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9. New and Innovative Technologies and Machinery in Conservation Agriculture

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Abstract:

The practice of conventional agriculture with the reliance on intensive farming practices has led to serious ill effects on soil, plant and ecosystem and thereby threatened the sustainability and stability of the systems. This led to the evolution of a more reliable and sustainable crop production system which is today known as conservation agriculture. A rising number of people are turning to conservation agriculture (CA) as a means of achieving the twin objectives of feeding a growing global population and protecting natural resources. Mechanisation is a crucial component of CA. A variety of CA machines, including the laser land leveller, no-till drill, Turbo Happy Seeder, multi-crop planters, and relay seeders, which are all suitable for the main cropping systems in India, have been developed and evaluated with satisfactory progress. However, smallholder farmers frequently find it challenging to make the necessary financial commitments. To offer mechanisation inputs a supply chain for equipment inputs must be established to ensure easy availability of innovative and new machineries.

Equipping and educating business owners who offer CA services can also be a practical approach. These entrepreneurs may sustain themselves by offering high-quality CA and other mechanised services on a fully costed basis with the suitable equipment, chosen for the demands of their local farmers, and the appropriate technical and business management training. This chapter inculcates the characterization of various machineries and implements which are suitable and inevitable for conservation agriculture.

9.1 Introduction:

Mechanization of agriculture has pushed the agriculture sector so far in terms of production. however, it has also led to severe repercussions. The mechanization process involved multiple cultivations of land (4-5 times), faulty agricultural operations, cultivation of single high value crops every season, which totally degraded the soil, environment and ultimately the health of planet. The crop residue burning had been a common phenomenon in many parts of India especially, north-eastern region. The crops which are harvested leave behind tonnes of residues on the fields. Large volumes of attached and loose crop residues are left on the fields when rice and wheat are harvested together. Contrary to rice straw, which is regarded as a poor feed due to its high silica content and has no other economic use, wheat straw is collected using a straw combine for use as fodder approximately 75% of the time.

The loose rice residues in the fields make it difficult to till the soil and plant the wheat crop that will follow. To prepare fields for the timely sowing of wheat, northwest India often burns rice residue in open areas. The process results in significant losses of plant nutrients, particularly N and S, and organic C, with significant ramifications for soil quality and human health [1]. Only by implementing conservation agriculture practises will soil degradation caused by ongoing use of large machinery and inefficient farming practises be reversed. Conservation agriculture (CA) supports long-term RW production systems by restoring soil nutrient stocks and organic matter through in-field crop residue retention [2].

The idea behind conservation agriculture (CA), which is focused on boosting natural and biological processes above and below the ground, is to produce agricultural crops while conserving resources. Through the long-term, judicious, and sustainable use of the resources at hand, CA seek to increase productivity and profitability [3]. Besides other good agricultural practices, CA is defined by three interconnected principles (Figure 9.1), including: (i) no or minimal mechanical soil disturbance (implemented by the practice of direct planting into untilled soil and no-till seeding or broadcasting of crop seeds and causing least soil disturbance from any agronomic operation, harvest operation or farm traffic); (ii) maintaining a continuous biomass soil mulch layer over the surface of the soil (accomplished through retaining atleast 30% agricultural biomass, root stocks, stubbles, cover crops, and other ex situ biomass sources); and (iii) Cropping systems with crops in rotations, sequences, associations, and/or sequences incorporating annual and perennial crops, as well as a balanced combination of legume and non-legume crops, are used to diversify crop species [4].

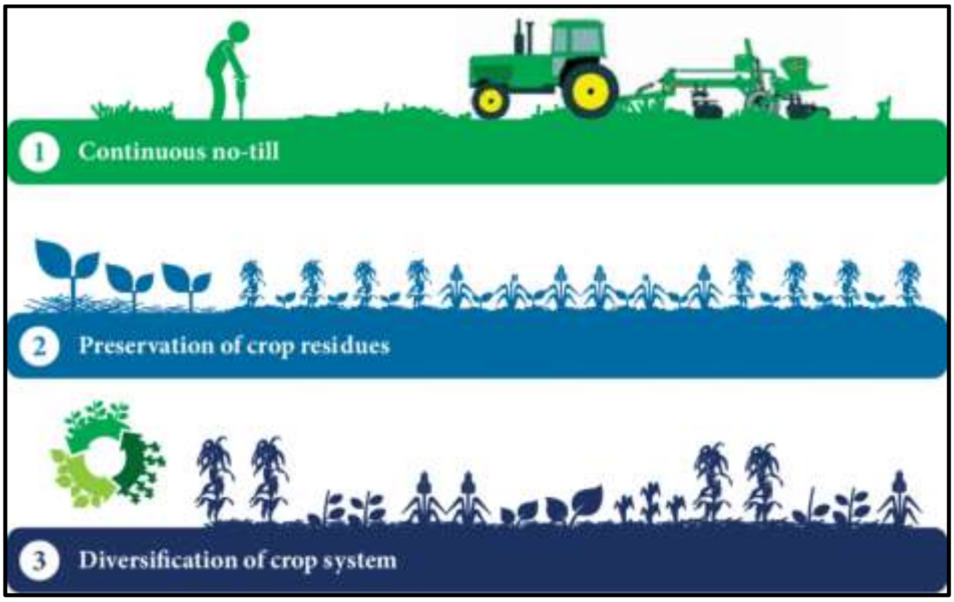

Figure 9.1: Key principles of Conservation Agriculture [5]

Another aspect which is nowadays emerging as a fourth principle is controlled traffic that reduces soil compaction. According to [6,7], CA is a potential technique for the long-term sustained production and efficient rational use of the available resources. According to [8,9], conservation agriculture-based management practises are realistic solutions for sustainable agriculture and efficient techniques to stop land degradation.

Around 180 Mha of cropland, or about 12.5% of all cropland worldwide, were used for CA in 2015–16, a significant increase of 74 Mha from 2008–09 [4]. Various cropping systems involve the late harvesting of the *kharif* season crops which delays the sowing of the succeeding *rabi* crops. In such scenarios, relay cropping has emerged as quite a viable option. Relay planting provides a fantastic chance to raise crop yield and farmer revenue in India's wheat-based systems. Due to the delay in sowing cotton, wheat yields in the cotton-wheat system are noticeably lower than those after rice and maize.

Therefore, new equipment is required for the timely sowing of wheat into the existing cotton crop. Similar to this, adding short-duration mungbeans to wheat-based agricultural systems can increase farmer profitability while also supplying protein to undernourished populations. Mungbean planting, on the other hand, is delayed after wheat harvest, which causes crop failure since the maturity time overlaps with the start of monsoon season. In order to accelerate sowing and ensure that the crop matures before the monsoon season, relay planting mungbean in standing wheat crops is helpful. More focus than ever is being placed on maize-wheat and rice-maize systems to diversify the RW system.

A variety of other crops and cropping sequences currently lack CA technology, despite advances in the development and promotion of machinery for direct seeding of wheat into combine harvested rice fields. The machineries that have been developed are generally high-power requiring and expensive which makes them unaffordable to the small and marginal farmers of the country. Since most Indian land holdings are between 1-2 ha, both large and smallholder farms require CA machinery. Major barriers to the use of CA machinery in India include a small proportion of land holdings, poor economic conditions of farmers, low seasonal usage of machines, uneven size and shape of fields, competition between machine and manpower, and farmers' attitudes towards zero-till planting of crops. Therefore, there is a need to develop need based, energy efficient, cost efficient machineries and technologies which could be feasible in long run.

9.2 CA Technologies and Machinery in India:

Conservation agriculture refers to the selective application of new, modern methods of farming. According to the [10]**,** conservation agriculture is a method for growing crops that produces high and consistent yields while preserving the environment by using less resources. The use of external inputs, such as agrochemicals and mineral or organic nutrients, is administered at a desired level, in a method and amount that does not interfere with the biological process, and interventions like mechanical soil tillage are restricted to the bare minimum. According to [11]**,** direct seeding or planting has been proven to have positive effects. It was found that only by adopting high conservation tillage techniques like zero tillage, happy seeding, laser field levelling, etc. land preparation costs could be lowered by 25–30%. Irrigation, pesticides, and herbicides may not be necessary for crop establishment if applied at the appropriate time and on the appropriate covering machinery. To enhance soil organic matter, as many residues as feasible are to be left behind, and they are to be distributed as uniformly as possible. The following goals may be accomplished by conservation agriculture: greater crop production, which in turn increases farmer income; climate resilience; food security; soil nutrition; and energy reduction. Conservation tillage practises can help farmers deal with the labour scarcity and hardship they are now experiencing.

A crucial input for CA is mechanisation, particularly power units, seeders, rippers, and sprayers. No-till planting and weed control equipment are the main mechanisation needs for smallholder CA [12]. The different machineries and technologies that may be used with conservation agricultural techniques include:

9.2.1 Machineries and Technologies for Sowing Management:

A. Laser Land Leveler:

a. Four-wheel tractor driven Laser leveler:

A laser-guided precision levelling technology called Laser Land Levelling is used to achieve very precise levelling with the desired grade on the field within 2 cm of its average micro-elevation. It makes use of a laser transmitter unit that continuously discharges a 360° rotating beam that is parallel to the necessary field plane (Figure 9.2.). This is received by a laser receiver (receiving unit) mounted on a mast on the scraping unit. A two-way hydraulic control valve automatically adjusts the scraper level in accordance with the signal's conversion into cut-and-fill level adjustment. By automatically handling the cutting and filling operation, laser levelling preserves the grade. To find the highs and lows in the field, a grid survey is carried out using grade rods. The high expense of purchasing a laser leveller prevents individual farmers from purchasing the machinery. Therefore, even for low-income small farmers, using LLL is economically viable and available through custom hiring services. According to the findings of several studies, laser land levelling (LLL) increased the application efficiency of irrigation systems, saving 20–25% of irrigation water. It increased rice, wheat, and sugarcane crop and water production by 15–25% and brought financial rewards to the farmers [13,14].

Figure 9.2: Laser land leveller

b. Two-wheel tractor driven Laser leveler:

For efficient field operation, a 50-horsepower tractor is necessary for the typical laser leveller. Additionally, in the eastern parts of the IGP, the small holding size and irregular shapes of the field make it difficult to use a 4-wheel tractor-driven laser leveller economically.

A laser leveller that can be placed into 2-wheeled tractor and is suitable for small-size holdings has been developed. The Borlaug Institute for South Asia (BISA), Ladhowal, Punjab, created a prototype of a 2WT-operated laser leveller for the region's small farmers.

B. Slit till Drill:

It is a tractor-powered machine (45-50 hp) that is used to sow seeds into the slits that are opened by the rotating slit disc that is mounted in front of the machine's furrow openers in only one operation in stubbles fields (Figure 9.3.). In the stubble fields of soybean, maize, and paddy, the machines prepare a 20 mm slit in the soil and insert seed and fertiliser into the prepared slits. In comparison to strip and roto till drill, it decreases moisture loss and draught force. In comparison to strip till drill machines, cost reduction through time and energy savings and environmental health optimisation through reducing soil compaction were less significant [15].

Figure 9.3: Slit till drill.

C. No-Till (NT) Seeder for Anchored Stubble Conditions:

In India, the most common No-Till equipment is a 4WT-drawn seed drill, which plants wheat seeds straight into tilled soil in one operation. For ripping of anchored stubbles, the NT drill uses inverted T-type furrow openers rather than shovel type furrow openers. The coulter and seeding system draws the seed through the soil with a 4WT while the Inverted-T creates a small split in the soil. NT seeders typically have a 6-row, 1.2 m-wide seed-cum-fertilizer drill.

A tractor with 35 horsepower or more can drive it. It produces an efficient 0.35 to 0.40 hectares per hour. In compared to conventional tillage, NT seeding of wheat is advantageous in terms of economics, irrigation water savings, and enhanced timeliness of wheat sowing [16]. The greater wheat yields produced under the NT method are mostly attributable to earlier planting. However, because loose residue frequently obstructs the placing of seeds, wheat sowing with an NT drill can only be implemented after the removal or burning of loose rice residue from the fields. Farmers typically burn the loose leftovers on their fields as a result, which is not a sustainable method.

D. No-Till Drill for Seeding into Crop Residues:

Direct drilling of wheat or any other crop into loose rice residue poses challenges because (i) straw builds up in the seed drill's furrow openers and (ii) heavy residue conditions necessitate frequent lifting of the implement, which affects seed depth and ultimately crop establishment. So, for no-till seeding into crop residues, drills that can cut through loose straw, enter the soil, and properly depth the seeds are needed. The development of Turbo Happy Seeder (THS) for seeding into rice residues began in 2002 at PAU Ludhiana with support from ACIAR. The first edition of Happy Seeder was produced and suggested in 2007 [17,18]. By making a number of additional adjustments, the most recent Happy Seeder (also known as THS) was enhanced and tested by PAU, Ludhiana, for direct seeding wheat into large amounts of rice residue in 2012 [19]. In the THS, wheat is sown using a zero-till drill and a rotor for handling paddy residues. By leaving the seeded rows uncovered and readily visible, the THS allows for precise alignment of subsequent sowing passes. With a 45 horsepower tractor, this PTO-driven equipment can cover 0.3 to 0.4 hectares per hour (Figure 9.4)

Figure 9.4: Turbo Happy Seeder.

The THS method of sowing wheat into rice residue offers several advantages for the environment and the economy. Significant air pollution can be decreased, soil nutrients can be recycled, and soil organic matter can grow by not burning the rice residue [20]. THS performed successfully in farmer farms throughout Punjab, increasing wheat yields by an average of 3.2%. Previous research on farmer fields and on-station [21] shown that happy seeder seeded wheat produced yields that were comparable to or greater than those of conventional practise. Increases in wheat production for the Turbo Happy Seeder may be attributable to enhanced soil thermal regime with surface residue retention and increased soil water availability as a result of decreased soil evaporation [22]. Mid-March saw a 10–20% improvement in grain production in the THS-sown wheat plots compared to farmers' fields due to the lower canopy temperature [23]. When compared to CT, the THS may save up to 83% of the energy needed for wheat planting, and it also uses less fuel, which lowers CO_2 emissions. Due to the existence of sufficient residual soil moisture in the rice fields, pre-sowing irrigation was not necessary in the majority of the studies for early sowing of wheat utilising THS. Thus, the use of happy seeder technology may be able to save 75–100 mm of irrigation water.

When irrigation scheduling was based on soil moisture potential, residue mulch reduced soil moisture loss through evaporation by around 40 mm and may therefore save one irrigation in wheat. In the IGP, THS is currently widely employed for direct planting of wheat into paddy fields. The addition of triple action straw management rotors and energy-efficient blades in THS further decreased the operational power consumption by 20–25% and increased the field capacity by 15%. Wheat, dry seeded rice (DSR), moong beans, and maize may all be sown in rice residue using THS.

E. Turbo Happy Seeder for Seeding Mungbean and Maize Fodder:

Typically, 25% of the residual wheat straw is burned by farmers, and the remaining 75% is gathered using straw combines in the area after combine harvesting. After making a little change to the seeding mechanism, the Turbo Happy Seeder may also be used to directly sow summer mungbean or maize for fodder right after the harvest of wheat, generating extra revenue for the farmers (Figure 9.5.). Thus, CA interventions not only boost farmers' income but also open the door for the addition of a legume crop to the RW cropping system [24,25].

Figure 9.5: Turbo Happy Seeder for Seeding Mungbean and Maize Fodder

F. Low Powered Tractor Operated Turbo Happy Seeder:

Nowadays, efforts are concentrated on growing CA among South Asian smallholder growers. The creation of smaller versions of Turbo Happy Seeders that require low powered 4-Wheeled Tractors and 2-Wheeld Tractors when human and animal labour becomes less readily accessible is an example of innovation in CA planters for smallholder farmers in eastern IGP of India and Bangladesh (Figure 9.6.). With 5 seeding rows, the low-hp 4 wheeled tractor operated THS can directly seed wheat into rice residue for smallholder farmers. By taking out the tiller attachment, it is possible to put the smaller THS on the 2-wheeled tractors.

Despite the fact that 2 wheeled tractors require more maintenance and have more operating complexity (and related expenses), the manufacturers supplied a better level of training support. Up to four rows of zero tillage can be planted with the THS machine mounted to the back of a 2 wheeled tractor.

Figure 9.6: Low Powered Tractor Drawn Turbo Happy Seeder

G. No-Till Planter for Direct Seeding of Rice:

Due to a lack of workers for traditional Puddled Transplanted Rice, DSR cultivation is becoming more and more popular in India, particularly in the northwest. According to [26] this approach greatly lowers the cost of producing rice. Farmers were utilising either ineffective seed drills or a very high seeding rate for manual seeding in the lack of proper DSR seeding equipment, which results in low yields. The use of a DSR planter with inclined plates that was created in India is currently being encouraged among farmers in NW India. The seed box, inclined rotary metering plates, seed cups, seed metering strip, seed delivery pipe, and seed boot make up the planter's seed metering and delivery system. The DSR planter maintains the appropriate plant to plant and row to row (20 cm) distances without mechanically harming the seeds while employing a seed rate of 15-20 kg ha^{-1} at a depth of 2-3 cm. The planter has a 1.8 m operating width and a 0.4 ha/h field capacity. For various crops, there are several tilted seed metering plates. Currently, the gadget costs around Rs. 75,000. The DSR planter is likewise becoming more and more well-liked in the eastern IGP. A Luck seed drill with a spraying attachment for DSR has also been developed by PAU, Ludhiana. The drill had nine furrow openers, an inclined plate seed metering system with notched cells, a tank, a hydraulic pump, and nozzles positioned on a boom. The weedicide is sprayed while the drill plants the rice seeds (Figure 9.7). Thus, manpower may be saved, and weeds can be better controlled with timely spraying.

Figure 9.7: No-till Planter for DSR

H. Machinery for Permanent Raised Bed Planting System:

The resource conservation technique of raised bed planting, a type of controlled traffic, was first used for wheat in India in the middle of the 1990s. The possibility of no-till planting of crops with the related benefits of CA is added by permanent raised beds (PRBs) with stubble retention.

The PRB planting method offers additional chances to lessen the negative effects of excessive water use on crop productivity besides providing other advantages, such as the ability to mechanically manage weeds [27,28], a 25–30% reduction in irrigation water use, and decreases in lodging and seeding rates.

The size of the bed ranges from 50 to 120 cm depending on the kind of soil and cropping strategy used (such as row spacing) with 37.5 cm broad furrows. For farmers that produce crops on PRBs, bed planters have been created that simply rearrange the beds before planting the following crop and keep all or part of the crop leftovers on the surface.

The PRB planter includes a bed shaper and double disc furrow openers (Figure 9.8). In comparison to other types of openers, the double disc furrow openers provide a small slit for the planting of seed and fertiliser as well as for controlling corn residue. In the maize-wheat system, the PRB planting aids in strong crop stand, improved production, and resource use efficiency [29].

Figure 9.8: Inclined plate planter with double disc furrow openers sowing wheat on PRBs (left) and earthing up/weeding in PRBs in wheat (right).

When fertiliser is applied on the soil surface (or broadcasted) under CA, more nutrients are lost, which results in inefficient nutrient utilisation and environmental degradation. In order to ensure that crop roots can absorb the necessary nutrients during the growth season and consequently boost the nutrient usage efficiency, fertiliser placement is vital [30]. Using 4WT with narrow tyres, the no-till planters may also be used to apply fertiliser at the proper depth to standing crops of wheat, direct-seeded rice, and maize (Figure 9.9). The standing crop under CA or a permanent raised bed system can have the nutrient placed at a depth of 5 to 10 cm near the root zone.

Fertilizer drilling increased wheat grain yield (670 kg/ha) and profitability (7700 rupees/ha). The two-wheeled tractor-driven bed planters are used to construct raised beds for the planting of various crops, such as maize, wheat, and rice, on PRBs.

Figure 9.9: No-Till Planters for Fertilizer Placement

I. Two-Wheel Tractor Self -Propelled Relay Planter:

The Cereal Systems Initiative for South Asia (CSISA) and CIMMYT team created a self-propelled relay seeder for two wheeled tractors in cooperation with PAU Ludhiana and Amar Agro Industries, Ludhiana, Punjab. Relay wheat sowing enhanced cotton productivity by 11–14% by allowing for an extra picking, which was made feasible by the crop's approximately 30-day prolonged growth season.

Relay planting resulted in a 25% increase in wheat production when compared to conventional sowing [31]. When compared to conventional till wheat after cotton, the self-propelled walk behind type relay seeder increased wheat yield by 12-41%. It is manually operated and only has a small field capacity (0.6 hectares per day).

J. Hand Jab Planter:

It is a manually operated equipment for seeding under no-tilled residue retained soils. A predetermined quantity of seeds and fertilizer is inserted into the soil by jab planters. The jab-planter is set on a wooden frame with two points and contains two compartments: one for seeds and one for fertiliser (Figure 9.10). Seed and fertilisers fall into the planting hole once the operator pushes the tips into the ground and opens them.

They frequently have two tips so that fertiliser may be applied together with the seed. The flow of seeds and fertiliser may both be altered. The handles are pulled apart after the point is pushed into the ground with the tip closed, releasing seed and fertiliser into the seeding hole. The seed and fertiliser points are refilled at the end.

Figure 9.10: Hand Jab Planter

K. Multi Crop Raised Bed Planter:

Multi-crop raised bed planters can be used for minimum tillage planting on permanent beds (Figure 9.11). Although significant soil disturbance occurs during the initial bed formation, once established, regular bed reshaping only causes minor soil disturbance. On the two raised beds made by ridgers, it is used to sow bold grains like maize, groundnut, peas, cotton, and sunflower. It is possible to swap out the planting discs for various crops without removing the main shaft of the seed hopper. It is suitable for small holder farms and operated with 12-16 hp two-wheeled tractor. Depending on the situation fertilizers can also be applied. A roller is available to correctly shape the raised bed and cover the seeds [32]. The effective field capacity of this multi-crop planter is between range of 0.11 to 0.20 ha h^{-1}. Bed planting increases wheat production by 05–10% compared to flat sowing, saves 25–30% on seed and fertiliser and irrigation water by 30-35%.

Figure 9.11: Multi Crop Raised Bed Planter

L. CRIDA Precision Planter:

The ICAR-CRIDA precision planter (zero till planter with herbicide and fertiliser applicator) features seed, fertiliser boxes, a seed measuring system, seed and fertiliser delivery tubes, and seed depth control wheels in addition to the herbicide tank (Figure 9.12.). It is powered by tractors with 35 hp. Inverted T type openers are used to properly place seeds and fertilisers in narrow furrows unlike wide furrows in conventional planters. This aids in seed placement at the proper depth and seed coverage. Improved seed-soil contact and seed coverage aid in crop establishment and germination [33].

Figure 9.12: CRIDA- Precision Planter Cum Herbicide Applicator

M. Sugarcane Residue Management Using Stubble Shaving Off-Barring Root Pruning and Fertilizer Drilling Machine (Sorf):

NIASM, Baramati developed this drill machine, which is three-point hitch linkage-operated and powered by tractors with 50–65 horsepower (Figure 9.13). The machine is ideal to carry out a number of additional activities, such as stubble shaving, covering garbage with loose soil, off-barring, and root trimming for sugarcane ratoon crop in a single pass, in addition to drilling fertilisers (upto 0.15-0.25 m soil depth depending on height of raised beds).

In a nutshell, the equipment consists of a power transmission unit, two vertical discs for off-barring, a central horizontal rotating disc attachment with fixed peripheral blades for stubble shaving, and mechanisms for placing fertiliser and root pruning. Old roots of the sugarcane ratoon crop can also be pruned using off-barring and root pruning.

It is a simple, inexpensive, efficient, and environmentally friendly agricultural equipment with a variety of uses, including stubble shaving, covering rubbish with loose dirt, root trimming, and applying fertiliser to a sugarcane ratoon crop [34].

Figure 9.13: SORF Machine Developed By NIASM, Baramati

N. Rippers

The extension of area under CA might have been an interim solution through the use of ox-drawn CA equipment. The reduced tillage principles also apply to ripping as they do to permanent basins. A groove in the soil is made by a ripper where seeds are sown and fertilisers are added (Figure 9.14).

The ripping lines, which are typically 75–90 cm apart, should be in the same location each year and the surrounding soil should not be disturbed. The nutrients and moisture gathered only benefit the crops in the lines. During the dry season, rip lines are opened up (these are often relatively shallow and no deeper than 10 cm) with a chisel-tined ripper to break the plough pan [35].

Figure 9.14: Rippers for Conservation Agriculture

9.2.2 Nutrient Management Technologies and Equipment:

One of the most important and inevitable part of crop production is nutrient management which is a very crucial issue in conservation agriculture. The availability of nutrients is also impacted by conservation agriculture, notably the availability of mineral N, with stubble retention resulting in increased immobilisation and a shortage of crop N early in the growing season. The stubble load, meteorological factors, and natural soil N fertility all have a role in how much immobilisation affects early N supply. However, with larger stubble loads, the ideal N rate tends to be greater under stubble retention due to immobilisation. Stubble loading of 1-3 t/ha are unlikely to change the optimal N fertiliser rate. Therefore, optimization of nutrients to fulfil the crops needs and increase in nutrient use efficiency require to be resolved with new and different approaches.

A. Site Specific Nutrient Management:

In SSNM approach, the plant's need for fertilizer N, P or K and micronutrients is determined from the gap between crop demand for sufficient nutrient to achieve a yield target and the supply of nutrients from indigenous sources, including soil, crop, residues, manures, and irrigation water (Figure 9.15). Management of nutrients (N, P, K) is done according to field- and season-specific conditions [36].

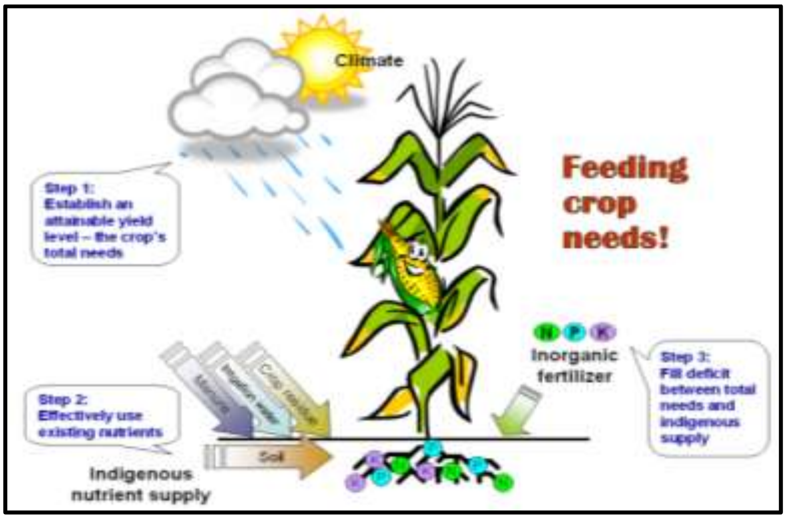

Figure 9.15: Site Specific Nutrient Management Source: Seap.Ipni.Net

B. Leaf Color Chart:

Leaf colour chart is an easy to use and inexpensive tool to manage N fertilizer more efficiently in rice. It is a plant health indicator, developed in Japan (Furuya, 1987) which consists of six colour shades form light yellowish to dark green (Figure 9.16). The colour strips are fabricated with veins resembling rice leaves. The leaf colour below critical value suggests the application of fertilizer. Around 25% N requirement can be cut with the use of LCC.

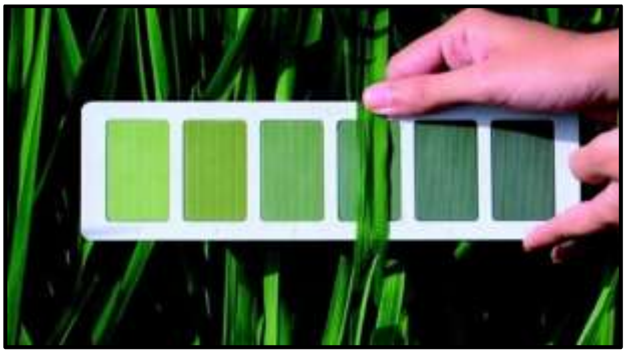

Figure 9.16: Leaf Color Chart For Real Time N Management

C. Green Seeker:

A variable rate application and mapping tool called Green Seeker (GS) is made for usage all through the growing season. It is an optical sensor-based nitrogen management tool that provides useful data to determine NDVI and Red to infra-red ratios (Figure 9.17). Here, the normalised difference vegetative index (NDVI), a measurement of crop vigour, serves as the foundation for N recommendation rates. According to [37], the findings of GS sensor-based N management produced equivalent (in rice) to greater yields (in wheat) with lower N rates which in turn increased NUE.

$$\boldsymbol{NDVI = \frac{NIR - RED}{NIR + RED}}$$

Figure 9.17: Green Seeker

D. Spad (Soil Plant Analysis Development) Meter:

Because chlorophyll molecules hold the bulk of the leaf's nitrogen, the two components of leaves can be correlated. Therefore, monitoring leaf greenness throughout the growing season with a chlorophyll metre like the SPAD metre can detect any possible N deficit early enough to remedy it without affecting yields [38] (Figure 9.18). In comparison to farmers' practises in China, the SPAD meter-based SSNM boosted partial factor productivity of N in rice by 48% [39].

Figure 9.18: Soil Plant Analysis Development Meter

E. Nutrient Expert:

A recently created decision support system (DSS) called Nutrient Expert® allows maize and wheat farmers to quickly adopt SSNM for each of their particular fields by combining the results of on-farm research into an easy delivery mechanism. The International Plant Nutrition Institute (IPNI) and the International Maize and Wheat Improvement Centre (CIMMYT) jointly developed and validated the Nutrient Expert (NE) DSS for wheat, a user-friendly, interactive computer-based decision tool that can quickly recommend nutrients for a farmer's field whether or not soil test results are available.

The tool calculates the potential yield for a farmer's field based on the growing conditions, calculates the nutrient balance in the cropping system based on yield and fertilizer/manure used in the previous crop, and combines this data with soil characteristics to predict expected N, P, and K response in the concerned field to produce a location-specific nutrient recommendation for wheat [40].

9.2.3 Cover Crop and Weed Management Equipment:

The major reason behind the success of conservation agricultural practices is the control of weeds through herbicides. The herbicidal weed control is the most prominent way of weed management under CA farms. However, the heavy usage of herbicides leads to weed flora shift (the dominance of perennial weeds in the field), herbicide resistance etc. In this context the exploration of other innovative measures needs to be addressed.

There have been several cultural methods which can be used in conservation agriculture practices such as stale seedbed technique, cover crops, mulching, crop diversification and many more [41]. Mechanical weeding is typically more cost-effective than manual labour because it involves the use of tillage tools like harrows, weeders, and cultivators that are propelled by animals or an engine. These tools rely on burying and uprooting weeds that have grown between crop rows and are large enough to move without significantly harming the crops. Thus, there can be some tools and machineries which can help in the successful weed management under CA.

A. Knife rollers: Prior to direct drilling, it is convenient to manage cover crops, residues, and weeds with knife rollers. Knife rollers are cylinders with blades that crimp vegetation without actually cutting it, and in many situations, this is enough to kill the plants (Figure 9.19). Knife rolling may be done using tractor power and animal traction as holdings are bigger. It can be a useful management strategy for some weeds as well as for cover crops [42].

Figure 9.19: Knife Roller

B. Star weeder: It contains V-shaped serrated blades that a person may manually use to perform weeding operations on any dry land crop. 0.024 ha/h is the field capacity (Figure 9.20).

Figure 9.20: Star Weeder

C. SWI weeder: It is a manually driven weeder that is frequently used in SWI (System of Wheat Intensification) fields in all sorts of soil regions for weeding and intercultural operations. 0.0160 ha/h is the field capacity of this tool (Figure 9.21).

Figure 9.21: SWI Weeder

D. Herbicide protector box: For the effective and efficient use of herbicide in the field, the Water Technology Centre, IARI, New Delhi, has created a Herbicide Protector box (Figure 9.22.). This box-like structure may be positioned in the space between rows of crops. As the box is being pulled between rows, the herbicide may be sprayed. To obtain the proper swath and reduce herbicide drifting, the height of the nozzle must be kept at half the height of the herbicide box. By maintaining the nozzle within the box, it is necessary to guarantee that the herbicide is sprayed inside the container. For improving herbicide application efficiency, a flat fan nozzle is suggested. Herbicide protector boxes cost about Rs 1500 [43].

Figure 9.22: Herbicide Protector Box

E. Allelopathy: To effectively manage weeds under CA, crop allelopathy against them may be used. Alfalfa, barley, black mustard, buckwheat, rice, sorghum, sunflower, and wheat are among the crops that may effectively reduce weeds by the release of allelochemical substances from living plant parts or from decaying residues. The development of sustainable CA systems may greatly benefit from the application of allelopathic features from crops or cultivars that exhibit significant weed inhibitory properties in conjunction with conventional weed control techniques. For instance, sunflower leftovers mixed into field soil had a strong inhibitory effect on the overall quantity and biomass of weeds developing in a wheat field [44].

Similar practises for managing weeds in California include mulching allelopathic plant residues and using specific allelopathic crops in crop rotations, intercropping, or as cover crops. Depending on environmental and management circumstances, these various allelopathic application methods may operate as natural weed controlling agents to varied degrees of effectiveness [45]. Thus, allelopathy presents a practical choice for weed management in CA.

F. Site specific weed management: Site specific weed management is the use of concepts and technology to control the spatial and temporal variability related to the quantity and make-up of weeds in an agricultural field [46]. This idea is supported by three facts: Because of the following factors: (i) weed populations are frequently dispersed irregularly within crop fields; (ii) geospatial technologies (such as GPS and GIS) have made it possible to detect and map weeds; and (iii) new smart sprayers, robots, and mechanical cultivators (Figure 9.23. a,b,c,d) have made it possible to carefully tailor weed management to fit the unique characteristics of each field [47].

Figure 9.23: Smart robots and mechanical implements for SSWM a. Quadrocopter UAV b. Terrasentia weeding robot c. Ecorobotix d. Weed Seeker

9.3 Water Management Technologies and Machineries:

Agriculture is one among the major sectors which utilizes water resource in enormous amounts and which is also considered as one of the major causes of soil and water pollution. The leaching of chemicals, pollutants, pathogens and organic matter from the soil through run-off is the most important cause of water pollution. On the other hand, CA reduces the leaching of these chemicals through runoff from the soil surface. It not only increases the infiltration capacity of soil but also reduces the amount of water used and lost through evaporation [48]. The farming practices coming under CA which enhances the water use efficiency are described briefly.

9.3.1 Direct Seeded Rice:

For manpower and water savings, direct seeded rice is an alternative to puddled transplanting. If the weeds are managed with careful herbicide application, it is a labour-, fuel-, time-, and water-saving method that produces rice with a yield comparable to puddled transplanted rice [49]. It minimises the total demand for the puddled transplanted rice by avoiding the water needed for puddling.

The quality of the rice is not impacted by direct seeding, which is an option in highland, medium, lowland, deep water, and irrigated regions among other ecologies (Figure 9.24). Direct seeded rice uses fertilizer and water more effectively, improving soil health and conserving 35–40% of water. This method may be used for water management in conservation agriculture [50].

Figure 9.24: Direct Seeded Rice

9.3.2 System of Rice Intensification:

System of Rice Intensification (SRI) aims to boost the output of rice grown by farmers. It is a low water, time-consuming technique that employs younger seedlings spaced individually and usually weeded by hand using specific equipment. Henri de Laulanié developed it in Madagascar in 1983. Rice yields are boosted by 20–50% or more, depending on present yield levels. increased income as a result of greater grain quality, higher yield, and less water usage. Water needs are decreased, often by 25–50%, because SRI fields are not kept permanently submerged (Figure 9.25).

Although commercial inputs can be utilised with SRI methods, the system does not call for the acquisition of new types of seed, chemical fertiliser, or agrochemical inputs. SRI farming practises are more affordable for low-income farmers since they don't need them to borrow money or incur debt, in contrast to many other breakthroughs. Costs of production are often decreased, typically by 10% to 20%, however this number fluctuates depending on how intensively farmers are already using inputs [51]. Farmers' net income increases more than their increased yield due to higher output and decreased costs. SRI is a more resilient system since it keeps producing under adverse situations including pest and disease pressure, drought, and climate change.

Figure 9.25: SRI System of Rice Cultivation

9.3.3 Micro-Irrigation Systems:

The micro-irrigation systems such as sprinkler and drip irrigation systems can also be used under conservation agricultural practices to improve the water use efficiency of crops. The use of saline and alkaline water along with good quality water can be easily done which enhance the water productivity in these systems.

9.3.4 Harvest Management Using Combine Harvesters:

The 'combine' harvests wheat and rice in a width equal to the width of its cutter bar and scatters straw from straw walkers in the middle of the harvested area. It equally slices and spreads the loose straw that comes from the harvester straw walkers. It can be attached at the back of a self-propelled combine harvester with a cutter bar length of 4.27 metres and a 110 hp engine [52]. Straw from the combine harvester's straw walkers is fed into the unit from one side and expelled out the housing's outlet. To evenly distribute the leftovers across the breadth of the combine harvester, the chopped material is blasted off tangentially and deflected with the aid of a deflector (Figure 9.26).

Figure 9.26: Combine harvesters for rice and wheat harvesting

9.4 Conclusions:

The problems and bottlenecks of conventional agriculture can be addressed and reduced by conservation agricultural practices. The mechanization is the basis of conservation agricultural practices. The development of suitable machineries to handle the on-farm residues, for seeding the crops in standing stubbles, efficient nutrient management, weed management, water and harvest management under conservation agriculture has aided in its adoption for sustainable long-term productivity. There is still a need for low-cost, precise CA machinery for various agronomic operations (such as fertiliser placement, weed and pest management, etc.) that are appropriate for various soils and cropping systems, both in irrigated and rainfed systems, despite the fact that several CA machines have been developed in India for various crops and cropping systems. A continuous process involves the creation of new machine designs, the improvement of the current CA machines, and their adaptation to regional variations in soil, climate, and crop production systems.

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