Conservation Agriculture is a sustainable approach for future

Abstract:

Conservation agriculture (CA) embodies a forward-looking and sustainable approach to cultivation. It is characterized by a farming system that prioritizes sustainability through practices such as minimizing soil disturbance, maintaining permanent soil cover, and implementing crop rotations. The overarching goal is to preserve soil health and enhance productivity. This method emphasizes the optimization of natural resources, the reduction of inputs, and the enhancement of nutrient utilization efficiency. The primary focus of this review article around conservation agriculture (CA), characterized by revolutionary practices involving minimal soil disturbance (no-till, NT) and the maintenance of continuous soil cover (mulch). Agriculture heavily relies on cultivation and tillage practices. The review first explores the advantages of conventional cultivation techniques before the introduction of conservation tillage (CT), a method that originated in response to the American dust bowl of the 1930s. Subsequently, the review delves into the benefits of CA, considered an improvement over CT. The incorporation of no-till (NT), mulching, and related innovations significantly enhances soil qualities and various biotic factors within the framework of CA. Nevertheless, the promotion of Conservation Agriculture (CA) technologies encounters several challenges. These include the absence of suitable seeders tailored for small-scale farmers, conflicts between the use of CA and livestock feeding for crop residues, the practice of burning crop residues, a scarcity of skilled manpower, and the challenge of overcoming traditional attitudes towards tillage. Drawbacks of conservation agriculture encompass factors such as limited adoption, insufficient knowledge and skills, reliance on herbicides, and initial investment costs, among others.

Keywords: Conservation, Agriculture, Resilient, Sustainable

Introduction: A widely shared viewpoint is emerging, indicating that the attainment of sustainable agriculture hinges on the adoption of practices associated with Sustainable Intensification (Vanlauwe *et al*., 2014). Traditional agricultural methods promote soil tillage, the burning of crop residues, and the use of external inputs, leading to soil degradation. These practices contribute to a reduction in organic matter, increased erosion, and soil compaction (Piyush *et al.,* 2018). The burning of agricultural residue is commonly conducted for purposes such as land preparation for the next crop, elimination of excess plant matter from the field, or pest and disease control. However, residue burning has been recognized as a significant contributor to short-lived climate pollutants, including methane and black carbon (Sarkar *et al*., 2018). Conservation agriculture, as defined by the United Nations' Food and Agriculture Organization (FAO), is described as "a farming system that promotes the maintenance of a permanent soil cover, minimal soil disturbance, and the diversification of plant species." This approach aims to enhance biodiversity and natural biological processes both above and below the ground surface. The goal is to contribute to increased water and nutrient use efficiency, ultimately leading to improved and sustained crop production. Conservation agriculture is guided by three main principles: 1. Minimum soil disturbance, limiting it to not more than 30% of total soil disturbance; 2. Soil coverage with organic biomass, involving mulching the soil with the residue of the harvest; 3. Crop diversification is another key principle of conservation agriculture, involving the cultivation of various crops using different methods and at different times. Approximately 180.4 million hectares, equivalent to 12.5% of the world's arable land, have consistently been under cultivation using Conservation Agriculture (CA) worldwide.

Zero Tillage Technology: Zero Tillage (ZT) is a significant practice within Conservation Agriculture (CA). In the context of conservation agriculture, ZT refers to a method of cultivation where the soil is left undisturbed or minimally disturbed between crops. The key principle is to avoid or minimize traditional tillage operations such as ploughing. Instead, farmers plant seeds directly into the untilled soil, often leaving the previous crop residues on the field as mulch. The study revealed that zero tillage had a notable impact on increasing soil organic carbon levels. Furthermore, the depth of this increase in soil organic carbon was observed to correlate with the finer texture of the soil. In other words, as the soil texture became finer, the accumulation of organic carbon in the soil depth showed a corresponding increase under zero tillage practices (Singh *et al*., 2014). The aim of zero tillage in conservation agriculture is to promote soil health, reduce erosion, enhance water retention, and increase overall sustainability in farming systems. By minimizing soil disturbance, ZT helps maintain soil structure, preserve beneficial soil organisms, and prevent the release of carbon dioxide into the atmosphere that occurs during conventional tillage. This approach contributes to improved water and nutrient use efficiency, ultimately supporting more sustainable and environmentally friendly agricultural practices (Chauhan *et al*., 2002). According to Rani *et al.* (2019), the use of crop residue mulch was found to decrease evaporative flux. However, it was observed to increase the deep percolation flux under wheat crops in wheat under rice-wheat cropping system in semi-arid regions of Indo-Gangetic plains. Krishna and Veettil (2014) conducted a study on the on-farm adoption of zero tillage in wheat in Haryana. They found a notable 5% increase in wheat crop productivity as a result of this adoption. Additionally, the adoption of conservation tillage, coupled with improved plant nutrient management and 30% residue retention for three years in the rice-rice cropping system, commonly practiced in eastern and north-eastern regions of India, led to a substantial enhancement in grain yield, ranging between 51.1% to 52.2% compared to the existing practices of farmers (Yadav *et al.,* 2019).

Benefits of zero-tillage technology: Zero tillage (ZT) is recognized for its favorable effects on soil quality across various aspects, such as enhancing soil structure, fertility, and biological properties. Particularly in rice-wheat systems where soil organic carbon levels are typically low, studies indicate that ZT practices result in higher organic carbon content compared to conventional tillage (CT) methods. It's important to note, though, that ZT-treated soils may exhibit a lower pH, potentially due to nitrification.

Crop diversification practices: Crop rotation is a crucial element of conservation agriculture, alongside conservation tillage and residue management. A well-suited crop rotation plays a vital role in the creation of diverse micro and macro-pores in the soil. These pores contribute to the movement of water, air, and nutrients into the soil, providing favourable conditions for crop root growth. According to Jat *et al.* (2019), the cultivation of a Maize-Mustard-Mungbean rotation in a permanent bed system of conservation agriculture led to an approximately 11% higher benefit-cost ratio, increased net energy, and a 9% reduction in carbon footprint.

Happy Seeder: The described machine has the capability to sow seeds and apply fertilizer simultaneously without tilling or disturbing the soil. It is adaptable to various types of crop residue and can handle a load of 10 to 12 tonnes. However, effective operation requires a double clutch tractor with a consistent force of 400 to 500 rpm. The machine, weighing approximately 740 kg, is equipped with nine tines and can be utilized for different crops by attaching a multi-crop planter box. Ensuring proper seed and fertilizer placement at the correct depth in all nine rows is crucial, and this is achieved through the use of depth controllers. Additionally, the development of the Straw Management System (SMS) ensures the uniform distribution of residue across the field (Singh *et al*., 2023).

Herbicide Application: Zero tillage is indeed a widely adopted agricultural practice that involves minimal soil disturbance. While it offers several benefits such as improved water retention, reduced erosion, and enhanced soil structure, it can also lead to increased weed growth. This is because zero tillage leaves the soil surface largely undisturbed, providing a suitable environment for weed seeds to germinate and grow**.** To address weed issues in zero tillage systems, farmers often resort to the use of herbicides. Herbicides are chemicals designed to control or eliminate unwanted vegetation, including weeds. They can be an effective tool in managing weed growth, helping to maintain crop productivity in zero tillage systems. On the other hand, conservation agriculture emphasizes the use of minimum tillage or no-till practices to maintain soil health and structure. Conservation agriculture aims to promote sustainable and environmentally friendly farming methods. While the reduced tillage associated with conservation agriculture can contribute to weed management, the emphasis is on minimizing soil disturbance rather than relying solely on herbicides. The combination of zero till technology and the application of paraquat herbicide can indeed be an effective strategy for weed control and promoting healthy crop growth (Li Hongwen, Li Wenying. 2012). Here's a breakdown of how this approach works:

i): Zero Till Technology: Reduced Soil Disturbance: Zero tillage involves minimal disturbance of the soil, leaving crop residues on the field surface. This practice helps in maintaining soil structure, reducing erosion, and improving water retention.

ii): Weed Seed Burial: Zero tillage may limit the burial of weed seeds, allowing them to remain on the soil surface. This can contribute to an initial increase in weed growth, making effective weed control measures crucial.

iii): Paraquat Application: Non-Selective Herbicide: Paraquat is a non-selective herbicide, meaning it can control a wide range of weeds. It acts by disrupting the photosynthetic process in plant cells upon contact, leading to rapid desiccation and death of the plant.

iv): Quick Action: Paraquat has a relatively quick action, which can be advantageous in controlling emerging weeds. It is often used as a pre-plant or pre-emergence herbicide to manage weeds before crops emerge.

v): Balanced Approach: Combining zero till technology with paraquat application provides an integrated approach to weed management. The minimal soil disturbance from zero tillage helps conserve soil structure, while paraquat addresses weed challenges effectively.

vi): Reduced Dependency on Soil Disturbance: Instead of relying solely on soil disturbance for weed control, the use of paraquat allows for a reduced dependency on mechanical methods.

This can be especially beneficial in situations where zero tillage alone might lead to increased weed pressure.

Weed management: The primary and widely cited obstacle in farmers' adoption of Conservation Agriculture (CA) is the shift in weed species and the consequent increase in weed density, leading to reduced crop yields. Numerous researchers have indicated that cover crops could serve as a crucial component in weed management within the CA system. Numerous researchers have reviewed that cultivating wheat crops using zero tillage after rice harvesting in the Indo-Gangetic plains has been shown to reduce the infestation of P. minor weed by minimizing soil movement (Mehla *et al.,* 2000; Mehta and Singh, 2005). Integrated weed management strategies incorporating bio-herbicides, allelopathy, optimal crop nutrition, and chemical herbicides have been suggested as effective methods for weed control without causing harm to the environment (Bajwa, 2014). Additionally, for efficient weed management in Conservation Agriculture (CA), occasional hand weeding at appropriate crop stages could be practiced. However, further research is needed to develop suitable and integrated weed management tools.

Nutrient Management

A. **Leaf colour chart:** To regulate the nutrient levels in plants, farmers have the option of employing tools such as the leaf colour chart. The leaf colour chart is a calibrated scale featuring 5 or 6 green colour strips, ranging from a yellowish green to a deep green shade. The process involves comparing the colour of the leaves to this chart. For instance, if, out of a set of 10 leaves, 6 display a slightly yellow hue, and the greenness of these leaves rates below number 4 on the colour chart, farmers should apply 25 kg of nitrogen per acre to the farm. Typically, the leaf colour chart is employed at regular intervals, ranging from 7 to 14 days, to assess the nitrogen status in plants. This practice is generally continued up to 14 days after sowing but is discontinued after the flowering stage. This strategic use of the leaf colour chart helps prevent the excessive application of nitrogen, promoting enhanced nitrogen usage efficiency and ultimately boosting crop productivity. The leaf colour chart (LCC) stands out as an innovative and cost-effective instrument for the real-time or crop-need-based nitrogen (N) management in Rice, Maize, and Wheat. Serving as a visual and subjective gauge of plant nitrogen deficiency, the LCC offers an economical, user-friendly, and straightforward alternative to chlorophyll meters or SPAD meters (soil plant analysis development) (Parihar *et al* 2018).

Conclusion:

In conclusion, conservation agriculture is a sustainable and holistic farming approach that emphasizes minimal disturbance to the soil, cover cropping, and crop residue retention. By promoting these practices, conservation agriculture aims to enhance soil health, prevent erosion, and improve water efficiency. The adoption of conservation agriculture contributes to long-term environmental sustainability, mitigates the impact of climate change on agriculture, and fosters resilient and productive farming systems. As a comprehensive strategy, it not only conserves natural resources but also promotes economic viability for farmers, making it a crucial paradigm for the future of agriculture. In order to achieve sustainability in Conservation Agriculture (CA) technology, it is imperative to institutionalize CA within relevant government ministries, departments, and regional institutions. The successful global adoption of CA hinges on essential factors such as providing credit to farmers for acquiring equipment, machinery, and inputs through banks and credit agencies, all at reasonable interest rates. Additionally, crucial support is required to adapt and validate CA technologies specifically in local environments, especially in rainfed systems. This entails tailoring CA practices to the unique challenges and conditions of diverse regions. A collaborative approach is key, necessitating partnerships among scientists, farmers, extension agents, policy makers, and other stakeholders in the private sector. Such collaborations are vital for the development and promotion of CA at local, national, and global levels. By fostering these collaborations, we can pave the way for the widespread and effective implementation of CA, contributing significantly to sustainable and resilient agricultural systems.

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