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Conservation agriculture for combating climate change and sustainable agriculture: A review

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Abstract
Conservation agriculture (CA) is a practice in which soil is kept nearly undisturbed by adopting the techniques like zero tillage or minimum tillage, soil mulch, crop rotation, *in-situ* crop residue management etc. CA is in practice from the last two decades in India, though there are some constraints in its adoption. In Indo-Gangetic plains, wheat- rice based cropping system is very common and generally more tillage operations are applied to the soil. But, now the concept of CA is gaining popularity and no-till or minimum tillage practices are being adopted at a significant level. The main aim of CA is to decrease the input and increase the output in terms of crop yield as well as reduction in the production cost. CA technology is also environmental friendly as it promotes the efficient and precise use of resources in a sustainable manner. There are various constraints which limit the adoption of CA technology in India like poor availability of modern implements, continuously decreasing land holding size, unavailability of finance and lack of awareness in small and marginal farmers etc. So, from the sustainability point of view, there is an urgent need to make strategies to promote CA through the development of new policies beneficial for the farmers. This article reviews the various aspects of conservation agriculture in the Indian context.

Keywords: Conservation agriculture, resource use efficiency, zero tillage, sustainability

1. Introduction
Worlds' population is anticipated to reach approximately 9.7 billion by 2050. To feed such a huge population, food production must be increased in the near future. But the present day situations are challenging for the farming community as the resources required for cultivation of crops i.e. arable land and good quality water is limited in amount. Moreover, the climate is changing at a faster speed and the frequency of extreme weather events like drought, flood and temperature have increased significantly in the past decades. Therefore, we require newer and sustainable agricultural systems to meet the requirements of people.

In the current scenario due to the increase in cost of input in agricultural systems, changing of climate, depleting of natural resources, increase in population and poverty it is very challenging for most of the Asian countries to attain the food security. Some other challenging factors viz. soil erosion, salinization and decrease in soil organic matter also leads to non-sustainability. Eliminating non-sustainable part of conventional agriculture viz. Tillage practices, ploughing, monoculture, removing organic matter from the soil is very critical for future sustainability. Therefore, to maintain the balance between demand and supply as well as to attain sustainability, Conservation agriculture is practiced. CA at present has increased to 8 percent of world's arable land.

CA is a practice in which soil disturbance is made negligible by adopting the concept of zero tillage or minimum tillage, soil mulch, rotation of crop, avoiding burning of paddy straw in the field (Pradhan *et al*., 2017) [23].

Main aim of CA is to maintain the yield and profit to attain a balance between agriculture, environment and economics. It promotes both the economic and social benefits by decreasing the costs of input and labour and at the same time it conserves the environment. By CA, farmers provide healthier environment to the larger community by reducing the use of pesticides, herbicides, fossil fuels, machinery and other soil and water pollutants to maintain the environmental integrity.

As per FAO definition, conservation agriculture is to1) attain high profit, 2) sustainable production levels, and 3) to protect the environment.

CA is better alternative of conventional agriculture practices which includes burning of crop residues, intensive agriculture and use of pesticides (Table 1). CA is mainly based on improving and conserving natural resources more efficiently. It can only be achieved when there is sustainable or integrated management of water, soil and biological resources.

Table 1: Distinguishing features of Traditional tillage (TT), Conversation tillage (CT) and Conservation agriculture (CA) (Partially adopted from Hobbs *et al*., 2007) [13]

Sr. No.	Traditional Tillage (TT)	Conservation tillage (CT)	Conservation agriculture (CA)
1.	High Soil disturbance	Lower soil disturbance compared to TT	Zero or minimal tillage and surface is covered
2.	High wind and soil erosion	Wind and soil erosion is low as compared to TT	Wind and soil erosion is negligible
3.	Biological processes are destroyed	Reduce compaction in the soil	Use of mulch and it is best of all the three practices
4.	Soil biological health poor	Moderate soil biological health	High soil biological health
5	Poor water infiltration	Water infiltration is good	Water infiltration is best of all
6.	Soil organic matter lost due to high tillage	Soil organic matter remain but lesser than CA	Soil organic matter highest
7.	Weeds are controlled but more weed seeds will germinate due to dispersal through air or machines	Reduces the weed population	In the initial phase weed population is high but due to laying down of crop residues in the field will suppress the weed population
8.	Variability in surface soil temperature	Intermediate surface soil temperature	Highest surface soil temperature
9.	Highest consumption of diesel	Consumption of diesel is moderate	Much reduced consumption of diesel as compared to all
10.	Yield is good	Same yield as TT	Same yield as TT but if planting done on time it can be higher

1.1 Status of conservation agriculture worldwide

Conservation agriculture is now practiced in 125Mha (FAO 2012) [6]. Majorly it is practiced in USA, Brazil, Argentina and Australia which is about 75.5% of the global area. In India, CA is practiced on about 1.5Mha (Jat *et al*., 2012 [17]; www.fao.org/ag/ca/6c.html). Moreover, in the Indo- Gangetic plains a latest technology is introduced in Rice-Wheat cropping system viz. zero till (ZT) as conventional agriculture is gradually changing to CA i.e. from intensive tillage to zero tillage. CA is now practiced in other cropping systems also to enhance the sustainability in agriculture. To change the RW system, new cropping pattern or systems are introduced i.e. relay cropping of sugarcane and pulses, intercropping of wheat and mustard. Combining of all resources conservation technology i.e. cropping, livestock, land and water use management will further enhance the sustainability.

CA is being promoted from last 8 to 10 years and now it is being widely adopted by the farmers of India. ICAR and State agriculture universities are being instrumental in developing and spreading of conservation agriculture. Zero- till- seed-cum fertilizer is rapidly dominating now-a-days in rice-wheat cropping system. Some other CA systems including raised bed planting system, laser leveller and residue management practices. In India there is approximately 25-30% increase in zero-till-drill in wheat crop (Sangar *et al*., 2005) [26]. Laser leveller and raised bed planting technologies are also used in North West region of India.

Some other countries where CA is being practiced now a day are Canada (13.5Mha), Russian Federation (4.5Mha), China (4.1Mha), Paraguay (2.4Mha) and Kazakhstan (1.6Mha) (FAO, 2012) [6].

2. Principle of Conservation Agriculture

CA is now practiced in most of the part of the world and its main principle is to make the land suitable for production in future (Wassmann, 2009; Behera *et al*. 2010; Lal, 2013) [33, 2, 19]. Today adoption of conservation agriculture is very necessary to enhance the crop productivity by conserving the natural resources to make the agriculture more sustainable. There are 3 main principles on which CA depends (Bhan and Behera, 2014). These are:

2.1 Minimal soil disturbance

Least or minimum soil disturbance means that we are practicing minimal or zero tillage in the field. It improves the biological and physical properties of the soil which helps in improving the soil structure. Uses of heavy mechanical tillage practices are known to reduce the organic matter content in the soil and thereby increase the chances of re-germination of weeds (Kassam and Friedrich, 2009) [18].

2.2 Soil cover

Soil mulch aims to reduce the weed population or completely eliminate the weeds by cutting off the light. Permanent soil mulch also prevents soil from the direct contact of sun and rain and sequentially improves the soil's biological activity in the soil (Ghosh *et al*., 2010) [9].

2.3 Crop rotation

Every crop has its own mechanism and response w.r.t. effect on the quantity and quality of inputs provided viz. water extraction rate, nutrient use (Huggins *et al*., 2007) [14]. Substitution of monoculture with crop rotation in the field increases the deposition of residues in the soil organic carbon content (SOC) (Huggins *et al*., 2007; Santos *et al*., 2011; Concericao *et al*., 2013) [14, 27, 3]. Legume crops contain sufficient amount of N which is responsible for increasing the soil fertility as well as biomass production of the crop (Hansen *et al*., 2012; Mbuthia *et al*., 2015; Raphael *et al*., 2016; Veloso *et al*., 2018) [12, 21, 24, 30]. Residue cover on the soil also reduces the soil erosion, pests, weeds, diseases and nutrient leaching in the field (Tittonell *et al*., 2012; Gabriel *et al*., 2013; Veloso *et al*., 2018; Williams *et al*., 2018) [29, 7, 24, 34].

Crop rotation is necessary to provide diverse nutrition to the soil microbes and it also helps in replenishment of nutrients in

the soil which has been lost by leaching. It has been reported to decrease the pest population through biological nitrogen fixation and increasing biodiversity (Dumanski *et al*., 2006) [4].

3. Benefits and Constraints of Conservation Agriculture:

There are various agronomical, economic and environmental benefits of CA which will increase the awareness and attraction amongst the farmers to implement CA practice on agricultural land. These benefits are listed below:

1. It increases the production and productivity of crop.
2. Increases the profitability of the farmers by the use of natural resources efficiently.
3. Conserves the environment and make the agriculture more suitable for future generations.
4. It increases soil organic carbon content and reduces global warming in the environment.
5. Saves energy (60-90%), time and reduces the production cost by (15-16%) thereby increases farm income.
6. Improves different physical, chemical and biological properties thereby increases crop production and productivity by improving soil quality (Jat *et al*., 2009a; Gathala *et al*., 2011) [15, 8].
7. Increases efficiency of nutrient and water availability (Jat *et al*., 2012; Saharawat *et al*., 2012) [17, 25]
8. Output is more and input is low hence profitability is higher. This is achieved by utilizing the natural resources efficiently.
9. Decreases incidence of weed population viz. *Phalaris Minor* in wheat crop (Malik *et al*., 2005) [20].
10. Use of mulching technology to reduce surface evaporation and weed population on one hand and to increase the biological activity on the other hand. (Jat *et al*., 2009b; Gathala *et al*., 2011) [16, 8].
11. By adoption of zero tillage farmers will be able to save 50-60 litres of diesel per hectare in the Indo-Gangetic plains (Sharma *et al*., 2005) [28].

3.1 Demerits of Conservation Agriculture

Mentality of the farmers who are more influenced to intensive agriculture is the major constraint of CA.

Without fertilizers and tillage there can be immobility of nutrients which will leads to reduction in yield (Giller *et al*., 2009) [10]. By the decomposition of crop residues, in the field the amount of C: N ratio will increase which may lead to N immobilization due to increase in biological activity (Verhulst *et al*., 2010) [31]. Weed pressure will also be increased by the use of minimal tillage practices (Baudron *et al*., 2007) [1]. If the weed population is high it can be controlled either by the use of herbicides or manually by hand weeding so increase the labour cost (Baudron *et al*., 2007) [1]. Roots of perennial weeds are deeper so they can only be removed by the use of herbicides (Vogel, 1995) [32].

Further, there is shortage of hybrid legume seeds in the market and also there is shortage of market for the leguminous crop (Baudron *et al*., 2007; Haggblade & Tembo, 2003) [1, 11]. Farmers are not much aware about the legume crops in the planting system because of the spacing. (Baudron *et al*., 2007) [1].

In an experiment of crop rotation of maize, sun hemp and cotton, it is analyzed that maximum profit is in the maize crop (Thierfelder & Cheesman, 2011) [35] despite yield increases from rotation. Due to mulching practice there can be infestation of termites (Nyathi *et al*., 2011) [22].

4. Conclusion

Conservation agriculture is the latest technology. Its main aim is to reduce the practices of intensive tillage to achieve sustainability in agriculture. A shift to CA has become very necessary not only to conserve the resources but also to conserve the environment. Conservation agriculture reduces the costs of input, cultivation and wise use of field resources to maintain sustainability. It is very necessary to make the farmers more aware about CA and it can be done only when there is awareness among the people and a change can be brought in the mindset of the farmers using traditional tillage through educational programmes by demonstrating them the benefits of conservation agriculture.

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