surface due to soil disturbance than no-tillage system (Halvorson *et al*., 2001; Malhi *et al*., 2006). Conventional tillage recorded significantly higher values of soil P and K, and zero tillage recorded lower values (Gangwar *et al*., 2004; Anil Kumar Singh, 2006).

3.3.3. Soil Organic Matter (SOM)

Doran (1980) found that the organic C and Kjeldahl N contents of surface soil (0-7.5 cm) with no-till averaged 1.25 and 1.20 (25 and 20%) times higher, respectively for no-till than for conventionally tilled soil. The comparison is made by Frye *et al*. (1985) on a soil that is initially low in soil organic matter; the organic matter content will usually increase with conservation tillage, but remain fairly constant, or perhaps decrease further, with conventional tillage. Freitas et al. (1999) observed that increases in SOM in coarse particle size fractions (200-2000 µm) down to 20 cm depth compared to similarly cropped but ploughed land in a clays cerrado oxisol after 4 years of zero tillage, while other work reported a decrease in SOM compared to ploughed soil down to a depth of 10 cm after 3 years in a oxisol in Toledo (Riezebos and Loerts, 1998) and to a depth of 20 cm after 11 years of zero tillage in a oxisol in Passo Fundo (Machado and Silva, 2001). Sisti *et al*. (2004) and Castro Filho *et al*. (2002) found that no significant increase in SOM down to 30 cm depth in a clayey Typic Hapludox oxisol after 13 years of zero tillage in Passo Fundo or down to 40 cm depth even after 21 years of zero tillage in a Typic Haplorthox oxisol in Londrina, respectively. Six *et al.* (2002) remarked that relative increase in SOM in the upper 40 cm of zero tillage soil after 6-8 years when compared to tilled systems under similar cropping regimes. Mielniczuk (2003) estimated the rate of SOM mineralization under conservation tillage regimes in Southern Brazil to be on average 5-6% per year compared to an average of about 3% per year in zero tillage soils. Bornoux *et al*. (2006) reported that Carbon accumulation rates is excess in zero tillage compared to ploughed soils vary from around 0.4 – 1.7 t C ha^{-1} $year^{-1}$ for the 0-40 cm soil layer in the cerrado region. Subbulakshmi (2007) found that, SOM was not significantly influenced by neither zero tillage nor conventional tillage in clay loam soils.

3.4. Biological property

An important aspect of tillage with respect to soil property is its effect on soil fauna activity, especially earthworms. Because earthworm activity and intensive tillage are highly incompatible, there are few earthworms in most cultivated soils. Ehlers, (1979) reported that, greater number of worm channels and to their continuity, which was better in no-tilled soil than in plowed soil attributed the higher infiltration rate of loess soil in Germany. Earthworm channels, which increase soil porosity, are highly stable and provide for rapid water entry into a soil (Hopp and Slater, 1961). Lal (1976) found five times greater earthworm activity in no-tillage areas than in plowed soil in the tropics.

Doran (1980) reported that total aerobic counts and facultative anaerobic counts for no-till soil were 1.35 and 1.57 times (35 and 57%) higher, respectively, than those for conventionally tilled soil. Among the aerobic organism, the fungi and aerobic bacteria increased most with no-till as compared with conventional tillage. The population of denitrifying bacteria was 2.7 times higher in no-till relative to plowed soils. On the other hand, Stately and Fairchild (1978) found no effect of tillage on denitrifier population size in samples from the surface 30 cm. Burford *et al*. (1977) reported that N_2O flux from direct-drilled soil (no-till but mulch removed by burning) was three to five times greater than the flux from plowed plots. Kaminski *et al.* (2000) proposed that crops grown on zero tillage land recorded more insect activity than ploughed soils. Treatments those received conventional tillage recorded higher number of bacteria, fungi and actinomycetes due to better aeration of soil which increased the growth of these organisms than zero tillage plot (Subbulakshmi, 2007)

4. Tillage and crop environment

4.1. Weed control

`According to Clements *et al.* (1996), lower total weeds at early crop growth stage with either country plough tillage or cultivator tillage against minimum tillage. Kandasamy and Krishnakumar (1997) observed that the effect of summer ploughing in reducing sedges was more pronounced. They also reported that tractor and power tiller puddling controlled most of the weeds except broad-leaved weeds in rice. Chinnusamy *et al.* (2000) reported that disc ploughing followed by cultivator tillage recorded the least dry weight production by weeds, whereas country plough tillage was found to record maximum weed dry weight in black clay loam soils. Barberi and Blo Cascio (2001) observed that relative abundance index of *Amaranthus spp*. was the highest in no tillage and the lowest in chisel ploughing plots, whereas the opposite situation occurred for *conyza Canadensis*. In Wheat, annual broad-leaved species showed higher populations in conventional tillage, and grass annuals and perennial species showed an erratic response with tillage system (Tuesca *et al.,* 2001).

Any tillage system that leaves substantial mulch at the surface provides shading that may suppress weeds because the environment is unfavorable for germination of some weeds. Research has shown that rye killed in spring inhibits the growth of weeds (Smeda and Weller, 1988). No-till planting reduced emergence of hairy nightshade by 77 to 99% and Powell amaranth emergence by 50 to 87% compared with conventional tilled planting. Buhler *et al*. (1994) recorded higher density of perennial grass weeds in reduced tillage systems as the rooting depth of the soil was not disturbed. According to Peachey *et al*., (2004) weed density increased as soil disturbance increased. Tilled plots (conventionally tilled and disked) had greater overall weed populations than rye residue plots at both 3 and 6.5 weeks after planting. Optimum weed suppression was observed in rye residue plots and weed suppression increased as the degree of soil disturbance decreased (Rapp *et al*., 2004).

4.2. Root distribution

The spatial distribution of the roots reflects the crop's potential to take up nutrients and water. The most important soil physical properties affecting root growth are porosity, mechanical impedance, water content and soil structure. Investigations elsewhere have indicated that roots elongate more slowly at first under no-tillage than with conventional ploughing (Baeumer and Bakermans, 1973), whereas lateral branching generally starts earlier, resulting in a dense but shallow root system in undisturbed soil. Allmaras and Nelson (1973) observed that straw mulch on untilled soil enhanced root growth in the upper 15 cm of soil and increased lateral spread of roots during the early staged of crop development.

Root growth decreases as penetration resistance increases (Gregory, 1994), showing a linear (Ehlers *et al.*, 1983), exponential (Hamblin, 1985) or inverse (At well, 1993) relationship. Pearson *et al.* (1991) found no effect of tillage on the diameter of wheat roots. High soil strength has been proved to reduce and even stop root growth (At well, 1993). No-tillage often results in a higher bulk density of the soil and correspondingly greater soil strength (Martino and Shaykewich, 1994). The roots in the no tillage system accumulated to a greater extent from 0-5 cm compared with the roots in the conventional tillage system (Wulfsohn *et al.,* 1996). Higher bulk denstiy can impede root growth, stimulate root branching and hinder the growth of the main axes (Lampurlanes *et al.,* 2001). Siridas *et al.* (2001) reported thicker barley roots under conventional tillage than under no tillage. Root length density profiles sometimes showed greater values for no tillage than for the other tillage systems, revealing a good soil condition for root growth under no tillage. Therefore, an increase in soil strength is observed under no tillage in the first year after its introduction and doesn't greatly affect root growth in well structured soils (Lampurlanes and Cantero-Martinez, 2003). No tillage resulted in a slightly lower root length density and a slightly larger mean root diameter compared with conventional tillage (Qin *et al.,* 2004).

4.3. Yield

Zero tillage resulted in lower yields than conventional tillage in barley (Mahli *et al.*, 1988). . However, this was contrast to the findings of Brandt (1989) who observed that zero-tillage was superior to conventional tillage resulting in higher yields. Similarly several studies have shown that crops grown under zero tillage have yielded as similar as or better than those grown under conventional tillage (Mahli and Nyborg, 1990; McAndrew *et al.,* 1994). Buhler, (1992) reported that corn yields were not affected by tillage. However, Vencill and Banks (1994) observed that sorghum grain yields were higher with no tillage system when it was combined with high degree of weed management than in conventional tillage system. Both corn and soybean yields were greater in mould board ploughing than in no tillage (Mulugeta and Stolenberg, 1997).

Kandasamy and Krishnakumar (1997) reported that tractor and power tiller puddling increased the grain yield in rice. Higher grain yield of maize was recorded by disc ploughing followed by cultivator tillage (Chinnusamy *et al.,* 2000). Zero tillage can be particularly effective in enhancing crop yield during years of relatively low precipitation (Donovan and McAndrew, 2000). Dheer Singh and Tripathi (2001) reported that, the highest grain yield of rice was recorded in the plot puddled by rotavator and lowest in direct sown unpuddled soil. Whereas, Sathyamoorthi *et al*. (2001) recorded higher grain and stover yields of maize with disc ploughing followed by cultivator tillage in black clay and red sandy loam soils. Crop yield in reduced tillage were comparable with conventional tillage only if weeds were controlled (Bottenburg *et al.,* 1997; Rapp *et al.,* 2004). Wilhelm and Wortmann (2004) reported, tillage treatment has significant effect on corn yield. According to him no-tillage treatment yielded less than with plow.

4.4. Economics

Lower labor, animal or equipment requirement is a major advantage of conservation tillage because it allows elimination of several operations, depending on the conservation tillage systems used. Maximum reduction in operations occurs with no-tillage system, but this system generally involves the use of herbicides to control weeds (Wiese *et al*., 1979). Additional economic benefits results from conservation tillage if water conservation is increased, which results in higher crop yields (Unger and Wiese, 1979). No tillage generally had less than 5 per cent yield decrease and equal or greater economic returns compared with conventional tillage system on well drained soils (Yin and Al-Kaisi, 2004). Average cost of cultivation was 15.5% less with zero tillage compared to conservation tillage due to no expenditure on ploughing for field preparation (Gurminder Singh *et al*., 2006). Zero tillage technology reduced the cost of wheat production with a benefit in yield which ultimately reflects into net return and B: C ratio (Tomar, 2007).

CONCLUSIONS

As we are in the twenty-first century, the technology to successfully grow crops using a variety of conservation tillage systems is available to our farmers. The alliance of farmers, scientists, and agribusiness has transformed crop residue management strategies and tillage methods from an idea to a system that effectively reduce erosion, reduces soil degradation, is cost-effective, and is environmentally acceptable. Soil properties and their ecological environment determine the limitations and suitability for using conservation tillage methods.

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