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Resource Conservation Technologies in Era of Climate Change: A Review

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ABSTRACT

Declining per capita land, water and other resources triggered by changing climate and increasing population need resource conservation technologies (RCTs) for agricultural sustainability. This paper has presented findings from recent research on resource conservation technologies that have been attempted in different regions of India. The superiority of resource conservation technologies (RCTs) such as laser land leveling, zero tillage, bed planting, direct seeded rice, leaf colour chart, green seeker and crop diversification over conventional methods of cultivation practices is evaluated in terms of saving of energy, water and labour, increase in crop yield, water productivity, nutrient-use efficiency, net returns and making agriculture climate smart. Zero tillage with residue retention increase soil organic carbon sequestration, conserve soil moisture and lower soil temperature thus making agriculture climate smart. Direct seeded rice is solution for labour scarcity, excessive water and fuel use in transplanted rice. Use of leaf colour chart saves nitrogenous fertilizers. Laser land leveling and bed planting practices increase water productivity and crop yield over conventional practices. But the machinery required for adoption of RCTs are heavy and costly, so the study has suggested the use of machines on co-operative basis and also the wider scale testing of new technologies under diverse production systems.

Key words: Bed planting, Direct seeded rice, Laser land leveling, Leaf colour chart, Resource conservation technologies.

Green revolution in India witnessed a boom in agricultural food grain production from 50.82 million tonnes to 296.65 million tonnes between 1950-2020 which helped to keep balance between demand and supply (Anonymous, 2020a). But, the real challenges have surfaced in the recent years with ever increasing food demand to feed increasing population using fewer resources (land, water, labor and chemicals).

Land resources are shrinking at faster rate due to urbanization, industrialization, development of roads and railway tracks. The per capita arable land availability in India was 0.34 ha during 1961, which got decline to 0.12 ha by 2019 which is mounting pressure to increase yield per unit area for burgeoning population (Anonymous, 2019). Intensification in cropping, industrial growth, human demand of water and lifting more and more groundwater cause water scarcity. The per capita water availability in India was 1816 m^3 and 1545 m^3 during the years 2001 and 2011, respectively which may further reduce to 1486 m^3 and 1367 m^3 in the years 2021 and 2031, respectively (Anonymous, 2020b). Although, food production in India has increased almost 5-fold during the last 50 years but, the efficiency of major inputs like water and nutrients are still very low (30-40%). On the other hand, labour scarcity is being felt as an impediment in agriculture due to higher wages in other sectors of economy and seasonal demand of agricultural pursuits (Prabakar, 2011).

Climate change is major issue affecting agriculture sustainability through changes in average temperatures, erratic rainfall, climate extremes (*e.g.,* heat waves), atmospheric carbon dioxide and pests and diseases (Singh *et al.* 2017). Agriculture sector in India contributes to greenhouse effect primarily through the emission of GHGs such as CH_4, N_2O and CO_2. Of the several sectors of agriculture, enteric fermentation contributes 211,429 Gg (51%), paddy cultivation 74,360 Gg (21%) and soil 57,810 Gg (16%). Other sources are burning of crop residues and manure heaps (NATCOM, 2012). The average surface temperature has risen about 1.02°C since the beginning of 20th century (Anonymous 2020c). Increase in temperature allows plants to grow faster, lesser time for grain to grow and mature and thus reduce yield (Neenu *et al.* 2013). For every 1°C increase in temperature, yield of rice, wheat, soybean, mustard, groundnut, potato is expected to decline by 3 to 7% (Dagar *et al.* 2012). The global atmospheric carbon dioxide concentration was 380 ppm in 2006, which has increased to 415 ppm in 2020 (Anonymous, 2020c) and crops grown under elevated carbon dioxide levels are most susceptible to insect pest and low in nutritional quality (Mall *et al.* 2006).

Keeping in view the above points, there is dire need of an energy, water and labour efficient technologies that can

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promote sustainable utilization of natural resources, protect the environment, produce more at less cost and improve quality of life for farmers (Jat *et al.* 2011). In this context, various resource conservation technologies (RCTs) like laser land leveling, zero tillage, crop residue management, bed planting, direct seeded rice, leaf colour chart, green seeker and crop diversification hold promise to save soil, water, human resources, increase crop yield, minimize greenhouse gas emission and enhance the resilience of modern agriculture to climate change. Different resource conservation technologies are as under:

Laser land leveling

Land preparation and leveling of the field is an important practice completed before the sowing of any crop. In an undulated field, water does not reach all parts of the field, get accumulate unevenly on the ground and creates larger biotic and abiotic pressures on crop growth, which affect crop productivity and loss of significant amount (10-30%) of irrigation water (Kahlown *et al.* 2000). The undulated and uneven fields are generally leveled using wooden logs or metal scrapper mounted either on a bullock or tractor. These methods are labour-intensive, expensive, time consuming and not very precise.

Laser land leveling through laser levelers is highly useful proven technology in the conservation of irrigation water. It is a process of smoothening of the land surface (± 2 cm) to a constant slope of 0 to 0.2% using a guided laser beam throughout the field. Several field studies (Jat *et al.* 2006, Kaur *et al.* 2012, Sattar *et al.* 2003) conducted in the Indo-Gangetic Plains, where flooding is a common method of irrigation, have brought out that laser leveling technology could save irrigation water by 10-30%, improve fertilizer-use efficiency by 6-7% and enhance crop yield by 3-19%, besides expanding the cropped area by 3- 6%. Rajput *et al.* (2004) established the superiority of precision land leveling in terms of higher application and distribution efficiencies of applied water over traditional land leveling in Indo-Gangetic plains. Under clayey soils of Navsari (Gujarat), laser land leveling resulted in higher total uptake of applied nutrients in wheat crop in comparison to traditional land leveling (Das *et al.* 2018). The study of Jat *et al.* (2003) at Meerut (U.P.) indicated reduction in the weed population in wheat after 30 DAS under precisely leveled fields in comparison to traditional leveled fields.

Zero tillage

The delay of every successive day in planting of wheat beyond November third week due to late harvesting of paddy decreases the grain yield progressively (Irfaq *et al.* 2005, Ali *et al.* 2010 and Ramesh *et al.* 2016). Therefore, to avoid delay in planting and reduce the cost of production, wheat sowing after rice can be advanced by 7-10 days by adopting zero tillage technology. In zero-till planting, specially designed tractor operated zero-till seed-cum-fertilizer-drill places the seeds and fertilizers into the soil in a narrow slit through the stubbles left from the previous harvest in one pass across the field (Pandey *et al.* 2007). The major benefits (Gupta and Sayre 2007, Gupta and Seth 2007 and Sharawat *et al.* 2010) of zero-till technology include i) reduced costs owing to saving in fuel and labour, ii) timely planting of crops resulting in higher yields iii) reduced weed density iv) saving of irrigation water up to 15-20% vi) improve input use efficiency viii) build up of soil organic carbon owing to reduced burning of crop residues and ix) reduced emission of green house gases.

Various studies have reported the comparative advantages of zero tillage. Tripathi *et al.* (2013) found that zero tillage saved human labour by 6.68%, machine labour by 46.30% and irrigation water by 17.65% over conventional tillage at Karnal (Haryana). Jat *et al.* (2011) promoted conservation agriculture based resource conservation technology *viz.* zero tillage for timely planting of winter crops to mitigate terminal heat stress. Another benefit of earlier sowing under zero tillage is that *Phalaris minor,* a herbicide-resistant weed in wheat, is less competitive than when wheat is sown late under conventional tillage (Malik *et al.* 2002). Evidences on yield effects of zero tillage are highly variable (Giller *et al.* 2009). Under mid hill conditions of Palampur (Himachal Pradesh), zero tillage in *Kharif* and *Rabi* seasons resulted in comparable yield as with multi-crop planter, manual seed drill and conventional tillage methods (Ramesh *et al.* 2014).

Crop residue management

In India, about 500 million tonnes of crop residues are generated every year (MNRE 2009) and about 93 million tonnes of crop residues are burnt on-farm (Pathak *et al.* 2010) to clear the agricultural ûeld promptly and allowing tillage practices for sowing of next crop. It has been found that one tonne of rice straw on burning releases about 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2 leading to atmospheric pollution (Gadi *et al.* 2003). By adopting efficient resource conservation technology (zero tillage with residue retention), these residues can be used for improving soil health, increasing crop productivity, reducing burning and pollution, enhancing sustainability and resilience of agriculture. With zero till machine sowing can be easily done in standing paddy stubbles but, loose rice straw cause interruption to the seeding operation and leads to their burning. But, it's new variant happy seeder can sow seeds in standing as well as loose rice straw. Happy seeder is a tractor-mounted machine that cuts and lifts rice straw, sows wheat into the bare soil and deposits the straw over the sown area as mulch (Singh *et al.* 2013). It allows farmers to sow wheat immediately after rice harvest without the need to burn any rice residue for land preparation.

Chakrabarti *et al.* (2014) under sandy loam soils of Hisar (Haryana) found that zero tillage along with residue retention resulted in higher soil moisture content (23.75%) in surface soil layer followed by zero tilled plots without residue (21.31%) and conventional tillage (19.3%). In addition, zero tillage with residue retention plots lowered soil temperature by 4.8°C over conventionally tilled plots. Zero tillage with residue retention improves soil moisture supply to plants for a longer period of time and thus mitigates terminal heat stress in wheat (Gupta *et al.* 2010). In loamy sand soils of Jaipur (Rajasthan), Saini *et al.* (2013) found significantly higher bacteria, actinomycetes and fungi population, when zero tillage with rice straw was done as compared to ZT after burning, as high temperature might have killed the microorganisms due to burning. Another study conducted at Hisar (Haryana) indicated that zero tillage with residue retention by happy seeder resulted in significantly higher wheat grain yield and soil organic carbon sequestration over zero tillage without residue and conventional tilled plots (Kumar, 2016). Considering all sources of emissions from the whole production cycle, Sapkota *et al.* (2015) found that rice and wheat under zero tillage with residue retention (ZTR-ZTW +R) had a significantly lower (negative) global warming potential (kg CO_2-eq Mg^{-1}) than all other systems without compromising grain yield and net returns, indicating that this production system actually mitigates climate change.

Bed planting

In bed planting, crops are grown on the raised beds alternated by furrows. Beds are usually made at 0.6-1.0 m wide and 2-3 rows of crops are sown on the beds and irrigation water is applied in the furrows. First time these beds are made after tilling the soil and the same beds may be used for subsequent years with little reshaping. The sowing on raised bed is done with the help of raised bed planter. The machine has adjustable blades for making raised beds of different widths and heights that can be adjusted by the shifting of blades on the frame and roller on the rear. It has seed-cum-fertilizer drilling mechanism for sowing one, two or three rows on each bed. The planter makes two beds at a time.

Wheat cultivation on furrow irrigated raised bed system results in saving of seed by 25-40%, water by 25-40% and nutrients by 25% without affecting the grain yield (Pathak *et al.* 2012). On raised bed, border effects allow the canopy to intercept more solar radiation. Whereas, furrows act as pathways for drainage during excessive rains and conserve rainwater in dry spells (Astatke *et al.* 2002). Bed planting increases fertilizer use efficiency because of better placement including top-dressing, facilitates mechanical weed control and minimizes lodging in the wheat crop (Gupta *et al.* 2000). Bed planting provides opportunity for crop diversification through intensification and more efficient use of water (Jat *et al.* 2008).

Kumar *et al.* (2010) found that beds of 90 cm with 3 rows resulted in significantly higher wheat grain yield (61 q/ha) and water saving (40%) over flat planting at Hisar (Haryana). In sandy loam soils of Meerut (U.P.), Sager *et al.* (2018) found beds of 90 cm with 4 rows of wheat crop more economical in terms of net returns and benefit cost ratio over flat planting. The study carried out by Chopra and Angiras (2008) at Palampur (Himachal Pradesh), established the superiority of raised seed bed in terms of higher maize grain yield, lowest density and dry matter of weeds over conventional tillage. However, some studies have reported lower crop yields with bed planting. Sharma *et al.* (2002) under marginally sodic silt loam of Modipuram (U.P.), obtained lower yields on the permanent beds which were associated with increased accumulation of salts on the beds. Humphreys *et al.* (2005) noticed that the beds (at 10 and 20 cm) dried more rapidly than the flat plots after sowing on sandy loam and loam soils.

Direct seeded rice

Rice is the staple food for more than half of the global population. Looming water crisis, water-intensive nature of rice cultivation and escalating labour costs drive the search for alternative management methods to increase water productivity in rice cultivation. Direct seeded rice (DSR) is the only viable option which has received much attention because of its low-input demand. It involves sowing pre-germinated seed into a puddled soil surface (wet seeding), standing water (water seeding) or dry seeding into a prepared seedbed (dry seeding). Improved short duration and high yielding varieties and nutrient and weed management techniques encouraged the farmers to shift from traditional system of transplanting to DSR culture.

In the traditional transplanting system (TPR), large quantity of irrigation water is used for puddling which breaks capillary pores, destroys soil aggregates and results in formation of hard pan, creating problems for the establishment and growth of succeeding crops (Sharma *et al.* 2003). Water resources, both surface and underground, are shrinking and water has become a limiting factor in rice production (Farooq *et al.* 2011). Huge water inputs, labour costs and labour requirements for TPR have reduced profit margins (Sharma *et al.* 2003). The conventional transplanted rice is a major source of greenhouse gas emission, particularly methane causing global warming and climate change (Pathak, 2015). Efforts, therefore, have to be made to mitigate toxic gas emission from rice and develop strategies to grow rice with less water. In this context, direct seeded rice, a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour.

In sandy loam soils of Karnal (Haryana), direct seeded rice resulted in saving of diesel by 42%, labour by 24% and irrigation water by 36% over transplanted rice (Singh *et al.* 2015). The study of Gill *et al.* (2014) on sandy loam soils of Punjab (Ludhiana) indicated higher water productivity under direct seeded rice over transplanted rice. However, no significant effect of direct seeded rice was observed on rice grain yield. Combination of direct seeded rice and zero tillage (conservation agriculture) is gaining momentum as a pathway to address rising water and labour scarcity and to enhance long term system sustainability. Sutaliya and Singh (2017) obtained highest rice grain yield, net returns and benefit-cost ratio from zero till-direct seeded rice with 30 cm anchored wheat residue (ZT-DSR+AR) at Varanasi (Uttar Pradesh) followed by zero till-direct seeded rice (ZT-DSR) and reduced till-direct seeded rice (RT-DSR), whereas lowest with puddled transplanted rice (PTR).

Crop diversification

Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value added crops with complementary marketing opportunities (Khanam *et al.* 2018). It shows a lot of promise in alleviating the second generation problems such as i) lowering of water table ii) soil degradation iii) nutrient imbalance iv) soil salinity v) resurgence of weeds, insect-pests and diseases vi) environmental pollution vii) decline in farm profit and viii) change in climate through ix) fulfilling basic needs x) withstanding weather aberration xi) controlling price fluctuation xii) ensuring balanced food supply xiii) reducing pesticides and fertilizers loads and xiv) creating employment generation (Nishan 2014). Among different cropping sequences, rice-wheat is the most stable and dominant cropping sequence being practiced in Indo-Gangetic plains. But, evidence shows that this system is now showing signs of fatigue, yields of rice and wheat in this region have reached a plateau or are declining, the soils have deteriorated, the groundwater table is receding at an alarming rate, total factor productivity or input-use efficiency is decreasing, cultivation costs are increasing and profit margins are reducing (Khanam *et al.* 2018). Inspite of all odds, the rice-wheat system cannot be completely eradicated from the agricultural production system, as both are the major food crops. So, diversification of rice-wheat system can be done by inclusion of short duration pulses/ oilseeds or by replacing either rice or wheat by high value crops like vegetables.

Various studies have reported the benefits of diversification of rice-wheat cropping system. Saroch *et al.* (2005) diversified rice-wheat cropping system by replacing wheat with one or two crops of oilseeds or vegetables at Palampur (Himachal Pradesh). The results indicated higher rice equivalent yield and monetary returns from rice-pea-potato/frenchbean cropping systems than rice-wheat cropping system. In another study, Tripathi and Singh (2008) at Karnal (Haryana) concluded that inclusion of oilseed or pulses in rice-wheat system once in three years or intensification by growing vegetable pea in between rice and wheat or greengram after wheat showed higher net returns, organic carbon content and sustainable value index (SVI) as compared to rice-wheat cropping system. In nitrogen deficient soils of Jalandhar (Punjab), Reddy (2009) registered highest rice equivalent yield, economic efficiency, land use efficiency, irrigation water productivity and nutrient productivity in rice-potato-sunflower cropping sequence. Similarly, Sharma *et al.* (2015) obtained higher productivity and profitability from rice-potato-onion cropping sequence than the traditional rice-wheat cropping sequence at Palampur (Himachal Pradesh).

Among the cropping systems, maize-wheat is also a major system and diversification is **c**onsidered to be good alternative to improve system yield and profitability. In this context, maize-pea-potato and maize-pea-frenchbean to be better option for the diversification of maize-base cropping sequence under mid hills sub humid zone of Himachal Pradesh (Gangwar *et al.* 2006).

Real time nitrogen management

Nitrogen (N) is the most widely used fertilizer nutrient. Application of nitrogen fertilizer in fixed time at recommended rate without taking into account whether the plant really requires N at the time may lead to loss or may not be found adequate enough to synchronize nitrogen supply with actual crop nitrogen demand. Unbalanced and excessive use of N-fertilizers causes environmental pollution, lodging of plants, increase pest pressure and cost to farmers. The real time N management approach can help avoid application of excessive amount of N fertilizer by matching time of fertilizer application with plant need (Gupta *et al.* 2011). In this context, gadgets such as inexpensive leaf color chart (LCC), chlorophyll meter (SPAD meter) and green seekerhas been demonstrated as an effective tool to schedule N fertilization to crops like rice, wheat *etc*.

Leaf colour chart

A leaf colour chart (LCC) developed in Japan, is used to measure green colour intensity of leaves to assess the nitrogen requirements by non-destructive method. It is a high quality plastic strip consists of 6 colour shades ranging from light yellowish green to dark green. The critical value of the LCC is the intensity of green colour that must be maintained in the uppermost fully opened leaf and fertilizer N recommendations are given whenever leaf greenness is below the critical LCC value (less than 3 in Basmati and 4 in hybrid rice) (Nachimuthu *et al.* 2007). In nitrogen deficient soils of Allahabad (Uttar Pradesh), LCC critical value 4 based nitrogen recommendation resulted in higher rice grain yield and saving of 18 kg N/ha **o**ver recommended dose of nitrogen (Ali *et al.* 2017).

Green seeker

It is an optical sensor which generate red and near infrared (NIR) light and then measures the amount of each type of light that is reflected back from the plant and displays the measured value in terms of NDVI (Normalized Difference Vegetative Index reading).

$$NDVI = \frac{\text{NIR reflected - Red reflected}}{\text{NIR reflected + Red reflected}}$$

Normalized difference vegetative index is a measure of total biomass and greenness of leaves and thus variably applies the crop’s nitrogen requirements. NDVI ranges from 0.00 to 0.99.Healthy plants absorb more red lights and reflect larger amounts of NIR. Higher the reading, the healthier the plant (Rouse *et al.* 1974).

Chlorophyll meter

Chlorophyll meter (SPAD meter) instantly provides an estimate of leaf N status in un-plucked leafy tissue. Meter emit specific wavelength in the red and near infrared ranges to pass through the leaf. The detector analyses the ratio of two wavelengths to determine chlorophyll concentration index (CCI) range from 0-99.9. From a study conducted at Raichur (Karnataka), Swamy *et al.* (2016) found that LCC based N at threshold 5 resulted in higher green fodder yield of sweet corn and net returns which was at par with green seeker based NDVI at 0.8 and recommended dose of nitrogen. Whereas, SPAD meter based N at threshold 50 could not meet the nitrogen need of the crop.

Site specific nutrient management (SSNM)-Nutrient expert

Nutrient expert is a fertilizer decision support tool based on the principles of site-specific nutrient managementdeveloped by International Plant Nutrition Institute (IPNI) is an easy to use, interactive, computer based decision tool that provide nutrient recommendations in the presence or absence of soil testing data (Pampolino *et al.* 2012). The tool estimates the attainable yield for a farmer field based on growing conditions, determine the nutrient balance in the cropping system based on yield, residue management and fertilizer/ manure applied in the previous crop. Thus, nutrient expert provides balanced and location specific fertilizer recommendation on the basis of farmer resource availability. Mannade (2017) found that SSNM through nutrient expert resulted in significantly higher rice grain yield, total nitrogen uptake and higher nitrogen use efficiency over recommended dose of fertilizer, farmer's fertilizer practice and control at Raipur (Chhattisgarh).

CONCLUSION AND FUTURE PROSPECTS

Resource conservation technologies appear to be appealing options to achieve sustainable and intensive crop production under different agro ecological environments because they use available resources efficiently and maintain soil fertility. However, the availability of machinery/equipment for promotion of resource conservation technologies is a prerequisite. As the machinery required for adoption of RCTs are heavy and costly, so machines should be used on co-operative basis. There should be development of multi-purpose farm machines suitable for different size categories of farmers, located under varying production environments. Scientific validation of resource conservation technologies should be undertaken through multi-locational field trials and farmer's involvement in participatory research and demonstration trials can accelerate adoption of resource conservation technologies.

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