Role of cover crops and crop residues in conservation agriculture: A review

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Abstract

The growth of conventional agriculture remained linear for a longer duration and was based on maximizing the output/productivity, which has become unsustainable as it was based on depletion of natural resources and massive addition of external inputs. Presently, India is facing various challenges in agriculture sector like stagnating net sown area, reduction in per capita land availability, climate change effect and deterioration of land quality. Out of the various causes of agricultural land degradation, it is low soil carbon content which has disrupted many important soil-mediated processes. The principal indicators of non-sustainability in agriculture systems has forced us to shift towards farming practices aimed at eliminating unsustainable practices of conventional agriculture which are of immense value for future productivity gains. Conservation agriculture is the way forward and it is the resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with three interrelated principles, along with other good production practices of plant nutrition and pest management. Maintenance of permanent soil organic cover with crop residues and/or cover crops provides a protective layer of vegetation on the soil surface which suppresses weeds, protects the soil from the impact of extreme weather patterns, helps to preserve soil moisture, reduces soil compaction, improves soil biological activity, alter the soil microclimate for optimal growth and development of soil organisms. Many of the advantages of conservation agriculture currently in use can be derived from the cover crop or crop residues and can be applied successfully for gaining crop productivity.

Keywords: conservation agriculture, cover crops, crop residues, land degradation

Introduction

Agriculture is the most important sector in India accounting for 13.7% of the country’s GDP and employs more than 60% of labour force. Intensification of agriculture with introduction of high yield varieties, judicious fertilizer application and efficient pest control during and after green revolution, have made country self-sufficient in food grain production but the productivity levels are still low and stagnating. The prime indicators of non sustainability in agricultural system includes soil erosion and soil organic matter decline which are caused mainly by: (1) intensive tillage practices leading to organic matter decline, soil structural degradation, water and wind erosion, reduced infiltration rates, surface sealing and crusting and soil compaction, (2) insufficient incorporation of organic material, and (3) monocropping. Shift in agricultural practices aimed at eliminating unsustainable parts of conventional agriculture is crucial for future productivity gains while sustaining the natural resources. This has forced us to think about some alternative agricultural practices and - Conservation agriculture is one such alternative. Conservation Agriculture is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance (i.e. no tillage), and diversification of plant species. It is a way forward in maintaining a permanent soil cover thereby improving organic matter content in surface horizons with crop residue management and cover crops. CA emphasis on very beneficial impact and deterioration of land quality. Out of the various causes of agricultural land degradation, it is low soil carbon content which has disrupted many important soil-mediated processes. The principal indicators of non-sustainability in agriculture systems has forced us to shift towards farming practices aimed at eliminating unsustainable practices of conventional agriculture which are of immense value for future productivity gains. Conservation agriculture is the way forward and it is the resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with three interrelated principles, along with other good production practices of plant nutrition and pest management. Maintenance of permanent soil organic cover with crop residues and/or cover crops provides a protective layer of vegetation on the soil surface which suppresses weeds, protects the soil from the impact of extreme weather patterns, helps to preserve soil moisture, reduces soil compaction, improves soil biological activity, alter the soil microclimate for optimal growth and development of soil organisms. Many of the advantages of conservation agriculture currently in use can be derived from the cover crop or crop residues and can be applied successfully for gaining crop productivity.

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- Surface retention of residues (permanently covered)
- Infiltration rate of water is high
- Weeds are a problem in the early stages of adoption but decrease with time
- Controlled traffic and no compaction in crop area
- Diversified and more efficient rotations
- Mechanized operations, ensure timeliness of operation
- More resilience to stresses, yield losses are less under stress conditions
- Productivity gains in long-run are in incremental order

**Status of Conservation Agriculture**

Globally, conservation agriculture is being practiced on about 125 M ha. However, USA, Brazil, Argentina, Canada and Australia occupy about 90% of the area under conservation agriculture in the world. The conservation agriculture-as an alternative to the conventional agriculture, has been adopted by the Food and Agriculture Organization (FAO) of the United Nations as a lead model for improving productivity and sustainability. Presently, resource conserving technologies that include laser assisted precision land levelling, zero/reduced tillage, direct drilling of seeds, direct seeding of rice, unpuddled mechanical transplantation of rice, raised bed planting and crop diversification are being practised over 3 Mha in South Asia. However, in India, CA adoption is still in the initial phases and as per the estimates conventional agriculture has expanded to cover about 1.5 million hectares (Saharawat et al., 2012) [11].

**Principles of Conservation Agriculture**

Conservation agriculture basically relies on following 3 principles

1. Minimum mechanical soil disturbance (i.e. no tillage) through direct seed and/or fertilizer placement. This reduces soil erosion and preserves soil organic matter. The soil biological activity produces very stable soil aggregates as well as various sizes of pores, allowing air and water infiltration. This process can be called “biological tillage”.

2. Permanent soil organic cover (at least 30 percent) with crop residues and/or cover crops. Maintaining a protective layer of vegetation on the soil surface suppresses weeds, protects the soil from the impact of extreme weather patterns, helps to preserve soil moisture, and avoids compaction of the soil. A permanent soil cover is important to protect the soil against the deleterious effects of exposure to rain and sun; to provide the micro and macro organisms in the soil with a constant supply of “food”; and alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. In turn it improves soil aggregation, soil biological activity and soil biodiversity and carbon sequestration (Ghosh et al., 2010) [9].

3. Rotation of crops is not only necessary to offer a diverse “diet” to the soil microorganisms, 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 helps in minimal rates of build-up of population of pest species, through life cycle disruption, biological nitrogen fixation, control of off-site pollution and enhancing biodiversity (Kassam and Friedrich, 2009) [6].

**Cover Crops**

Agricultural farms and mostly in small holdings, biomass plays an important role as it improves nutrient recycling and controls the microbial population that maintain favorable soil properties. The strategies being presently used to decrease soil degradation are input based with high production costs but the use of cover crops is a technological strategy that is efficient and economically viable with the objective to increase and conserve soil organic matter. Cover crops are plants that are grown in order to provide soil cover and to improve the physical, chemical, and biological characteristics of soil. They can be grown independently or in association with crops. The principal conservation characteristics of cover crops that should be considered for the selection as advocated by Monegat, 1991 [8] are:

- Rapid growth and good soil cover under prevailing soil and climatic conditions
- Production of a great quantity of green and dry mass, of the above-arts and roots
- Slow decomposition of dry matter produced

**Objectives of cover crops**

- Provide soil cover which reduce evaporation, soil temperature and increases infiltration
- Protect soil from erosion
- Reduce weed infestation
- Addition of biomass to soil
- Improve soil structure
- Promote biological soil properties
- Reduce pest and disease infestation

**Role of Cover Crops in Conservation Agriculture**

**Maintenance and/or accumulation of organic matter**

Cover crops with a potential for biomass production is the practical and economic means to maintain or increase soil organic matter. Soil organic matter enhances the formation of aggregates, which stabilizes soil and reduces runoff and erosion (Sainju et al., 1997) [12] Roberson et al., (1991) [10] found that cover cropping increased the heavy fraction of soil carbohydrates and increased aggregate stability. The heavy fraction carbohydrates are enriched in extracellular polysaccharides produced by soil microorganisms. These extracellular polysaccharides can be described as “glue” that binds individual soil particles together in aggregates.

**Soil moisture conservation**

Cover crop residues helps to conserve soil moisture through reduced evaporation rates from the soil surface and by increasing water infiltration (Smith et al., 1987) [15]. The best strategy for managing cover crops during dry years is to kill the cover crops approximately two weeks before planting and during the wet years, the cover crop can be killed immediately before soil preparation (if any) and planting.

**Biological nitrogen fixation and nutrient recycling**

Cover crops which may be leguminous/ non-leguminous especially deep-rooted has the potential to recycle nitrogen and other nutrients moved into deeper soil layers and are not available to crops. The quantity and type of nutrients recycled by cover crops depends on species, total production of dry biomass as well as the concentration of nutrients. They can be effective in recovering mineral N from soil after crops are harvested and also plant available N lost due to leaching or runoff. Cover crop biomass and N accumulation depend on
the length of the growing season, local climate and soil conditions. Leaf fall during legume development can contain up to 35 lbs N per acre (Bergersen et al., 1989) [2]. As per the studies carried, N that is contained in the above ground biomass is approximately 75% for cereal rye, 90% for hairy vetch, and 80% for crimson clover (Shipley et al., 1992) [14].

**Weed control**

Cover crops can reduce weed population through reduction in competition for water, light and nutrients which represent an additional economic advantage by saving the labor for weed control. The left over crop residues on the soil surface can physically modify conditions for seed germination by improving the seed environment in terms of light availability, soil temperature and soil moisture and also cover crops has allelopathic effect. After cover crop dessication, it is important to prevent soil disturbance to maintain maximum soil cover from cover crop residues (Burgos and Talbert, 1996) [3].

**Improved crop productivity and reduced production costs**

Cover crops in most of the cases increases the production of the associated crops or subsequent crops. Also, minimum or no-tillage becomes viable as the soil preparation is avoided and crop management practices are reduced due to use of lessfertilizers and other inputs which reduces production costs.

**Role of Crop Residues in Conservation Agriculture**

Food production of nearly 286 million tonnes in 2018-2019 resulted in production of crop residues which can be on-farm or off-farm. Recent estimates have pegged the crop residues to be 500-550 million tonnes. Inspite of usage in different ways like animal feeding, soil mulching, bio-manure making, thatching for rural homes and fuel for domestic and industrial use, a large part of the residues still is burnt on-farm so as to clear the field for sowing of the succeeding crop. Several initiatives from the national government could not reduce this trend due to shortage of human labour, high cost involved in removing the crop residues and mechanized harvesting of crops. The burning of residues particularly rice and wheat is quite prevalent in different states of the country and is more severe in the irrigated agriculture. In such situation, conservation agriculture (CA) can act as better alternative to manage the residues in a productive and profitable manner. The adoption of technologies based on conservation agriculture can be used for improving soil health, increasing crop productivity, reducing pollution and enhancing sustainability and resilience of agriculture.

**Crop residue management**

Maintaining permanent crop cover with recycling of crop residues is a pre-requisite and integral part of conservation agriculture but sowing of a crop in the presence of residues of preceding crop is a problem.Conservation agriculture, with the three core inter-linked principles, can be put into practice for most of the rainfed and irrigated production systems, to strengthen ecological sustainability and to manage residues to which can be of immense help to improve soil organic C, enhance input efficiency and have the potential to reduce GHGs emissions (Kassam,2011 and Pathak et al. 2011) [7, 9]

**Impact of crop residues on soil health**

Incorporation of crop residues into soil or retention on the surface has several positive influences on physical, chemical and biological properties of soil. Addition of crop residues can increase hydraulic conductivity, reduce bulk density of soil, mulching of crop residues can raise the minimum soil temperature in winter and decreases soil temperature during summer, reduces runoff, reduces surface crust formation and enhances infiltration. Also, they act as a storage house for plant nutrients, decreases nutrient leaching, increase cation exchange capacity, provide suitable conditions for biological N₂ fixation, increase microbial biomass and enzymes such as dehydrogenase and alkaline phosphatase. The crop residues play an important role in GHGs mitigation through reduction in overall nitrogen loss by reducing ammonium-nitrogen loss and organic-nitrogen loss.

**Impact of crop residues on yield**

Addition of residues can increase yield but it varies with soil characteristics, climate, cropping patterns and level of management skills. Higher yields with crop residues is due to improvement in soil properties, improved soil structure, increased soil organic matter and increased microbial activity.

**Impact of crop residues on pests**

Incorporation of crop residues in conservation agriculture also influence directly and indirectly pest management. Retention of crop residues can lower soil temperature and increased soil moisture which can reduce pest infestation. Crop residues generally increase diversity of pests and ensure survival of a number of insects, both harmful and beneficial. The decomposition of crop residues under varied factors like climate, crop geometry, irrigation, fertilization, cultural practices and pesticides may alter the life cycle of insects by producing a chemical change in soil and production of phytotoxicity which may affect the host reaction to pests. The changes in weed pattern sometimes influence the survival of the insects which tend to develop on weeds, particularly during the fallow period. Since the zero/reduced tillage system reduces the fallow period among crops, it may result in altered incidence of certain insects. Organic mulching sometimes has reported to increase the damage by cut worms and surface retention of crop residues has increased population of snails and slugs causing damage to crops Population of termite and white grubs generally increases under the reduced tillage. However, the effect of crop residues on termite damage is contentious. Under sufficient crop residues, white grubs do not damage the crop even at a very high density. However, at some of the sites, organic mulching has been reported to increase damage of cutworms due to moisture conservation. Also crop residues on the soil surface that conserves the moisture, may favour snails and slugs, causing damage to crops. Increased pest and weed problems during the ‘transition period’ are major hurdles in adoption of conservation agriculture by farmers. Non-judicious application of pesticides under such situations may disrupt the ecosystem and cause pest outbreaks. Therefore, integrated pest management (IPM) should be adopted as a necessary component of a conservation agriculture system.

**Constraints of using crop residues**

- Problem in sowing and application, timing and placement of fertilizer and pesticides as it requires more attention
- Weed control is the other bottle-neck and excessive use of chemical herbicides may not be a desirable option for a healthy environment.
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- Nutrient management may become complex like application of fertilizers, particularly N as basal dose at the time of seeding may decrease its efficiency. Increased application of specific nutrients may be necessary and specialized equipments are required for proper fertilizer placement, which contributes to higher costs.
- Additional management skills with perception that lower crop yields or economic returns, negative attitudes or perceptions, and institutional constraints.

Conclusion
The high production levels have to be sustained for ensuring the country’s food security both in short and long-term and for this the soil resource base needs to be maintained. Conservation agriculture needs to be practiced and suitable alternatives like cover crops and crop residues should be involved in agricultural systems.

References