ISBN: 978-81-973427-0-7

16. Conservation Agriculture: Principles and Advantages

Himani Sharma, Sandeep Kaur

Department of Agronomy,
Eternal University, Baru sahib, Sirmour.

Chinmaya Sahoo

Dr. Rajendra Prasad Central Agricultural University,
Pusa, Samastipur, Bihar.

Ankit Saini

Assistant Professor,
Department of Agronomy, Eternal University,
Baru sahib, Sirmour.

Abstract:

The article centers on conservation agriculture (CA), which is defined as minimal soil disturbance (no-till, NT) and permanent soil cover (mulch) combined with crop rotations. Cultivation and tillage play a crucial role in agriculture. The document first examines the benefits of tillage in agriculture before introducing conservation tillage (CT), a practice that emerged from the American dust bowl of the 1930s. Subsequently, the paper outlines the advantages of CA as an enhancement over CT, demonstrating how NT, mulch, and rotations significantly improve soil properties and other biotic factors. In conclusion, the paper asserts that CA represents a more sustainable and environmentally friendly approach to crop cultivation. The paper also covers the advantages in relation to reducing greenhouse gas emissions and mitigating global warming. It concludes that in the coming decade, agriculture will need to produce more food sustainably using less land, while making more efficient use of natural resources and minimizing environmental impact to meet the demands of a growing population. The promotion and adoption of CA management systems can contribute to achieving this objective.

Keywords:

Conservation agriculture, Sustainable agriculture, Rotations, Mulch.

16.1 Introduction:

The concept of conservation agriculture (CA) originated in the 1930s when Edward Faulkner questioned the usefulness of ploughing in his manuscript "Ploughman's Folly". It gained popularity during the 1960s in the mid-western United States to prevent soil degradation after the Dust Bowl ecological disaster that occurred in the 1930s.

Since then, research has been conducted worldwide on adapting CA practices to cropping systems. In addition to reducing tillage intensity, CA also involves the application of organic amendments such as manure, compost, and by-products from agroindustry to improve soil health (Vicente et al., 2016) mineral fertilizers can improve N management and decrease N2O emissions (Powlson et al., 2016).

Conservation Agriculture (CA) is a set of soil management practices that aim to minimize the disruption of the soil's structure, composition, and natural biodiversity. These practices have been proven to increase crop yields while improving the long-term sustainability of farming from both an environmental and financial perspective. CA employs various management practices, including the use of green manures/cover crops (GMCCs) to produce residue cover, integrated disease and pest management, and controlled/limited human and mechanical traffic over agricultural soils. When farmers implement these practices, one of the significant environmental benefits is the reduction in fossil fuel use and greenhouse gas (GHG) emissions. Additionally, these practices also reduce the power/energy needs of farmers who use manual or animal-powered systems (Gonzalez-Sanchez et al., 2015).

Conservation agriculture is the result of the collective efforts of several previous agricultural movements, such as no-till agriculture, agroforestry, green manures/cover crops, direct planting/seeding, integrated pest management, and conservation tillage, among others. However, CA distinguishes itself from each of these agricultural practices by using many of the available technologies in unison, resulting in an outcome that is much greater than the sum of its parts.

Conservation Agriculture (CA) is a farming technique that helps to improve crop production and protect the environment. It promotes natural processes that help conserve soil and water, reduce the use of harmful chemicals, and increase the efficiency of nutrients. This farming technique is suitable for all types of farms and can be adapted to local practices.

CA also helps farmers to manage their land better, especially for crops that rely on rainwater or irrigation. By using good seeds and managing pests, nutrients, weeds, and water, farmers can sustainably increase their production and diversify their crops. CA also allows for the integration of different farming sectors, such as livestock and trees, which helps to create a more balanced and productive agricultural landscape (FAO 4).

16.2 Tillage and Cultivation Techniques:

The history of tillage stretches back many millennia when humans shifted from hunting and gathering to more sedentary and settled agriculture, primarily in the Tigris, Euphrates, Nile, Yangste, and Indus River valleys (Hillel 1991). Ploughing or tillage has been mentioned in Mesopotamia as early as 3000 BC, according to Hillel (1998). Lal (2001) discussed the historical development of agriculture, highlighting tillage as a key component of management strategies. Mechanical power and tractors were available for tillage operations with the arrival of the industrial revolution in the nineteenth century; today, a wide range of equipment is available for tillage and agricultural productivity. The following list explains the reasons for employing tillage.

- Weeds tend to grow wherever crops are grown and they compete with the crop for light, water, and nutrients. The resources used by the weed are resources that could have been used by the crop. Farmers have been able to give the crop an advantage over the weed by tilling their fields. This allows the crop to grow without competition during its early growth cycle, resulting in a higher yield.
- Tillage releases soil nutrients for crops by breaking down organic matter through mineralization and oxidation after exposure to air.
- Crop residues can cause problems for seeding equipment by raking and clogging. To avoid this, they are usually incorporated into the soil along with any soil amendments.
- Tillage helps release soil nutrients needed for crop growth through mineralization and oxidation by exposing soil organic matter to air. Incorporating soil amendments and nitrogenous fertilizers into the soil makes their nutrients more available to roots and reduces nitrogen loss to the atmosphere.

Table 16.1: A Comparison Between Traditional and Conservation Agriculture System

	Traditional Agriculture	Conservation Agriculture
Practice	Disturbs the soil and leaves a bare surface	Minimum soil disturbance and soil surface permanently covered
Erosion	Wind and water soil erosion maximum	Minimum
Soil physical health	Poor	Good
Compaction	Reduces compaction by tillage operation	Compaction can be problem but use of mulch and promotion of biological tillage helps to reduce this problem
Soil biological health	Poor due to frequent disturbance	More diverse and healthy biological properties and populations
Water infiltration	Lowest after soil pores clogged	Best water infiltration
Soil organic matter	Oxidizes soil organic matter and cause its loss	Soil organic build-up in the surface layers even better than traditional agriculture
Soil temperature	Surface temperature more variable	Moderated variable
Fuel use and cost	High	Low
Production cost	High	Low
Yield	Can be lower where planting delayed	Yield same as traditional agriculture but can be highest if planting is done timelier

16.3 Adoption of Conservation Agriculture (CA):

The concept of Conservation Agriculture (CA) is defined by the Food and Agriculture Organization as a sustainable agricultural production system that focuses on protecting water and agricultural soil by integrating agronomic, environmental, and economic aspects. CA is based on three core principles: minimum mechanical soil disturbance through conservation tillage, permanent soil organic cover using crop residues and/or cover crops, and crop diversification through rotations and associations involving at least three distinct crops, including a legume crop (FAO 2023, Kassam et al., 2009).

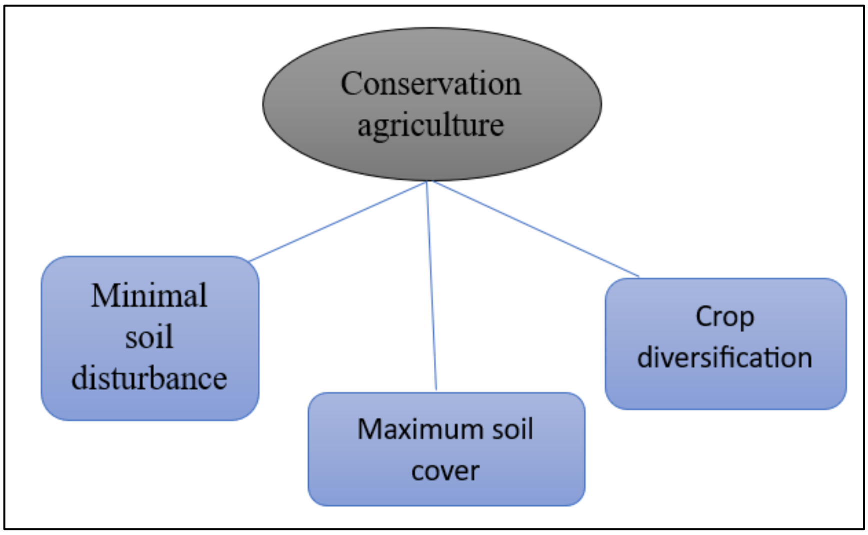

Figure 16.1: Conservation Agriculture

Conservation Agriculture:

Conservation agriculture is a farming system that maintains soil cover by retaining crop residues on the surface and using no-till or reduced tillage. It is a resource-saving approach to farming that aims to enhance natural and biological processes in the soil. According to FAO (http://www.fao.org.ag/ca), conservation agriculture is not about maximizing yields by exploiting the soil and agro-ecosystem resources, but rather about achieving a balance of agricultural, economic, and environmental benefits.

Goals:

- The goal is to optimize yields and profits while also conserving the environment, reducing input and labour costs, and providing healthy living environments for the community.
- Conservation agriculture aims to achieve acceptable profits, high and sustained production levels, and environmental conservation, as defined by FAO.
- It seeks to reverse the degradation caused by conventional agricultural practices such as intensive agriculture and burning/removal of crop residues.

- By effectively managing available soil, water, and biological resources, conservation agriculture aims to conserve, improve, and make more efficient use of natural resources. It is also known as resource-efficient or resource-effective agriculture (Dumanski et al., 2006).

16.3.1 Principles of Conservation Agriculture:

Many parts of the world use conservation agriculture practices that follow ecological principles, resulting in more sustainable land use. (Wassmann, 2009; Behera et al. 2010; Lal, 2013).

Adopting Conservation Agriculture (CA) is crucial for improving Resource Use Efficiency (RUE) and crop productivity, making it a powerful tool for natural resource management and achieving sustainability in agriculture. Conservation agriculture is based on three interconnected principles that must be considered together for effective design, planning, and implementation. These principles are:

16.3.2 Minimal Mechanical Soil Disturbance:

The activity of living organisms in the soil helps to create a healthy environment for plants to grow. These organisms create stable soil structures that allow air and water to enter, which is important for plants to thrive.

This process is called "biological tillage" and is different from traditional tilling which can destroy these structures. Keeping soil disturbance to a minimum helps to maintain a healthy soil environment, with good air and water movement, prevents weed seeds from germinating, and helps to preserve organic matter in the soil. (Kassam and Friedrich, 2009).

16.3.3 Permanent Organic Soil Cover:

A permanent soil cover is essential as it protects the soil from the damaging effects of rain and sun exposure. Additionally, it provides a consistent source of nutrition to the micro and macro-organisms present in the soil. The cover also modifies the microclimate in the soil, facilitating optimal growth and development for soil organisms, especially plant roots. As a result, soil aggregation, biological activity, biodiversity, and carbon sequestration are enhanced. (Ghosh et al., 2010).

16.3.4 Diversified Crop Rotations:

The rotation of crops is not only necessary to offer a diverse “diet” to the soil micro-organisms but also for exploring different soil layers for nutrients that have been leached to deeper layers that can be “recycled” by the crops in rotation. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna. Cropping sequence and rotations involving legumes help in minimal rates of the build-up of the population of pest species, through life cycle disruption, biological nitrogen fixation, control of off-site pollution, and enhancing biodiversity (Kassam and Friedrich, 2009; Dumanski et. al., 2006).

16.4 Different Practices of Conservation Agriculture:

A. Managing Topography:

- **Contour farming:** Contour farming is the practice of tillage, planting, and other farming operations performed on or near the contour of the field slope. This method is most effective on slopes between two and ten percent. Tillage and planting operations follow the contour line to promote positive row drainage and reduce ponding.
- **Strip farming:** Strip farming is a method of farming that involves cultivating a field partitioned into long narrow strips that are alternated in a crop rotation system. It is used when slope is too steep or when there is no alternative method of preventing soil erosion.
- **Terracing:** Terraces are formed by cut and fill areas. By filling areas, the arable land can be expended, thus making it possible to grow crops on a large scale in hilly areas. The ridges or embankments play an important role in the interception of runoff and field water.
- Waterways

B. Conservation Tillage:

It is any tillage and planting system that maintains at least 30% of the soil surface covered by residues after planting to reduce water erosion or where erosion is the primary concern maintain at least 1000 kg/ha of small grain residues equivalent on the surface during the critical wind erosion period.

Types of Conservation Tillage:

No Tillage or Zero Tillage: Soil is completely left undistributed from harvest to planting except sowing and nutrient application. Weed control is only by herbicides.

Reduced Tillage: Little soil disturbance before sowing to break the crust, loosen compact soil and prepare seedbed. Weed control by herbicides or some secondary tillage.

Mulch Tillage: Tillage is practiced only to sow crop; equipment’s don’t bury the crop residue. Weed control by herbicides or some secondary tillage.

C. Providing Soil Cover:

- **Mulching:** Mulch is a layer of material applied to the surface of an area of soil. Prevent splash erosion by heavy rains and surface runoff. Improve soil texture by adding organic matter.
- **Cover Crops:** Recycling nutrients and water enhance microbial activity. Cover crops provide multiple benefits as growing a variety of crops increase biodiversity in an agroecosystem and improves microbial biodiversity in the soil. Cover crops helps maximize farming livelihoods while improving the sustainability of the farm.

D. Crop Rotation:

- In crop rotation land is fixed but crop is rotated year after year
- Maintain and even improve soil fertility
- It checks the soil erosion and conservation moisture.
- The rotation of crops offers a diverse "diet'' to the soil microorganisms.

Potential Advantages of CA:

The benefits of CA can be classified into three broad categories:

a. agronomic benefits that improve soil productivity
b. economic benefits that improve production efficiency and profitability
c. environmental and social benefits that protect the soil and make agriculture more sustainable. CA improves soil organic carbon content and contributes to reducing global warming. It has been estimated that the total potential for soil carbon sequestration by agriculture could reduce about 40% of the estimated annual increase in CO2 emissions (FAO, 2009). CA improves water infiltration and thereby reduces run-off of surface and groundwater and enhances groundwater recharge Enhancement of water and nutrient use efficiency y (Jat et al., 2012; Saharawat et al., 2012). It improves the habitation of organisms, from larger insects down to soil-borne fungi and bacteria, which improve soil biological, physical, and chemical properties. Crop planting should be achieved promptly that helps improve the productivity of plant usage of nutrients, the availability of nutrients in the soil, and the optimal soil moisture content. All of these variables help to achieve more comparable yields through the application of CA with the conventional method. Conservation is mainly intended to allow minimum use of tillage operations and to help reduce both fuel and labour costs. It also helps to reduce the amount of inorganic fertilizer due to increased flexibility in the use of inputs, which eventually decreases the overall input costs of crop production. CA also leads to a significant reduction in labour costs relative to conventional farming systems. The method of managing weeds by planting cover crops and using mulch helps to minimize weed growth by managing seed loads. The ultimate benefits of the CA system are therefore the increase in the quality of production, soil fertility, and sustainability of the agricultural system with relative advantages, both ecologically and socially. Such advantages, which are multidimensional and complementary, have inspired the farmer to use the CA system to achieve sustainability in the agriculture sector. CA systems have higher adaptability to climate change because of the higher effective rainfall due to higher infiltration and therefore minimum flooding and soil erosion as well as greater soil moisture-holding capacity (Kassam et al., 2009). Conventional agriculture is characterized by plowing and limited recycling of organic materials. Organic agriculture uses no pesticides and mineral fertilizer whereas conservation agriculture is characterized by zero tillage, use of mulch, and crop rotations.

16.6 Conclusion:

In the coming decade, crop production will need to increase food yield while using less land, optimizing natural resources, and minimizing environmental impact. Conservation agriculture is essential for advancing sustainable agricultural practices. Conservation Agriculture, based on the core principles of maintaining permanent soil cover (via crop residues, cover crops, agroforestry), minimal soil disturbance, and crop rotation, is now recognized as the primary approach to sustainable agriculture. It is a means of attaining increased production targets while safeguarding natural resources and the environment.

16.7 References:

1. Behera UK, Amgain LP and Sharma AR. 2010. Conservation agriculture: principles, practices and environmental benefits. In Behera, U. K., Das, T. K., & Sharma, A. R. (Eds.), Conservation Agriculture (pp. 28-41). Division of Agronomy, *Indian Agricultural Research Institute*, New Delhi – 110012, 216 p.
2. Conservation Agriculture. Available online: https://www.fao.org/conservation-agriculture/overview/what-is-conservationagriculture/en/ (accessed on 13 February 2023).
3. Dumanski J, Peiretti R, Benetis J, McGarry D and Pieri C. 2006. The paradigm of conservation tillage. Proceedings of World Association of Soil and Water Conservation, P1, 58-64.
4. FAO. 2009. Conservation Agriculture. Food and Agriculture Organization of the United Nations http://www.fao.org/ag/ca Rome, Italy.
5. Ghosh PK, Das A, Saha R, Kharkrang E, Tripathy AK, Munda GC and Ngachan SV. 2010. Conservation agriculture towards achieving food security in northeast India. Current Science, 99(7), 915-921.
6. Gonzalez-Sanchez EJ, Veroz-Gonzalez O, Blanco-Roldan GL, Marquez-Garcia F and Carbonell-Bojollo R. 2015. A renewed view of conservation agriculture and its evolution over the last decade in Spain. *Soil Till. Res*. 146, 204–212.
7. Hillel D. 1991. Out of the earth: civilization and the life of the soil. New York, NY: Free Press.
8. Hillel D. 1998. Environmental soil physics. San Diego, CA: Academic Press.
9. https://www.fao.org/conservation-agriculture/overview/what-is-conservation-agriculture.
10. Jat ML, Malik RK, Saharawat YS, Gupta R, Bhag M and Paroda R. 2012. Proceedings of regional dialogue on conservation agriculture in South Asia, New Delhi, India, APAARI, CIMMYT, ICAR, New Delhi. pp. 32
11. Kassam AH and Friedrich T. 2009. Perspectives on Nutrient Management in Conservation Agriculture. Invited paper, IV World Congress on Conservation Agriculture, 4-7 February 2009, New Delhi, India.
12. Kassam A, Friedrich T, Shaxson F and Pretty J. 2009. The spread of conservation agriculture: Justification, sustainability and uptake. Int. J. Agr. Sustain. 7: 292-20.
13. Lal R. 2013. Climate-resilient agriculture and soil Organic Carbon. *Indian Journal of Agronomy*, 58(4), 440-450.
14. Lal R. 2001. Managing world soils for food security and environmental quality. *Adv. Agron*. 74, 155–192.
15. Powlson DS, Stirling CM, Thierfelder C, White RP and Jat ML. 2016. Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems? *Agric. Ecosyst. Environ*. 220, 164–174.

16. Saharawat YS, Ladha JK, Pathak H, Gathala M, Chaudhary N and Jat ML. 2012. Simulation of resource-conserving technologies on productivity, income and greenhouse gas emission in rice-wheat system. *J. Soil Sci. Environ*. 3: 9-22.
17. Vicente-Vicente JL, García-Ruiz R, Francaviglia R, Aguilera E and Smith P. 2016. Soil carbon sequestration rates under Mediterranean woody crops using recommended management practices: A meta-analysis. *Agric. Ecosyst. Environ*. 235, 204–214.
18. Wassmann R, Jagadish SVK, Sumfleth K, Pathak H, Howell G, Ismail A, Serraj R, Redona E, Singh RK and Heuer S. 2009. Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. *Advances in Agronomy*, 102, 91-133.