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3. Revolutionizing Agriculture: The Vital Role of Conservation Agriculture in Sustainability

Babli, Priyanka Sharma,
Pawan Kumar, R. P. Saharan

Faculty of Agriculture,
Guru Kashi University,
Talwandi Sabo, Bathinda, India.

Abstract:

This chapter explores the transformative potential of conservation agriculture (CA) in revolutionizing agricultural practices towards sustainability. Conservation agriculture represents a holistic approach encompassing minimum soil disturbance, permanent soil cover, and diverse crop rotations. This paper delves into the vital role CA plays in enhancing soil health, mitigating erosion, and conserving water resources, thereby fostering sustainable farming systems. Through a synthesis of current research and case studies, it highlights the multifaceted benefits of CA, including increased crop yields, improved resilience to climate change, and reduced environmental footprint. Moreover, the abstract underscores the socioeconomic implications of CA adoption, emphasizing its capacity to bolster livelihoods, alleviate poverty, and promote food security. By elucidating the principles and practices of conservation agriculture, this abstract advocates for its widespread implementation as a cornerstone for sustainable agricultural development, necessitating interdisciplinary collaboration, policy support, and farmer empowerment.

Keywords:

Conservation Agriculture, sustainability, tillage, health.

3.1 Introduction:

Total cultivable area of India is 142.2 million hectares. About 87 m ha area comes under rainfed agriculture and it meets 44% of India's food requirements. The total area under irrigation is about 62 million hectares and meets 56% of India's food demand. The total degraded land area of India due to water erosion, wind erosion, salinity, alkalinity and acidity is 120.7 m ha. There are also some problems which are associated with conventional agriculture such as erratic rainfall distribution, delayed planting, reduction of soil fertility, increased erosion and high labour & energy requirement.

Conservation Agriculture (CA) is a bridge to sustainable land management, environmental protection and climate change adaptation and mitigation. Conservation agriculture is a concept for resource saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Conservation agriculture has come as an alternative practice for conserving the natural resources.

FAO encourages the farmers to follow conservation agriculture principles such as minimal soil disturbance (no-till, NT), permanent soil cover (mulch) and crop rotations. These principles are universally applicable in all agricultural landscapes and cropping systems. Sustainable is 'kept up without interference or flagging, maintained over a long period'. This is an important strategy in today's agriculture, since the human race will not desire to negotiation the ability of its future offspring to produce their food needs by degrading the natural resources used to feed the population today. Crop production by intensive agriculture practices has depleted soils to the extent that future production in these areas is jeopardized. Healthy soils are base to develop sustainable crop production systems that are resilient to the situations due to climate change.

Legumes in rotation with cereals contribute organic matter and nitrogen that boost crop yields by 25 percent and reduce cost of cultivation. Zero tillage enhances wheat yields, in the range of 6 to 10 percent, because it leads for timely sowing, better crops stand and generates big savings on tractor operations, time and fuel. It was reported by FAO, 2016 that on the western part of the Indo-Gangetic plains, the adoption of zero-tillage in wheat production reduced farmer's costs per hectare by 20 percent and increased net income by 28 percent. They help in providing a diverse community of organisms that control insect-pest attack, plant diseases, and diverse flora of weeds. Permanent soil cover that is mulch recycle soil nutrients and improve soil structure through positive impact on water holding capacity (Maintain soil moisture in the soil), nutrient retention and supply and levels of organic carbon.

Conservation Agriculture is 20 to 50 percent less labour intensive and thus reduces the emission of greenhouse gas through lower energy inputs as well as improved nutrient use efficiency. At the same time, it boosts the formation of aggregates and protects soil from breaking down and releasing carbon to the atmosphere. Conservation agriculture is a modern agricultural practice that can empower farmers in many parts of the world to achieve the goal of sustainable agriculture. The world has lost most of its arable land, about 430 million hectares. Conservation Agriculture is a farming system that can only reduce the impact of such losses while regenerating degraded lands. CA enhances biodiversity and natural biological processes above and below the ground surface, which in result enhances the water and nutrient use efficiency and to improved and sustained crop production.

3.2 Cultivation Techniques/Tillage:

The historical development of agriculture with tillage being a major component of management practices. With the advent of the industrial revolution in the nineteenth century, mechanical power and tractors became available for tillage operations. Today, an array of equipment is available for tillage practices. The following summarizes the reasons for using tillage:

- Tillage was used to make the soil soft and prepare a well pulverised seedbed that allowed seed to be placed easily at a suitable depth into moist soil using seed drills or manual equipment. This results in good and uniform seed germination.
- Tillage helped in release of soil nutrients needed for crop growth through mineralization and oxidation process after exposure of soil organic matter to air.

- Wherever crops grow, weeds also grow and compete for growth factors such as light, space, water and nutrients. Every gram of resources used by the weed is one less gram for the crop. By tilling their fields, farmers were able to shift the advantage from weeds to the crop and allow the crop to grow without any competition early in its growth stages with resulting higher yield.
- Many soil amendments and their nutrients are more available to roots if they are incorporated into the soil. As some nitrogenous (Ammoniacal form) fertilizers are also lost to the atmosphere in high pH soils if they are not incorporated.
- Tillage gave temporary relief from compaction using implements that could shatter below-ground hard layers formed in the soil.
- Previous crop residues were incorporated along with any fertilizers and organic manures into the soil. The drawback of crop residues incorporation, especially loose residues that it creates problem for seeding equipment by raking and clogging.
- Summer tillage was determined to be a special management practice for controlling perennial weeds, soil-borne diseases and insect- pests.

There is no doubt that this list of tillage benefits was beneficial to the farmer, but at a cost to him and the environment, and the natural resource base on which farming depended. The three key principles of conservation agriculture are minimal soil disturbance, permanent residue soil cover and crop rotations. Table shows a comparison of conservation agriculture with conservation tillage (CT) and traditional tillage (TT).

Issues	TT	CT	CA
Practice	Disturb the soil and leaves a bare surface	Reduces the soil disturbance and keeps the soil covered with crop residue	Minimal soil disturbance and soil surface permanently covered with mulch
Erosion	Wind and soil erosion: maximum	Wind and soil erosion: reduced significantly	Wind and soil erosion: the least of all these
Soil physical condition	Worst	Significantly improved	The best practice among all of the these
Compaction	TT used to reduce compaction and can also induce breaking of soil aggregates	Reduced tillage is used to reduce compaction	Hard layer can be a problem, but use of loose mulch and promotion of biological tillage helps in reducing this problem
Soil biological health	the lowest of the three owing to frequent disturbance	moderately better soil biological health	more diverse and healthy biological properties and populations
water infiltration	lowest after soil pores clogged	good water infiltration	best water infiltration

3.2.1 Permanent or Semi-Permanent Organic Soil Cover:

The force of raindrops falling on a bare soil surface result in destruction of soil aggregates, clogging of soil pores and rapid reduction in infiltration rate which results in increases run-off and soil erosion. Organic mulch intercepts the energy of raindrops and protects the surface soil from soil aggregate destruction, enhances the infiltration of water and reduces the loss of soil. Crop residues result when a previous crop is left anchored or loose after harvest or when a cover crop is grown and killed or harvested to provide mulch. The crop residues of cultivated crops are a considerable factor for crop production through their effects on soil physical, chemical and biological properties as well as water and soil quality. Surface mulch helps in reducing evaporation losses from the soil by evaporation and also helps in maintaining soil temperature. Organic mulch promotes activities of soil microbes and enhances nitrogen mineralization, especially in the surface layers. Mulching is an important factor in tropical and sub-tropical environments but has been shown to be a hindrance in temperate climates due to delays in soil warming in the spring and delayed germination.

A cover crop helps in reducing weed infestation through competition and not allowing weed seeds for the light often needed for their germination. The allelopathic properties of cereal residues in respect to inhibiting surface weed seed germination. Weeds will be managed when the cover crop is cut, killed and incorporated into the soil. Cover crops also contribute to the accumulation of organic matter in the upper soil horizon.

3.2.2 Minimal Soil Disturbance/Zero Tillage:

Permanent soil cover and minimal soil disturbance these two practices in combination are helpful for obtaining the best results. Zero-tillage reduces the cost of cultivation and emissions of gases. Tillage practices take valuable time that can be used for other useful farming activities. Zero-tillage takes less time as compared to conventional tillage for establishing a crop. The time required for tillage delays timely planting of crops, with subsequent reductions in yield potential. By reducing turnaround time to a minimum, zero-tillage can get crops planted on time, and thus increase yields without greater input cost. Conventional tillage practices result in the decline of soil organic matter due to increased oxidation over time, leads to soil degradation, loss of soil biological fertility and resilience.

No-tillage practice reduces soil organic matter losses and is a gifted strategy to maintain or even boost soil carbon and nitrogen stocks. The use of zero-tillage practice along with a permanent residue cover, even when bulk density was higher, resulted in higher infiltration rate. An economic consideration is that tillage results in more wear and tear on machinery and higher maintenance costs for tractors than zero-tillage systems.

3.2.3 Rotations:

Crop rotation is one of the agricultural management practices to control plant diseases. The rotation of various nature crops with different rooting patterns combined with minimal soil disturbance in no-till systems encourages a more extensive network of root channels and macropores in the soil. This combination helps in enhancing infiltration from upper layer to

root zone of the soils. Because crop rotation increases microbial diversity, the risk of pests and disease outbreaks from pathogenic organisms is reduced, since the biological diversity helps keep pathogenic organisms in control.

3.3 Equipment for Conservation Agriculture:

Zero-till and conservation agriculture are bound to fail if equipments are not available to drill seed into residues covered soil at the proper depth for good germination. The main requirements of equipment in a conservation agriculture system are to handle loose straw, seed and fertilizer placement, furrow closing and seed/soil compaction. The straw wheels attached to the coulter to support move residues aside and reduce clogging. It also has the merit that it can be used in breaking of soil clods.

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