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Impacts of Tillage Technologies on Soil, Plant, Environment and Its Management: A Short Communication

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ABSTRACT

Tillage is the physical manipulation of soil to improve physical soil conditions. In Pakistan, various tillage technologies such as primary and secondary tillage affect plant growth, incorporate organic matter residues into the soil, eradicate weeds, and prepare the bed for seed germination preventing soil erosion and preparing the ground for irrigation. Furthermore, tillage practices change soil water holding capacity, temperature, aeration, and the mixing of crop residues within the soil matrix. Today's real agricultural problems are resource depletion with declining production, decreased human resources, and rising prices and societal shifts due to different anthropogenic activities (tillage). These changes in the physical environment and the food supply of the organisms affect different groups of organisms in different ways. In addition, they are also affecting the environment health. Therefore, its management, including conservation tillage and other includes cover crop, organic residues, and direct sowing of rice seedling is necessary to mitigate the problems. The present review discusses the tillage systems effects on soil, plants, environment and their possible solutions.

Keywords: *Tillage systems, Crop production, Resource depletion, Advanced technologies, Management.*

INTRODUCTION

Tillage is characterized as the mechanical manipulation of soil for crop production, which significantly impacts soil characteristics such as soil temperature, soil water conservation, evapotranspiration processes, and infiltration (Reicosky & Allmaras, 2003).

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There are two types of tillage operations used to prepare the seedbed: primary tillage and secondary tillage. Moldboard ploughs, chisel ploughs, and disc ploughs are examples of primary tillage tools. It is often the most intensive kind of tillage. Moldboard ploughing, for example, inverts the soil around the whole field. Primary tillage signals the culmination of one cropping season and the start of the next, resulting in a drastic visual effect on the landscape. Secondary tillage refers to subsequent tillage operations used to prepare the seedbed. Tandem or offset discs, farm cultivators, harrows, and packers are examples of these operations. Tertiary tillage refers to procedures that disturb the soil when seeding, managing or harvesting the crop (Hayden, 2015). Tillage may be used to avoid a continuing erosion process from a dynamic field applied using a chisel or lister plough along the upwind edge of the eroding area to expose coarse subsoil aggregates. Chisel ploughs are often chosen because they retain seed residue (Thokal et al., 2004).

1.1. Tillage systems in Pakistan

Tillage is the physical manipulation of soil to improve physical soil conditions for plant growth, mix organic matter and residues into the ground, eradicate weeds, prepare the seed bed for seed germination, and prevent soil erosion and preparing the soil for irrigation. In Pakistan, mould bold ploughs, chisel ploughs, and other tillage systems are used for the last decades. Mostly, Heavy tined cultivator, Einbock Tines, Spring Tines, Close up of older furrow press, Furrow press (mounted behind plough), Heavy tined cultivator is essential.

1.1.1. Mould bold plough

An essential plough for primary tillage in canal irrigated or heavily rainy areas where weeds are abundant. Ploughing with a Mould Board aims to entirely invert and pulverising the soil, uprooting all weeds, waste, and crop residues and burying them under the earth. In the soil tillage system with ridges, the weeds are controlled with herbicides usually applied when sowing or before sowing by covering the soil with restoring hills or during hoeing plants work (Gardner et al., 1999). It is recommended to plough with moldboard every four years.

1.1.2. Chisel plough

A chisel plough is a popular tool for deep tillage with minimal soil disturbance. The primary purpose of this plough is to remove and aerate the soil while leaving crop residue on top. This plough can help split up the plough pan and hardpan and reduce the impact of compaction. The chisel, unlike many other ploughs, does not invert or transform the dirt. This property has made it a valuable addition to no-till and limited-tillage farming methods to maximize the erosion-prevention advantages of maintaining organic matter and agricultural residues on the soil surface during the year. Because of these characteristics, some people believe that using a chisel plough is more sustainable than using a moldboard plough.

Reduced soil tillage with chisel plough/Para plough is an essential agroecology requirement that applies to some soil types as an agro-ameliorative measure for preserving or restoration of soil fertility. Salty soils with a salt layer at the surface, sloping land to avoid soil leaks and store water, and sandy soils to retain the soil are examples. The key benefit of such loosening technologies is that after sowing, over 30% of the field is covered with crop residues, creating favorable conditions for protection against destructive organisms while also reducing soil tillage (loosening and shredding) (Marin et al., 2009; & Vlăduț et al., 2015).

1.1.3. Reversible Plough

The Reversible Plough is a one-of-a-kind implement that attaches directly to the tractor. This is a simple land preparation tool that is hydraulically controlled. It's great for rough, dry, trashy stumpy ground, as well as the soil where scouring is an issue. The plough's high-duty clearance requires it to work on heavy crop residue. This plough can be used on both the left and right sides of the field. When ploughing, it automatically reverses the role, saving time and reducing fuel consumption. Two moldboard ploughs are mounted back-to-back on the reversible plough, turning to the right and the other to the left. One is operating on the ground, while the other is being dragged upside-down into the air. The paired ploughs are switched over at the end of each row so that the other can be used.

1.1.4. Zero Tillage

Null tillage is a technology where the crop is seeded with a specially built seed-cum-fertilizer drill in a single tractor operation without any field planning, in the absence of anchored residues, in an optimized to slightly wetter soil. In more than 1 million ha of land, zero tillage has effectively reduced water demand in the Indo-Gangetic plains. Gupta (2003) found 13-33% less water for irrigation under zero tillage than conservation tillage in wheat. Furthermore, zero tillage has a direct mitigation effect because it transforms CO2 into O2 in the atmosphere and enriches soil organic matter (Venkateswarlu & Shanker 2009).

1.1.5. Ridge Tillage

The ridge tillage is favoured on soils having slopes and low internal drainage. Soil tillage with ridges (ridges oriented in the direction of the contour line) on slope lands allows rainwater to be retained between the shelves, favouring infiltration and reducing erosion. Compared to farming up and down hills, contour farming can minimize soil erosion by up to 50%.

1.2. Effects of tillage systems on soil properties

Soil tillage is one of the main factors influencing soil properties and crop yield. Tillage contributes up to 20% of crop production factors (Khurshid et al., 2006) and impacts the productive usage of soil capital through its effect on soil properties (Lal & Stewart, 2013). Tillage practices used wisely transcend edaphic limitations, while inopportune tillage will result in a host of undesirable outcomes, such as soil structure degradation, increased deterioration, depletion of organic matter and fertility, and disturbance in the water, organic carbon, and plant nutrient cycles (Lal, 1993). Reduced tillage has a beneficial impact on many facets of the soil, while unsustainable and unwanted tillage operations cause the opposite phenomenon, which is detrimental to the soil. Hence, there is currently a lot of interest and attention on shifting from intensive tillage to conservation and no-tillage approaches for managing erosion (Iqbal et al., 2005). Tillage, on the other hand, has permanently harmed soil health. Tillage cracks the soil, disrupting soil composition and speeding up surface runoff and soil erosion. Tillage also decreases seed residue, which helps to absorb the force of raindrops. The pH, CEC, exchangeable cations, and total soil nitrogen are typical soil chemical products caused by tillage systems (Gondal et al., 2021a; Gondal et al., 2021b; Ch et al., 2021; Husnain et al., 2021; Farooq et al., 2021; Haroon et al., 2021). According to Lal (1997), the chemical properties of the surface layer of soil usually are better under the no-till system than in tilled soil. The consistent decrease in soil fertility, which is closely related to soil use, is a significant issue for conventional agriculture, especially in the tropics. This is primarily due to soil erosion and organic matter loss caused by traditional tillage methods, which leave the soil bare and exposed during heavy rainfall, wind, and fire (Derpsch, 1998). Higher mineralization or leaching rates may be responsible for decreasing organic C and total N under tilled plots due to soil structure degradation after tillage.

1.3. Effects of tillage systems on plants

Root structures serve as a link between the effects of agricultural practices on soil and improvements in shoot function and harvested yield. For example, tillage influences root production and process, which is the most significant factor in crop growth. Furthermore, tillage systems also affect the plant water contents, which are an essential source. Tillage has an effect on grain yield as well as crop output. In mustard, minimum tillage with or without straw, improved moisture management in the soil profile, and increased water supply during the crop growth cycle increase yield components, root mass and seed yield (Asoodari et al., 2001).

1.4. Effects of tillage systems on environmental health

The cultivation method chosen in arable agriculture has a significant impact not only on soil quality and crop production but also on the broader climate. Agriculture is said to be responsible for around a third of global greenhouse gas emissions. Direct emissions from agricultural activities accounted for 10–12% of global greenhouse gas emission (Tubiello et al., 2013). The UNEP (2013) pollution gap study illustrated agriculture as the first of four sectors that can help achieve national goals while also demonstrating efficiency in reducing greenhouse gas emissions. Carbon sequestration is one of the benefits of no-tillage farming (Lal et al., 2007) accounts 367–3667 kg CO2 per ha per year (Tebrügge & Epperlein, 2011). Conservation tillage minimizes the susceptibility of unmineralized organic compounds to microbial processes, limiting SOM decomposition and CO_2 emissions (Baye & Bogale, 2019). In addition to carbon dioxide ($C0_2$), other greenhouse gas emissions such as nitrous oxide and methane have been caused by tillage regimes. Soil emissions account for about 38% of all pollution to the air, in which methane is the 2nd most active greenhouse gas after carbon dioxide (IPCC, 2001). Ploughed sites had substantially higher N_2O concentrations than no-tilled sites.

2. Management's strategies

Non-inversion conservation tillage conserves soil carbon, decreases erosion risk, and improves soil quality. Furthermore, conservation tillage has been found to sequester more carbon within the soil than inversion tillage, resulting in lower carbon dioxide emissions into the atmosphere. Because of the lower power requirements for agriculture, stable, well-structured topsoil forms due to long-term conservation tillage contribute to more energy-efficient systems. Long-term studies, such as those lasting more than 20 years that affirm the effect of conservation tillage over time, are uncommon. The impact of various tillage methods and winter wheat straw management, either integrated or omitted, on organic matter turnover and soil quality indicators is investigated here. Tillage affects the environment mainly by releasing toxic gases from the soil into the atmosphere (Lal et al., 2007). According to reports, about one-third of global greenhouse gas emissions are caused by agriculture.

2.1. Conservation Tillage

The harmful consequences of organic farming and the need to change traditional agricultural methods are becoming more widely known worldwide. To overcome this, a new farming model known as Conservation Tillage is emerging. Conservation tillage (CA) is characterized as any tillage activity that leaves more than 30% of plant residues on the soil surface after seeding, with minimal soil disruption and crop rotations to increase productivity. The CA, a term developed in response to global issues regarding agricultural sustainability, has steadily grown worldwide to occupy approximately 8% of the world arable land (FAO, 2012). Based on differences in soil characteristics and properties, the soil is tilled using advanced conventional tillage techniques. By varying tillage applications, advanced tillage approaches aim to use less fuel and energy while minimizing soil disturbance. Advanced tillage methods are referred to by terms such as variable depth tillage, site-specific tillage, and precision tillage. These tillage applications can change the soil tillage depth based on data from a data source, such as a variability chart or a real-time sensor. Today's real agricultural problems are resource depletion with declining production, decreased human resources and rising prices, and societal shifts (Erenstein, 2011). As a result, energy, CA technologies such as low- or minimum-tillage with direct planting and bed planting, residue management, and plant diversification (Gupta & Sayre, 2007) have the potential to increase soil organic matter while also increasing soil quality and productivity (Bhattacharyya et al., 2013).

2.2. Disadvantages of Conservation Tillage

The only disadvantage being that it requires meticulous farm management functions. Others are;

- Increased number of pests in the soil
- Increase use of herbicides to control weeds that interfere with the main crops.
- Pest insects and diseases spread from crop residues to the next crop.
- Organic matter in the topsoil is unevenly dispersed and condensed.
- It will take some time for methods to achieve outstanding soil consistency.
- Conservation tillage is therefore not recommended where there are soil compaction problems. Soil compaction limits the growth of roots and seeds, resulting in lower yields (Gorucu et al., 2010).

3. Other Management strategies

Other managing strategies include;

3.1. Integrated Farming System

The basic principles of an integrated farming system (IFS) model are best resource utilization, maximum productivity through synergistic effects of interrelated farm activities and farming components available to farmers, resource conservation, and best waste utilization at a farm (Singh & Bhoj, 2011). Integrated Farming Systems play a unique role in the preservation of agriculture. For example, crop residues from the field can be used as animal feed, and livestock waste can increase agricultural production by improving soil fertility and reducing synthetic fertilizers. Since nothing is lost and the output of one system becomes the input for another (Gupta et al., 2012).

3.2. Crop Residue Cover

Crop residues are the remains of a plant or crop left in the field after harvest or that are not used domestically sold commercially, or discarded during processing. Annually, more than 340 Mt of crop residues is derived from various crops, with rice and wheat contributing to nearly 240 M.tons (Rao, 2014). They safeguard the soil from both wind and water erosion by keeping it moist, control weed growth, and serve as the home for soil biota (Blanchart et al., 2006). They also help to prevent land degradation.

3.3. Bed Planting

Permanent beds have ridges at regular intervals across furrows between crops. They have been proven to increase yield and water use efficiency in sorghum (Jones & Clark, 1987). (Akbar et al., 2007) recorded 36 percent water savings for broad-beds and 10% water savings for narrow-beds compared to flat sowing, a 6 percent increase in wheat grain yield, and a 33 percent increase in maize grain yield in Pakistan.

3.4. Crop Rotation

Crop rotation is essential not only for providing various “diet” for microbes and investigating different layers of soil, for nutrients that are leached to deeper layers and can be “recycled” by the crop rotation. Furthermore, a varied crop rotation produces rich soil flora & fauna. Crop rotation with legumes helps keep insect population growth to a minimum through life cycle degradation, biological nitrogen fixation (BNF), off-site emission control, and biodiversity enhancement (Kassam & Friedrich, 2009; & Dumanski et al., 2006).

3.5. Direct Seeding Rice

There is growing interest in switching from puddling and transplanting to DSR due to labour and water shortages and soil fertility issues. DSR will save up to 50% on labour costs (Santhi et al., 1998). The DSR scheme incentivizes water conservation (Humphreys et al., 2005).

CONCLUSION AND FUTURE PROSPECTS

Long-term productivity growth requires integrating productivity, resource conservation, reliability, and the environment. The CT offer a modern structure for agricultural research and development, in contrast to previous paradigms based mainly on meeting specific food grain production goals. Development of low-power-required tools for tillage and crop establishment practices that cause the fewest disturbances to soil or soil cover (in situ crop residues), especially on small farms. To optimize resource use and increase efficiencies, intensive major cropping systems require precision input control and site-specific nutrient management. To improve soil quality and minimize pollution, discourage the burning of residues and instead use them profitably for CA. In areas where crop residues of crops are used to feed animal may be recycled into the soil. Development of low-cost technologies for in-field crop residue management and efficient application of various fertilizers and herbicides to support conservation agriculture practices, especially in water harvesting, nutrient, pest, and disease management. Coordination of technology transfer among researchers, extension workers, farmers, service providers, agricultural machinery manufacturers will be critical in hastening new interventions.

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