Class- B. Sc. (Ag.) VI-Semester

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"Conservation Agriculture: Strategies and Prospects in India"

Attaining food security for a growing population and alleviating poverty while sustaining agricultural systems under the current scenario of depleting natural resources, negative impacts of climatic variability, rapid increase in 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: continuous depleting productivity and ground water table, soil fertility, degradation in soil properties, rapid loss in biodiversity, environmental pollution, soil organic matter decline, salinization and instability in agricultural income. These are caused mainly by: (i) intensive tillage induced soil organic matter decline, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, (ii) insufficient incorporation of organic material, and (iii) monocropping or faulty crop rotations.. Therefore, a paradigm 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. Conservation agriculture (CA), a concept evolved as a response to concerns of sustainability of agriculture globally, has steadily increased worldwide to cover about 8% of the world cultivable land (124.8 M ha) (FAO, 2012). CA is a resource-saving agricultural production system that aims to achieve production intensification and high yields while conserving or 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).

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). 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).

Definition

"Conservation agriculture is a management system that maintains a soil cover through surface retention of crop residues with no till/zero and reduced tillage." or

CA is described by FAO as "a concept for resource saving agricultural crop production which is based on enhancing the natural and biological processes above and below the ground."

CA is based on optimizing yields and profits, to achieve a balance of agricultural, economic and environmental benefits. It advocates that the combined social and economic benefits gained from combining production and protecting the environment, including reduced input and labour costs, are greater than those from production alone. With CA, farming communities become providers of more healthy living environments for the wider community through reduced use of fossil fuels, pesticides, and other pollutants, and through conservation of environmental integrity and services.

As per FAO definition CA is to **i)** achieve acceptable profits, **ii)** high and sustained production levels, and **iii)** conserve the environment. It aims at reversing the process of degradation inherent to the conventional agricultural practices like intensive agriculture, burning/removal of crop residues.

Hence, it aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It can also be referred to as resource efficient or resource effective agriculture.

Current scenario of conservation agriculture

The CA is followed in around 157 M ha area globally. The no-till area increased from 7 M ha in 1990 to 35.6 M ha in 2016, making South USA a pioneer (45% of the world's total CA) in adopting CA system. Other countries where CA practices have now been widely adopted for many years include USA and Canada (32%), Australia and New Zealand (14%), and 9% in Asia, Europe and Africa.

In India, efforts to adopt and promote conservation agriculture technologies have been underway for nearly a decade but it is only in the last 8 – 10 years that the technologies are finding rapid acceptance by farmers. 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. The spread of technologies is taking place in India in the irrigated regions in the Indo-Gangetic plains where rice-wheat cropping systems dominate. Conservation agriculture systems have not been tried or promoted in other major agro-ecoregions like rainfed semi-arid tropics and the arid regions of the mountain agro-ecosystems.

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), 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 (C. A.)

It mainly has following three major principles:

1. **Adoption of Minimum Tillage or Zero Tillage (ZT)**
   Minimal soil disturbance by direct planting through the soil cover without seedbed preparation. **Zero tillage** is a technology where the crop is sown in a single tractor operation using a specially designed seed-cum-fertilizer drill without any field preparation in the absence of anchored residue at optimum to slightly wetter soil moisture regimes.
2. **Mulching**
   Maintenance of a permanent vegetative soil cover or mulch to protect the soil surface.
3. **Diversification of Crops and Inclusion of Legume Crops**
   Diversified crop rotations along with growing of leguminous crops.

Recently, ‘**controlled traffic**’ is loosely presumed as the **fourth principle** of CA to ensure less or no compaction of soil by the broad wheels/tyres of the tractors. Also, nutrients and weed management sounds equally strong to be other principle of CA. However, a CA system, involving the three major principles is a perfect and true conservation agriculture system, which would be a more sustainable cultivation system for the future.

Major Practices of Conservation Agriculture

1. Conservation Agriculture Practices Laser land leveling (LLL)

The laser-assisted precision land levelling, popularly known as laser land levelling (LLL) is a prerequisite/initial technology for adopting CA practices like zero tillage, bed planting. It was introduced for the first time in India at farm level in Western Uttar Pradesh during 2001. It provides a very accurate, smooth and properly levelled field, otherwise, crop seed will not be placed at proper depth and germination will not be uniform. Fertilizer and water also will not be uniformly available to crops. Laser land levelling improves crop establishment, increases about 3-4% net cultivable area due to fewer requirements of bunds and channels, can increase water application efficiency by over 50% and water productivity of crops and crops yields by 15-25%, saves approximately 20-25% irrigation water, increases nutrient use efficiency by 15-25% and reduces weed problems and improves weed control efficiency. All these factors lead to about 1-2% increase in yield. Irrigation water reaches to the tail ends of the fields in less time. This technique can be very useful for rice since irrigation water requirement is reduced drastically.

2. Zero-till direct-seeded rice with residue retention

A CA- direct-seeded rice (DSR) with mungbean or other plants residue retention has great potential for minimizing the cost of production, soil health hazards and the negative impacts on the succeeding crops. Besides, CH_4 emission is considerably reduced due to DSR in rice-wheat system. DSR avoids water required for puddling and reduces overall water demand compared to transplanted puddled rice (TPR). It saves labour (about 40-45%), fuel (55-60%), water (30-40%) and time and gives comparable yield with TPR, if weeds are effectively controlled. DSR does not affect rice quality and can be practised in different ecologies like upland, lowland, deep-water and irrigated areas. It maintains or improves soil health, and increases water-use efficiency. Therefore, DSR can be a technically, economically and environmentally feasible alternative to TPR. A summer mungbean crop can be adopted without delay in sowing of rice crop. It gives grain yield of 8-10 q/ha and usually adds 40-60 kg N/ha in soil, reducing the requirement of N of the subsequent crop.

3. Brown manuring (for cover/mulch)

For brown manuring, rice is sown in lines with a seed drill and Dhaincha (*Sesbania aculeata* L.) is broadcast on the moist soil. *Sesbania* plants are allowed to grow with rice for 25-30 days, and then, knocked down by applying 2, 4-D @ 0.50 kg/ha or other is broad-spectrum effective weedicide. *Sesbania* while growing with rice smothers weeds, reduces herbicide use and irrigation water, and supplies 15-20 kg N/ha with a fresh biomass of 10-12 t/ha. It facilitates better emergence of rice where soil usually forms crust, conserves moisture with brown mulch, improves soil C content and increases farmers' income. This practice can be followed in crops like maize, pearl millet, sorghum. In broad-leaved crops, 2,4-D cannot be used, but *Sesbania* can be cut manually and spread as mulch between crop rows at 25-30 DAS for controlling weeds, and conserving moisture and nutrients.

4. Conservation tillage (zero/minimal) with residue retention

Under no-till/zero till (ZT) system with residue retention, soil is not ploughed, but disturbed to the smallest possible extent, and crop seeds are placed into soil by a specially designed seed drill, **turbo seeder/happy seeder**. At the time of seeding, fertilizers are simultaneously placed below the seeds. Both *kharif* (e.g. maize, pearl millet, sorghum, soybean, mungbean, pigeonpea) and *rabi* (e.g. wheat, gram, mustard, lentil) crops can be sown using ZT. It reduces soil erosion, compaction and organic matter loss; saves energy/fuel, time and money (~Rs. 3,000-4,000) for land preparation; advances wheat sowing by 10-12 days through direct drilling of wheat sooner after rice harvest (5-10% yield advantage), and reduces wheat yield losses caused by late sowing in rice–wheat system; reduces weed infestation particularly, *Phalaris minor* in wheat; prevents wheat crop from lodging at maturity; and provides opportunity to escape wheat crop from terminal heat stress.

5. Permanent bed with residue retention

In this technique, crops are sown on 30 cm raised beds (narrow or broad) alternated by furrows, using a bed planter. First, the beds are made after tilling soil, and the same beds can be used for subsequent years, but reshaping of beds are required once in a year, preferably before *kharif* crops. Beds have width about 40-60cm. Crops are sown in 2-3 rows on the beds and irrigation water is applied to the furrows. As a result, weed populations are reduced on the top of beds. The furrow irrigated raised-bed system (FIRBS) of wheat usually saves seed by 25-40%, water by 25-40% and nutrients by 25%, without affecting the wheat grain yield. Further, it reduces lodging owing to less physical contact of irrigation water with wheat culms, and vacant spaces in the form of furrows, facilitating easy air movement. Bed planting can be adopted in other sole crops like cotton, pigeon pea, maize, soybean, vegetables and sugarcane etc. also as intercropping eg. Pigeonpea (on bed)+maize (in furrow), Pigeonpea (on bed)+Sorghum (in furrow), Pigeonpea (on bed)+Pearl millet (in furrow), Urad (on bed)+maize /sorghum, pearl millet(in furrow), Moong (on bed)+maize/ sorghum, pearl millet (in furrow), Gram(on bed), + Radish (in furrow), Gram(on bed), + Radish (in furrow).

***In an experiment conducted at IIPR, Kanpur revealed that sowing of Pigeonpea on beds reduced Wilt and *Phtophthora* diseases in this crop.**

Crop Diversification

The 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).

Potential Benefits of Conservation Agriculture (C. A.)

By the implementation of all above three principles in crop production, various benefits have been observed by the scientists. Some of beneficial results of the experiments have been enumerated as under :

(1) Reduction in cost of production by Rs 2,000 to 3,000 ha^{-1} reported by Malik *et al.*, 2005.

(2) Enhancement of soil quality, i.e. soil physical, chemical and biological conditions (Jat *et al.*, 2009a, Gathala *et al.*, 2011b).

(3) Enhancement, in the long term C sequestration and build-up in soil organic matter constitute a practical strategy to mitigate Green House Gas emissions and impart greater resilience to production systems to climate change related aberrations (Saharawat *et al.*, 2012).

(4) Reduction of the incidence of weeds, such as *Phalaris minor* in wheat (Malik *et al.*, 2005).

(5) Enhancement of water and nutrient use efficiency (Jat *et al.*, 2012, Saharawat *et al.*, 2012);

(6) Enhancement of production and productivity (4% – 10%) (Gathala *et al.*, 2011a);

(7) Advancement in sowing date (Malik *et al.*, 2005);

(8) Reduction in greenhouse gas emission and improved environmental sustainability (Pathak *et al.*, 2011);

(9) Avoiding crop_residue burning reduces loss of nutrients, and environmental pollution, which reduces a serious health hazard (Sidhu *et al.*, 2007);

(10) Providing opportunities for crop diversification and intensification-for example in sugarcane based systems, mustard, chickpea, pigeonpea etc. (Jat *et al.*, 2005);

(11) Improvement of resource use efficiency through residue decomposition, soil structural improvement, increased recycling and availability of plant nutrients (Jat *et al.*, 2009a); and

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

Because of the ZT wheat benefits, the CA based crop management technologies have been tried in other cropping systems in India (Jat *et al*., 2011), but there are large knowledge gaps in CA based technologies which indicates there is a need to develop, refine, popularize and disseminate these technologies on a large scale.

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 per ha and reduce diesel consumption by 50 – 60 litres per ha (Sharma *et al*., 2005). Zero tillage allows timely sowing of wheat, enables uniform drilling of seed, improves fertilizer use-efficiency, saves water and increases yield up to 20%. Success has also been achieved in bed planting of wheat, cotton and rice. This has resulted in savings in irrigation water, improved fertilizer use and reduced soil crusting.

Comparison of Conservation Agriculture with Conventional Agriculture

Conservation agriculture systems require a total paradigm shift from conventional agriculture with regard to management of crops, soil, water, nutrients, weeds, and farm machinery (Table 1).

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

Conventional agriculture	Conservation agriculture
1. Cultivating land, using science and technology to dominate nature	Least interference with natural processes
2. Excessive mechanical tillage and soil erosion	No-till or drastically reduced tillage (biological tillage)
3. High wind and soil erosion	Low wind and soil erosion
4. Residue burning or removal (bare surface)	Surface retention of residues (permanently covered)
5. Water infiltration is low	Infiltration rate of water is high
6. Use of *ex-situ* FYM/composts	Use of *in-situ* organics/composts
7. Green manuring (incorporated)	Brown manuring/cover crops (surface retention)

Conventional agriculture	Conservation agriculture
8. 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
9. Free-wheeling of farm machinery, increased soil compaction	Controlled traffic, compaction in tramline, no compaction in crop area
10. Mono cropping/culture, less efficient rotations	Diversified and more efficient rotations
11. Heavy reliance on manual labor, uncertainty of operations	Mechanized operations, ensure timeliness of operations
12. Poor adaptation to stresses, yield losses greater under stress conditions	More resilience to stresses, yield losses are less under stress conditions
13. Productivity gains in long-run are in declining order	Productivity gains in long-run are in incremental order

Prospects of Conservation Agriculture

The conventional agriculture practices does not seem a sustainable option for sustainable gains in food-grain production, and hence CA-based crop management solutions adapted to local needs will have to play a critical role in most ecological and socio-economic settings of Indian Agriculture. The promotion of CA under Indian context has the following prospects:

(i) 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.

(ii) Reduced incidence of weeds – Most studies tend to indicate reduced incidence of *Phalaris minor*, a major weed in wheat, when zero-tillage is adopted.

(iii) Saving water and nutrients – Some 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 levelled and bed planted crops

(iv) Increased yields - CA has been reported to enhance the yield level of crops due to associated beneficial effects like prevention of soil degradation, improved soil fertility, improved soil moisture regime, water holding capacity, reduced evaporation loss and crop rotational benefits. Yield increases as high as 200 – 500 kg ha^{-1} are found with no-till wheat compared to conventional wheat under a rice-wheat system in the Indo-Gangetic plains.

(v) 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.

(vi) Crop diversification opportunities –Conservation Agriculture practices offer opportunities for crop diversification. Cropping sequences/rotations and agroforestry systems when adopted in appropriate spatial and temporal patterns can further enhance natural ecological processes.

(vii) Resource improvement – No tillage when combined with surface management of crop residues begins the processes whereby slow decomposition of residues results in soil structural improvement and increased recycling and availability of plant nutrients. Surface residues acting as mulch, moderate soil temperatures, reduce evaporation, and improve biological activity.

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