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Review Article

CONSERVATION AGRICULTURE: A NEW PARADIGM IN MODERN AGRICULTURE TO INCREASE RESOURCE USE EFFICIENCY

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Abstract: Conservation Agriculture aims at effective utilization of natural resources, reduction of production cost by saving labour, fertilizer, irrigation water, time, machinery use etc., minimization of environmental pollution by reducing the use of fossil fuel and avoiding the burning of crop residues. Basic three principles of conservation agriculture are minimum soil disturbance, permanent or semi-permanent organic covers and crop rotations. In rice-wheat sequences of Indo-Gangetic Plains (IGP), adoption of direct wet seeding of rice followed by zero tillage sowing of wheat is an effective tool for reducing wastage of natural resources, avoiding terminal heat stress and thereby maintains the sustainable yield of the system. Various resource conserving techniques like SRI, laser land levelling, FIRB (Furrow Irrigated Raised Bed system) etc have been proved useful in the climate change scenario. Tools like LCC (Leaf Colour Chart), Chlorophyll meter etc. can be adopted for precision nitrogen management in the crops. However, small farm holdings, deplorable financial and other socio political conditions are the main hindrances for adopting effective conservation agriculture in the developing countries like India.

Keywords: Minimum tillage, Zero tillage, Crop residues, Conservation agriculture

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Introduction

Conservation Agriculture (CA) is a good natural resource management and conservation tool for sustainable agriculture in the modern agriculture. CA has proven potential to improve crop yields, while improving the long-term environmental and financial sustainability of farming through minimum tillage/no tillage, crop residue recycling, rational crop rotation/diversification, conservation agriculture results in saving of energy, cost and also reduces the environmental pollution over the conventional practices. It permits management of water and soil for agriculture production without excessively disturbing the soil, while protecting it from the process that contributes to degradation like erosion, compaction, aggregate breakdown *etc*. Conservation agriculture is defined by FAO as a "resource saving agricultural crop production concept that strives to achieve high return along with sustainable production level and with less environmental pollution. Some of components of CA are- zero/reduced tillage, direct seeded rice, crop residue management, raised bed planting, crop diversification, intercropping, multi-tier cropping, laser land levelling, brown manuring, LCC based N management, geographical information system, global positioning system *etc*. What are the issues behind this CA?. India with only 2.4% of world total land is supporting 18% of world total population and projected population in India in 2050 will be 1.7 billion. So, there is increasing food demand to feed this huge amount of population in 2050. Projected food demand in 2050 will be 480 million tones but present level of production is only 210 million tones. However there are so many constraints to get such a huge amount of food by 2050 [1]. This are - declining soil productivity, plateauing yields/declining RUE (resource use efficiency), decrease in soil organic carbon, high input cost, deterioration in environment, multi-nutrient deficiencies, soil moisture stress/frequent drought/floods, mono-cropping/low diversification, low income, employment and un-sustainability. So, what are the strategies? Our main moto will be doubling food production in a sustainable manner from the same land by adopting strategies like - using locally available resources, utilization of skill and knowledge of farmers, validation and refinement of ITK (Indigenous technological knowledge), low-cost, eco-friendly and socially acceptable sustainable agro-techniques, climate resilient crop variety, enhancing RUE (Water, Nutrient, Energy *etc.*), Conservation of natural resources and effective utilization of natural resources in sustainable manner.

Main principles of Conservation Agriculture are

- Minimum soil disturbance
- Permanent or semi-permanent organic cover of the soil surface
- A diversified crops sequence or crop rotations

Minimum soil disturbance

No-till farming (also called zero tillage or direct drilling) is a way of growing crops or pasture from year to year without disturbing the soil through tillage. Intensive soil tillage is main cause of reduced soil organic matter hence soil degradation, tillage accelerates the mineralization of soil organic matter slows down resulting better soil structure. If wheat is sown in zero tillage after rice, results in save water and increased WUE and to achieve higher productivity as well as net return for the farmers. In general, soil carbon sequestration from CA during first decade of adoption is 1.8 ton CO_2/ha/year. For Each litre of diesel burned, 2.6 kg CO_2 is released to atmosphere. AICRP –Weed Management, Pantnagar, in 2014-15 conducted an experiment on rice-wheat cropping system regarding the effect of zero tillage and they reported that highest grain and straw yield is obtained as well as seed test weight obtained in zero tillage (DSR) followed by zero tillage (wheat) and zero tillage (*Sesbania* sp) cropping system as compared to other cropping system with conventional tillage. Regarding weed management best result obtained in IWM. They also reported that wheat grain yield under zero tillage was as high as 4.7 tonne per ha as compare to 4.5 tonne per ha in conventional tillage [2]. It was also estimated that for the production of 0.95 g lentil 1.0 kg rain water is required under no-till treatment. Similarly, for production of 0.22 g lentil, 1 kg water is evapo-transpired.

An experiment conducted at ICAR-CRIDA on conventional and minimum tillage practices (average of 5 years) reported that that minimum tillage gave significantly higher grain yield (1497 kg/ha) as compared to conventional tillage (1263 kg/ha) in sorghum. In another experiment of ICAR-CRIDA, where pigeon pea was sown after castor with three tillage practices – conventional, reduced tillage (RT) and Zero tillage (ZT), it was found that pigeon pea yield was increased in zero tillage to the tune of 30% and 20% over conventional and reduced tillage respectively [3]. Ghosh, *et al*., (2010) [4] conducted another experiment on performance of pea under varying degree of rice residue retention in upland condition and revealed that when 2/3 residues are retained in the field it gives more pod (3.5 t green pod/ha) than half residues retained (2.4 t/ha) and no green pod when residues are fully removed from the field. Under different tillage practices (after 4 year) showed that soil organic carbon and biological activity performs better like soil organic carbon 2.23%, soil microbial biomass carbon 128.5µg/g soil, earthworm population 1,60,000, dehydrogenase activity 131.5µg TPF/g/24h in no-till operation over conventional and minimum tillage. Yield enhancement of 11.6% and 4.4% were observed in lentil under no-till than conventional tillage and unpuddled than puddled, at upland and lowland, respectively. In an experiment on raised bed planting and planting on fresh preparatory tillage, permanent bed, flat sowing zero tillage and conventional flat sowing had shown that when sown on permanent bed save time 55.6% and 63.2% than conventional practices and fresh bed planting respectively [5].

Permanent or semi-permanent organic cover of the soil surface

Crop residues of the previous crop have several advantages in sustainable soil and crop management. It covers the soil and reduces evaporation loss, thereby provide required moisture and conducive temperature to the crop plants. It suppresses the weed growth to a significant level which is about 40% less weed population and ensures more plant population. Crop residues of paddy in wheat crop provided economic benefit by saving irrigation and weedicides and also added environmental benefit by avoiding burning of paddy straw for sowing of wheat [6]. It also protects the soil from physical impact of rain and wind and stabilizes soil temperature in the surface layers and helps retain soil moisture. In the conservation based system, retention of crop residues along with no-tillage condition increased the storage of soil water [7]. Cover crops reduces soil erosion, checks run-off loss of water and also provides favourable micro environment to the macro and micro soil organisms that help in maintaining soil fertility and productivity level. Rice bean is grown as cover crop for regeneration of fertility, reduce erosion and conserve moisture. Zero tillage (ZT) or minimum till (MT) along with various organic amendments like farm yard manure, vermicompost, poultry manure, weed mulching, straw mulching and grasses has several economic and environmental benefits. Water retention can be increased to 2-4% in semi-arid alfisol by long term application of crop residues or organic amendments which helps to cater the intermittent dry spell and terminal heat effect [8].

A diversified crops sequence or crop rotations

Crops of different types like cereals, pulse, oilseed, vegetable, fibre *etc*. can be grown in combination instead of monocrop throughout the year. In this way crops can be harvested for the long time and availability of food can be achieved throughout the year, the erosion in the upland cropping areas can be checked through afforestation with several perennial plant species along with subsistence supply of food, fodder, fuel, medicines *etc*. as the basic requirement of food and cash of the general farmers is met with intensive cultivation practices in the low land system on permanent raised bed [9]. Potato, okra, tomato, carrot, brinjal, french bean, cabbage, broccoli *etc*. to be grown on raised bed and Rice followed by lentil or pea or toria in sunken bed in soils with drainage facilities. An experiment conducted at Panipat district of Haryana revealed that growing of mustard and summer mung after non-scented rice cultivar HKR 47 or Sharbati resulted higher net returns and B:C ratio than rice - wheat cropping sequence [10]. In multi-storied cropping system utilize vertical space more effectively. Tallest component have foliage of strong light and high evaporative demand and shorter components with foliage requiring shade or relative high humidity. It increased income per unit area (harvesting different season), minimize risk of yield loss (farm products whole round the year), increased fertility, bio-diversity and maintain ecological balance. An example of multi-tier cropping is tomatoes + onions + marigolds. Another example is the tropical multi-tier system where coconut occupies the upper tier, banana the middle tier, and pineapple, ginger or a leguminous fodder, or herbs occupy the lowest tier.

Case study from the Rice–Wheat cropping system in Indo-Gangetic Plains (IGP)

Rice-Wheat is the main important cropping system in India. South East Asia covered about 13.5 million ha in rice-wheat cropping system, out of which India occupies near about 10 million ha and 90% of this is under Indo-Gangetic Plains (IGP) [11]. In traditional system, wet cultivation of rice or puddling and transplanting of seedling grown in separate seed beds. This system incurs huge amount of water. More surprisingly, this system is being followed year after year without declining the yield of rice. However, there are some research findings on long term trial on rice-wheat or other rice-rice cropping sequences using modern high yielding varieties which showed significant yield decline [12,13]. About 30% of the wheat grown area in the Indo-Gangetic Plains of India is late sown [14] terminal heat effect on wheat due to late sowing causes yield reduction of 1-1.5% per day delayed after 20th November [15].These yield losses due to delay sowing can be resolved by adopting zero tillage or direct sowing of wheat in the standing stubbles of paddy crops on the day of harvesting of the previous crop. In an experiment on rice-wheat system, it was reported that dry-direct seeding of rice and zero tillage resulted more labour savings, less machine use wheat and higher net return than the conventional system [16].

Climate change and conservation agriculture

Now days an important problem in our agriculture is excessive utilization of ground water which leads to utilisation of same amount of ground water which is consistent with the aquifer recharge. The best remedies of this problem are - water conservation, water harvesting, scientific irrigation management, efficient use of surface & groundwater along with safe utilization of saline or brakish water. The main objective of on farm water management project is to provide farmers with improved, reliable and equitable distribution of irrigation water to increase agricultural productivity. The efficiency of irrigation water can be increased by its judicious application, increasing conveyance efficiency of irrigation channels, proper scheduling of irrigation water *etc*. SRI (System of Rice intensification) – a water saving method of rice cultivation is quite relevant for the paddy grown countries now a days. In SRI techniques yield increase in paddy can be increased up to 25 – 30% over conventional system with significant reduction in cost of production as it is a input saving and water saving technique. SRI can save irrigation water to the tune of 40-50%. Conservation agriculture is quite fit for adapting climate change as it conserves more soil moisture, increases availability of moisture to the root zone and reduces losses of soil water through evaporation or run-off. It also reduces emission of pollutant gases to the atmosphere by lowering the fossil fuel use by 50-70%, fertilizer or chemical pesticide use by 20-50%, machinery use by 50% and enhances carbon sequestration 0.20-0.70 t/ha/year or more as per the crop ecology and residue recycling pattern [17]. For surface irrigated areas it is essential to have a properly leveled surface, traditional farmers method for leveling by eye-sight are not sufficiently accurate (particularly on larger plots), resulting in extended irrigation times, unnecessary water consumption and inefficient water use and thus why precision land leveling is very important. The process of land leveling involves shifting of soil from high points to low points. Precision land leveling is the process of smoothening the land surface within ±2 cm from its average elevation through the use of laser assisted land levelers. Precision land leveling is one of the few mechanical inputs in intensively cultivated irrigated farming that meets the twin objectives of achieving a better crop stand, save irrigation water and improves the input use efficiencies. In an experiment in western U.P, it was found that rice and wheat yields were affected significantly by traditional and precision land leveling. Rice and wheat grown under precision land levelling gave a minimum yields of 3.90 and 4.60 t/ha but in traditional levelling they were 3.50 and 4.20 t/ha respectively and in other experiment, the highest yield obtained under laser land leveling were 5.70 and

6.21 t/ha for rice and wheat respectively whereas under traditional land leveling they were 5.44 and 6.12 t/ha when number of farmers in both cases are same i.e 71 [18]. For precision nitrogen management, use of management tools like LCC (Leaf Colour Chart), Chlorophyll meter *etc*. can be adopted. These tools measure leaf colour intensity which is related to leaf N status and helps farmers determine the right time and amount of N application. Chlorophyll meter determines the leaf greenness which is based on N concentrations which in turn is correlated with crop yield. It displays a 3-digit SPAD value proportional to the amount of chlorophyll present in the leaf by measuring the transmittance of the leaf in two wavelengths (600-700 nm and 400-500 nm).

Furrow Irrigated Raised Bed System (FIRBS)

Crops are sown on ridges or beds in Furrow Irrigated Raised Bed (FIRB) planting system. It has several advantages and some of the advantages are saving of water up to 50%, reduction in drudgery, facilitates mechanical weeding by tractor, offers opportunity for last irrigation at grain filling stage, avoids temporary water logging problems, allows subsurface basal and top dressing of fertilizer, reduces N losses & promotes rain-water conservation. The beds height is maintained at 12 to 15 cm and width about 37 to 107 cm depending on the crops. Naresh, *et al*., (2012) [19] conducted an experiment on FIRB and reported that raised bed planting of crops is advantageous in the areas of low ground water levels and it facilitated crop diversification by intercropping with several vegetables like okra, cabbage, onion, radish, cauliflower *etc*. in the rice-wheat cropping system in the Indo-Gangetic Plains of India and thereby in enhanced the productivity and saved irrigation water. There are many research findings also on savings of irrigation water by growing high value vegetables crops on beds instead of growing in conventional tilled conditions. A savings of irrigation water to the tune of 18% to 30-50% has been reported by Hossain, *et al*. [20], Naresh, *et al*. (2010) [21] and Singh, *et al*. [22]. Furrow beds in the FIRB system of crop raising helped in mechanical weed control and enhanced fertilizer placement [23]. Permanent beds in the FIRB system gave the opportunity for diversification of the crops sensitive to water logging condition and not suited to conventional flat layouts and thereby increased market opportunities [24].

Constraints in adoption of CA

1) Small farm holdings: Most of the Indian farmers are marginal and small in nature that is their land as well as other resources are scarce.
2) Rapid urbanization: Immense pace in industrialization is leading to adoption of lands of farmers which leads to declining in the availability of cultivable land.
3) Farmers are reluctant.
4) Communication gap: Lack of dissemination of communication from lab to land.
5)Socio-economic problems: Poor economic condition of the small and marginal farmers also demoralizes them for adopting conservation agriculture.

Conclusion

Conservation agriculture Technologies should form an important component of the regional strategy for food security, rural development, enhanced profitability, improved environmental quality and sustainability of natural resources. Conservation technologies like zero and reduced tillage systems, help in better management of crop residues and planting systems, which enhance conservation of water and nutrients.

Application of review: Adoption of conservation agriculture leads to sustainable improvements in crop productivity, soil health, nutrients and water use efficiency. Conservation technologies reduce cost of cultivation by considerable saving in labour, diesel, time, fertilizers, pesticides and farm power and also reduce environmental pollution.

Review Category: Agronomy

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