Potential Utilization of Conservation Agriculture for Improved Soil Carbon Sequestration

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Introduction

Agriculture may help the global carbon budget since photosynthesis eliminates atmospheric carbon dioxide (CO_2). If the accumulation of soil organic carbon exceeds emissions, the sector will achieve net-negative emissions, resulting in reduced levels of greenhouse gases. Regenerative agriculture has helped a few farmers reach zero emissions (Searchinger et al., 2019). This significant change is challenging, expensive, entails prolonged soil dynamics, and requires the establishment of new supply networks and agricultural methodologies across many regions. Consequently, the scaling of regenerative agriculture will need some time (Runck et al., 2020). Conservation agriculture (CA) is promoted as a sustainable intensification system capable of meeting global food demand; yet, it has inherent limits (Lal, 2015). Conservation Agriculture (CA) has been associated with enhanced soil water retention, improved soil quality, decreased erosion, higher productivity, and elevated net agricultural income.

Major Causes and Factors for Soil Organic Carbon (SOC) Depletion

The transformation of natural ecosystems into agricultural ones is causing a rapid decline in the pool of SOC. According to research conducted by Lal in 2004, it has been observed that soils in temperate climatic zones experience a depletion of 25-50% in the SOC pool over a span of 20 to 50 years. Tropical soils deplete 50-75% in 5–20 years following deforestation. When crop residue retention and biosolid usage dominate outputs, soil depletion is negligible in managed ecosystems. In a farming system where the output exceeds the input due to fertility-mining and extractive agricultural practices, there is a risk of relatively higher depletion of soil organic carbon compared to a system with balanced input/output ratios. It has been reported that the depletion of the SOC pool can have a detrimental effect on soil quality and disrupt the balance of elemental and nutrient levels. It also disrupts the balance of water in the soil, leading to losses through runoff and high rates of evaporation. Additionally, it can cause a significant decrease in soil biodiversity, including the activity of microorganisms in the soil.

Why CA is important?

CA is aimed certain key aspects which include-

i) Optimization of natural resources through its conservations and enhancement.

ii) Integration of external inputs to the available soil, water and biological components

iii) Ensuring sustainable agricultural production along with environmental safety

Effect of Conservation Agriculture (CA) on SOC

Compared to traditional agricultural systems, Conservation Agriculture (CA) alters tillage techniques, crop/nutrient management and residue management. (Figure 1).

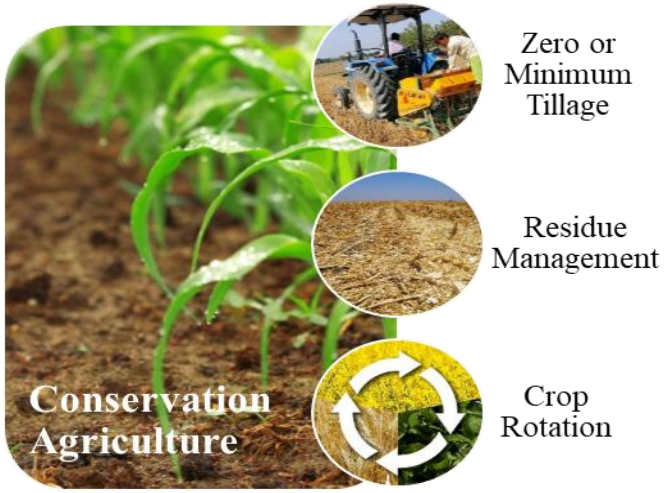

Fig. 1 Components of CA for Managing Soil Carbon Sequestration

i) Tillage Management

Conservation tillage is a method of managing crop residue on the soil's surface that involves little to no tillage at all. Agricultural equipment and weed control technologies have made conservation tillage possible for many crops (Smith et al., 2008). Thus,

lowering tillage or using no-till (NT) may reduce SOC loss from the profile by slowing macro-aggregate turnover, protecting particulate organic material, and minimizing soil-residue interaction.

ii) Residue Management

In conservation agriculture systems that prioritize the preservation of crop residues in field on the soil surface, increased residue input may enhance soil organic carbon storage. In regions with low fertility, coordinated nutrient management is crucial for the accumulation of soil organic carbon (SOC) and the efficacy of conservation agriculture (CA) systems. The reintroduction of more agricultural residues correlates with an elevation in soil organic carbon content (Dolan et al., 2006).

iii) Crop Rotation

According to Conceição et al. (2013), higher soil organic carbon (SOC) stock in CA systems is often linked to the eradication of monocultures and the insertion of plant species into rotations that return larger quantities of residue to the soil. Cover crops enhance soil organic carbon sequestration by augmenting the supply of crop residues and providing vegetative cover during essential times (Bowman et al., 1999). It would seem that the practice of replacing fallow land with legume "green manures" like lentil (Lens culinaris M.) and red clover (Trifolium pratense L.) is an efficient method for storing carbon (VandenBygaart et al., 2003).).

Challenges that farmers face while trying to implement conservation agriculture

- Soil organic carbon sequestration necessitates the incorporation of agricultural wastes, biosolids, and fertilizers or manures to augment biomass production. However, there are other competing needs for these inputs.
- At times, managing crop residues after sowing and other agricultural activities becomes challenging.
- Farmers may need to spend more on expenses, particularly during the first phase, while implementing conservation practices in agriculture.
- Challenges exist in managing weeds within conservation farming systems.
- Rising herbicide costs are associated with weed management, perhaps leading to increased expenditures.
- It is not easy to modernize farming equipment to meet the demands of conservation agriculture.

Conclusive remarks

Global agriculture is severely deteriorated. Increased input is needed to sustain yields even in high-yielding locations with healthy soils. In light of the food crisis, agriculture must be both high-yielding and sustainable. Concerning the viability of carbon capture as a carbon sequestration option, certain shortcomings must be rectified. No-till agriculture enhances soil vitality, ecosystems, and carbon storage. Zero-tillage and the preservation of crop waste as mulch may significantly diminish atmospheric CO_2 levels and enhance the efficiency of water and fertilizer use. Using crop rotation in conservation agriculture may help restore soil and trap carbon by boosting SOC accumulation rates at different soil depths. Also, it is necessary to keep in mind the possible obstacles while adopting CA.

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