Role of Conservation Agriculture in Sustainable Agriculture and Its Impact on Soil Property

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Conservation Agriculture (CA) is a farming system that can prevent losses of arable land while regenerating degraded lands. It promotes maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production. CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production. Complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.

Three principles of Conservation Agriculture

Minimum mechanical soil disturbance

Direct seeding involves growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in CA systems as synonymous with no-till farming, zero tillage, no-tillage, direct drilling, etc. Planting refers to the precise placing of large seeds (maize and beans for example); whereas seeding usually refers to a continuous flow of seed as in the case of small cereals (wheat and barley for example). The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are to be kept at the absolute minimum possible. Ideally the seed slot is completely covered by mulch again after seeding and no loose soil should be visible on the surface.

Permanent soil organic cover

Keeping the soil covered is a fundamental principle of CA. Crop residues are left on the soil surface, but cover crops may be needed if the gap is too long between harvesting one crop and establishing the next. Cover crops improve the stability of the CA system, not only on the improvement of soil properties but also for their capacity to promote an increased biodiversity in the agro-ecosystem. While commercial crops have a market value, cover crops are mainly grown for their effect on soil fertility or as livestock fodder. In regions where smaller amounts of biomass are produced, such as semi-arid regions or areas of eroded and degraded soils, cover crops are beneficial as they:

- Protect the soil during fallow periods.
- Mobilize and recycle nutrients.
- Improve the soil structure and break compacted layers and hard pans.
- Permit a rotation in a monoculture.
- Can be used to control weeds and pests.

Species diversification

The rotation of crops is not only necessary to offer a diverse "diet" to the soil microorganisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have been leached to deeper layers and that are no longer available for the commercial crop, can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients.

Table 1: Comparison between conventional and traditional agriculture

Issues	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 a 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 causes its loss	Soil organic build up in the surface layers even better than traditional agriculture
Soil temperature	Surface soil temperature more variable	Moderated variable
Fuel use and cost	High	Low
Production costs	High	Low
Yield	Can be lower where planting delayed	Yields same as TA but can be highest if planting is done timelier

CA include practices or technologies such as

Direct sowing: Direct sowing consists of promoting the growth of a new crop without the preparation of mechanical seedbed and minimal soil disturbance since the harvest of the previous crop.

No-tillage: is the process where the crop seed will be sown through drillers without prior land preparation and disturbing the soil where previous crop stubbles are present.

Reduced tillage: It involves considerable soil disturbance, though to a much lesser extent than that associated with conventional tillage.

Surface incorporation of crop residues: Crop residues can improve soil structure, increase organic matter content in the soil, reduce evaporation, and help fix CO2 in the soil.

Types of conservation tillage

Ridge Tillage

Ridge tillage is a form of conservation tillage that uses specialized planters and cultivators to maintain permanent ridges on which row crops are grown.

Minimum tillage

Aims at reducing tillage operations to the minimum necessity for a reasonably good seed bed to establish adequate crop stand and favorable Soil conditions for growth and development of crops.

Zero/No tillage: As the name implies, do not use tillage for establishing a seedbed.

Impact of Conservation Agriculture Practices

Reduction in Cost of Production

This is a key factor contributing to rapid adoption of zero-till technology. Cost reduction is attributed to savings on account of diesel, labour and input costs, particularly herbicides.

Reduced Incidence of Weeds

By supressing weed germination through incorporation of residue.

Saving in Water and Nutrients

Experimental results and farmers experience indicate that considerable saving in water (up to 20% – 30%) and nutrients are achieved with zero-till planting and particularly in laser leveled and bed planted crops. Higher soil water content under no-till than under conventional tillage indicated the reduced water evaporation during the preceding period.

Increased Yields and Productivity

CA enhance the yield level of crops due to associated effects like prevention of soil degradation, improved soil fertility, improved soil moisture regime (due to increased rain water infiltration, water holding capacity and reduced evaporation loss) and crop rotational benefits.

Environmental Benefits

Conservation agriculture involving zero-till and surface managed crop residue systems are an excellent opportunity to eliminate burning of crop residue which contribute to large amounts of greenhouse gases like CO_2, CH_4 and N_2O. Burning of crop residues, also contribute to considerable loss of plant nutrients, which could be recycled when properly managed. Large scale burning of crop residues is also a serious health hazard.

Conclusion

All conservation tillage practices significantly improved soil physical properties mainly aggregate stability, bulk density, porosity, and maximum water holding capacity as compared to conventional tillage practices. No-tillage with BBF and FB with crop residues retained on the surface significantly increased nutrient status in the soil and higher productivity as compared to conventional tillage with no crop residues in soybean-wheat and maize-chickpea cropping systems.

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