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A review paper on concept, benefits and constraints of conservation agriculture in India

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Abstract
Nowadays, in a context of climate change, economical uncertainties and social pressure to mitigate agriculture externalities, farmers have to adopt new cropping systems to achieve a sustainable and cost-effective grain production. Conservation agriculture (CA) consists of a range of cropping systems based on a combination of three main principles: (1) minimum soil disturbance, (2) permanent soil cover through crop residues or cover crops, and (3) crop rotations for achieving higher productivity. CA has been promoted as a way to reduce production costs, soil erosion and soil fertility degradation under both tropical and temperate conditions. In India, efforts to develop, refine and disseminate conservation-based agricultural technologies have been underway for nearly two decades and made significant progress since then even though there are several constraints that affect adoption of CA. Particularly, tremendous efforts have been made on no-till in wheat under a rice-wheat rotation in the Indo-Gangetic plains. The technologies of CA provide opportunities to reduce the cost of production, save water and nutrients, increase yields, increase crop diversification, improve efficient use of resources, and benefit the environment. However, there are still constraints for promotion of CA technologies, such as lack of appropriate seeders especially for small and medium scale farmers, competition of crop residues between CA use and livestock feeding, burning of crop residues, availability of skilled and scientific manpower and overcoming the bias or mindset about tillage. The need to develop the policy frame and strategies is urgent to promote CA in the region. This paper reviews the emerging concerns due to continuous adoption of conventional agriculture systems, Benefits of conservation agriculture and analyses the constraints of conservation agriculture in India.

Keywords: Conservation agriculture, conventional agriculture, constraints, crop residues, no-till

Introduction
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 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.
Attaining food security for a growing population and reducing poverty while sustaining agricultural systems under the current scenario of depleting natural resources, negative impacts of climatic variability, increasing cost of inputs and volatile food prices are the major challenges before most of the Asian countries. In addition to these challenges, the principal indicators of non-sustainability of agricultural systems includes: soil erosion and soil organic matter decline. These are caused mainly by: (1) intensive tillage induced soil organic matter decline, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, (2) insufficient return of organic material, and (3) monocropping.
Therefore, an ideal shift in farming practices through eliminating unsustainable parts of conventional agriculture (ploughing/tilling the soil, removing all organic material, monoculture) is crucial for future productivity gains while sustaining the natural resources. CA is a 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 (Abrol and Sangar, 2006) [1].

Table 1: Some distinguishing features of conventional and conservation agriculture systems

Conventional agriculture	Conservation agriculture
Cultivating land, using science and technology to dominate nature	Least interference with natural processes
Excessive mechanical tillage and soil erosion	No-till or drastically reduced tillage (biological tillage)
High wind and soil erosion	Low wind and soil erosion
Residue burning or removal (bare surface)	Surface retention of residues (permanently covered)
Water infiltration is low	Infiltration rate of water is high
Kills established weeds but also stimulates more weed seeds to germinate	Weeds are a problem in the early stages of adoption but decrease with time
Free-wheeling of farm machinery, increased soil compaction	Controlled traffic, compaction in tramline, no compaction in crop area
Mono cropping/culture, less efficient rotations	Diversified and more efficient rotations
Heavy reliance on manual labor, uncertainty of operations	Mechanized operations, ensure timeliness of operations
Poor adaptation to stresses, yield losses greater under stress conditions	More resilience to stresses, yield losses are less under stress conditions
Productivity gains in long-run are in declining order	Productivity gains in long-run are in incremental order

Source: Sharma *et al*., 2012 [25].

Traditional agriculture, based on tillage and being highly mechanized, has been accused of being responsible for soil erosion problems, surface and underground water pollution, and more water consumption (Wolff and Stein, 1998) [30]. Moreover, it is implicated in land resource degradation, wildlife and biodiversity reduction, low energy efficiency and contribution to global warming problems (Boatmann *et al*., 1999) [3]. Hence, conservation agriculture (CA) is a way to offer a permanent soil cover and a natural increase of organic matter content in surface horizons with crop residue management and cover crops. CA stresses the very beneficial impacts of a conservative way of cultivation on the global environment (soil, air, water and biodiversity), compared to traditional agriculture (Derpsch *et al*., 2010; Derpsch *et al*., 2011) [5, 6].

CA promotes most soils to have a richer bioactivity and biodiversity, a better structure and cohesion, and a very high natural physical protection against weather (raindrops, wind, dry or wet periods). Soil erosion is therefore highly reduced, soil agronomic inputs transport slightly reduced, while pesticide bio-degradation is enhanced. It protects surface and ground water resources from pollution and also mitigates negative climate effects. Hence, CA provides excellent soil fertility and also saves money, time and fossil-fuel. It is an efficient alternative to traditional agriculture, attenuating its drawbacks.

The conservation agriculture practices promises tremendous potential for different soils and agro-ecological systems. These are neutral to size of holdings but their adoption is most urgently required by smallholder farmers to reduce their cost of production, increase profit, and save resources (Derpsch, 2008) [4]. Often conservation agriculture is considered to be organic farming. There is little difference between these two concepts. Though both are based on natural processes to improve soil health, organic farming prohibits application of chemical inputs while conservation agriculture does not.

Conservation agriculture (CA) is being promoted as a solution to increase agricultural productivity and food security while at the same time preventing erosion and maximizing the ecological functions of the soil (Hobbs, 2007) [14]. CA is a package of technologies that includes minimum tillage, mulching and crop rotation (IIRR & ACT, 2005) [15]. CA has potential to reduce labour needs for land preparation and improve soil fertility while also reducing water stress in crops (IIRR & ACT, 2005) [15].

Status of conservation agriculture in India

Globally, CA is being practiced on about 125 M ha. The major CA practicing countries are USA, Brazil, Argentina, Canada and Australia. In India, CA adoption is still in the initial phases. Over the past few years, adoption of zero tillage and CA has expanded to cover about 1.5 million hectares (Jat *et al*., 2012) [18]. The major CA based technologies being adopted is zero-till (ZT) wheat in the rice-wheat (RW) system of the Indo-Gangetic plains (IGP).

In India, efforts to develop and spread conservation agriculture have been made through the combined efforts of several State Agricultural Universities, ICAR institutes and the Rice-Wheat Consortium for the Indo-Gangetic Plains. Spread of these technologies is taking place in the irrigated regions of the Indo-Gangetic plains where the rice-wheat cropping system dominates. The focus of developing and promoting conservation technologies has been on zero-till seed-cum fertilizer drill for sowing of wheat in rice-wheat system. Other interventions include raised-bed planting systems, laser equipment aided land leveling, residue management practices, alternatives to the rice-wheat system etc. It has been reported that the area planted with wheat adopting the zero-till drill has been increasing rapidly (Sangar *et al*., 2005) [23], and presently 25 – 30% of wheat is zero-tilled in rice-wheat growing areas of the Indo-Gangetic plains of India. In addition, raised-bed planting and laser land leveling are also being increasingly adopted by the farmers of the north-western region.

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) [11].

3. 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 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; Dumanski *et al.*, 2006) [19, 11].

Benefits of conservation agriculture

To be widely adopted, all new technology needs to have benefits and advantages that attract a broad group of farmers who understand the differences between what they are doing and what they need. The benefits can be classified into three broad categories:

1. agronomic benefits that improve soil productivity;
2. economic benefits that improve the production efficiency and profitability; and
3. environmental and social benefits that protect the soil and make agriculture more sustainable.

Some of the benefits of conservation agriculture are listed below:

1. CA improves soil organic carbon content and contribute in reducing global warming. Conservation agriculture is now receiving global focus for its carbon sequestration potential. It has been estimated that the total potential for soil carbon sequestration by agriculture could reduce about 40 per cent of the estimated annual increase in CO2 emissions (FAO, 2009) [9].
2. Improves water infiltration and thereby reduces run-off of surface and ground water and enhance ground water recharge.
3. Improves habitation of organisms, from larger insects down to soil borne fungi and bacteria, which improve soil biological, physical and chemical properties, thereby contribute in increasing crop productivity. enhancement of soil quality, i.e. soil physical, chemical and biological conditions (Jat *et al*., 2009a; Gathala *et al*., 2011) [16, 10].
4. Reduce cost of production (15-16 %) by saving energy, labor and water, thereby increase farm income.
5. Enhancement of water and nutrient use efficiency (Jat *et al*., 2012; Saharawat *et al*., 2012) [18, 22].
6. Reduction in poverty and enhance food and nutritional security due to higher, more stable yields and lower food prices.
7. Improvement of resource use efficiency through residue decomposition, soil structural improvement, increased recycling and availability of plant nutrients (Jat *et al*., 2009a) [16].
8. Time saving and thus reduction in labour requirement.
9. Higher efficiency in the sense of more output for a lower input.
10. Reduction of the incidence of weeds, such as Phalaris minor in wheat (Malik *et al*., 2005) [20].

Use surface residues as mulch to control weeds, moderate soil temperature, reduce evaporation, and improve biological activity (Jat *et al*., 2009b; Gathala *et al*., 2011) [17, 10].

In India, Erenstein and Pandey (2006) [6] did some systematic studies to quantify benefits of conservation agriculture in the Indo-Gangetic plain. Some of the measured benefits are listed below:

- Yield advantage of zero tillage to rice and wheat by 10-17 per cent over conventional tillage.
- Cost reduction by about Rs. 5760 per hectare (roughly by 5 to 10 per cent); ranging from Rs. 3055 to Rs. 8500 per hectare in different soils and ecoregions.
- Water saving by 20-35 per cent, and energy saving, especially of tractor time saved by 60-90 per cent.
- Projected saving of 1 million barrel of oil if the zero-tillage practice is adopted in about 3.5 million hectare area of Indo-Gangetic plain. High internal rate of returns (57 per cent) assuming 33 per cent adoption of conservation agriculture in Indian part of Indo-Gangetic plain.

Experiences from several locations in the Indo-Gangetic plains showed that with zero tillage technology farmers were able to save on land preparation costs by about Rs. 2,500 ($41.7) per ha and reduce diesel consumption by 50 – 60 litres per ha (Sharma *et al*., 2005) [24].

Constraints for adoption of conservation agriculture

There are a number of problems encountered in adoption of conservation agriculture. The most important is the mindset of farming community who were educated extensively and convinced about the intensive agriculture and use of external inputs. Some constraints are as follow:-

Reduced tillage constraints

Without fertilizer minimum tillage may lead to nutrient immobility causing farmers to experience reduced yields (Giller *et al*., 2009) [12]. The decomposition of crop residues, which have high carbon to nitrogen ratios, can lead to short term nitrogen immobilization because of increased biological activity by organisms that lock up nitrogen in their bodies (Verhulst *et al*., 2010) [27]. Tilling allows the incorporation of the residues, which speeds up the decomposition process, which allows the nutrients to be available to plants for the next cropping season.

One of the primary motivations for tillage is weed control (Wall, 2007) [29]; reduced tillage greatly increases weed pressure (Baudron *et al*., 2007) [2].

Increased labor for weed control with CA has been recognized as a constraint that can be overcome with herbicides (Baudron *et al*., 2007) [2]. Minimum tillage without herbicides faces the challenge of controlling perennial weeds (Vogel, 1995) [28] because of the need to remove their deep roots.

Mulch Constraints

The key challenges for crop rotation are the lack of a reliable markets for many leguminous crops and the shortage of improved legume seeds (Baudron *et al*., 2007; Haggblade & Tembo, 2003) [2, 13]. One analysis of the gross margin earned by different combinations of rotating maize, cotton, and sunhemp showed that the greatest profits were earned from growing maize only (Thierfelder & Cheesman, 2011) [26] despite yield increases from rotation.

The challenge of maintaining mulch is mostly caused by conflicts with livestock (Baudron *et al*., 2007; Nyathi *et al*., 2011) [2, 21].

Mulching may also lead to an increase in crop pests, especially termites (Nyathi *et al*., 2011) [21]. Furthermore, maintaining mulch may lock up nitrogen, requiring increased fertilization in the short term (IIRR & ACT, 2005) [15].

Rotation Constraints

Farmers are also hesitant to plant legumes in the permanent planting basins because of the spacing (Baudron *et al*., 2007) [2]. The key challenges for crop rotation are the lack of a reliable markets for many leguminous crops and the shortage of improved legume seeds (Baudron *et al*., 2007; Haggblade & Tembo, 2003) [2, 13].

Conclusion

Conservation agriculture offers a new ideal approach for agricultural research and development different from the conventional one, which mainly aimed at achieving specific food grains production targets in India. A shift to CA has become a necessity in view of widespread problems of resource degradation, which accompanied the past strategies to enhance production with little concern for resource integrity. Conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource – use-efficient, competitive and sustainable. Because with huge benefits there are also many constraints in adoption of CA, so it is necessary to break the mind set of peoples regarding tillage. A complete shift from intensive tillage to zero or minimal tillage needs extensive educational programme by demonstrating the benefits accrued by conservation agriculture.

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