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12. Resource Conservation Technology Advancements in Agriculture

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Abstract:

The chapter "Resource Conservation Technology Advancements in Agriculture" examines the cutting-edge technologies designed to enhance resource efficiency and sustainability in agricultural practices. It delves into innovations such as precision agriculture, drip irrigation, no-till farming, and integrated pest management, highlighting their roles in conserving water, soil, and energy. The chapter provides a detailed analysis of how these technologies reduce resource wastage, improve crop yields, and mitigate environmental impacts. It discusses the adoption challenges and economic benefits associated with these advancements, supported by case studies demonstrating successful implementations worldwide. The chapter also explores the role of data analytics, remote sensing, and automation in optimizing resource use and enhancing decision-making processes in agriculture. By integrating these technological advancements, the chapter underscores the potential for achieving sustainable agricultural practices that align with global environmental and food security goals.

Keywords:

Resource Conservation, Precision Agriculture, Drip Irrigation, No-Till Farming, Integrated Pest Management and Sustainability

12.1 Introduction:

Indian Agriculture has now somehow reached its maximum output, targets fixed during the era of the Green Revolution (1965-1966) that facing so many challenges such as land degradation, water scarcity, climate change, small land holder farming, income insecurity, price volatility and digitization, which cannot fulfil our dream as ‘Aatmanirbhar Bharat’.

Intensive and non-renewable based agriculture is the result of the strategies taken to fulfill the target “Self-sufficiency in food grain production” after independence. Indian agriculture made significant role to increase food grain production over the years contributing to food security and meeting the growing demands of a large and diverse population.

Using of chemical inputs, unorganized random use of underground water and dependency of hybrids instead of local cultivars makes Indian agriculture vulnerable and environment risky and also makes it planet unhealthy.

To rescue our ecosystem from this biggest threat, conservation of natural sources and return back to its environment is the only sustainable way that safe our surroundings.

Conservation Agriculture offers a promising approach for preventing land degradation and increase arable land area. Conservation agriculture promotes minimum soil interference, long lasting soil cover and diversification of field crops around the year. These three pillars of CA conserve soil physical, chemical & biological properties; enhance water retention percentage as well as groundwater recharge; increase soil organic carbon through carbon sequestration; and resilience of biodiversity. But, in modern terms to achieve the beneficial impacts of conservation agriculture, various Resources Conservation Technologies (RCTs) have to be adopted for not only conserve our natural resources but also make Indian agriculture more sustainable and profitable.

12.2 Resource Conservation Technologies (RCTs): Concept and Needs:

In layman's terms, the concept of RCTs aims to save natural resources in order to prevent their degradation and loss, as well as to maximise the benefits of the resources so that their productivity is not hampered over time, but rather improved to promote the sustainability of the entire ecosystem.

Resource conservation technology (RCT) refers to any management technique or technology that increases factor productivity, which includes land, labour, capital, and inputs. Capital, land, labour, machinery, and agricultural inputs such as fertilizers and pesticides are all considered agricultural resources.

RCTs save resources and boost output with minimal effort. RCT consists of two terms: resource and conservation. A resource is a limited-availability real or virtual entity that must be consumed to gain benefits. Resource management is necessary for allocating resources, whether commercial or non-commercial. Conservation involves managing natural resources to benefit current generations while ensuring future generations can meet their requirements.

Excessive cultivation has negatively impacted soil health, reducing nutrient and moisture retention capacity. Farmers are abandoning traditional operations including organic manure, green manuring, intercropping, crop rotation, and mulching for different reasons. The loss of soil fertility has obligated crop producers to employ increasing amounts of chemical fertilizers per unit area to increase crop productivity.

During Green Revolution, the main concentration was on increasing the per-hectare yield of specific grain crops. However, this led to resource degradation issues such as declining productivity, lowering the level of groundwater, soil salinization hazards, deterioration of fertility of the soil, degradation in soil physical health, biotic interferences, down turning biodiversity, limited access to quality food, and increasing ground water and air pollution.

As a result, in the post-green revolution era, conservation issues have grown more essential because of global resource deterioration problems and the aim to lower cost of production, enhance return on per rupee, and make agriculture more productive.

12.2.1 Resource Conservation Technologies:

A. Precision farming:

Precision farming, also popular as precision agriculture, revolutionizes traditional farming practices by employing technologies advanced in nature and data-driven technologies for profitable crop management. At its core, precision farming involves the precise application of inputs such as water, fertilizers, and pesticides, tailored to the specific needs of individual plants or sections of fields. This targeted approach aims to maximize crop productivity, enhance resource efficiency, and minimize environmental impacts. By utilizing tools such as GPS-guided tractors, drones, and satellite imagery, farmers can accurately map variations in soil properties, moisture levels, and healthy crops in their fields.

This detailed understanding enables them to make informed decisions regarding planting, irrigation, and pest control, leading to more efficient resource allocation and improved crop yields. Additionally, precision farming facilitates real-time monitoring and data collection, allowing farmers to quickly identify and address issues such as nutrient deficiencies, pest infestations, or water stress before they escalate (Karunathilake *et al.*, 2023). Moreover, by reducing input misuse and optimizing resource use, precision farming can result in significant cost savings for farmers while simultaneously reducing environmental impact by minimizing chemical runoff and greenhouse gas emissions.

B. Use of GPS and GIS systems:

Global Positioning System (GPS) has fundamentally transformed agriculture, ushering in an era of precision farming and sustainable practices. GPS helps targeted application of resources like fertilizers, pesticides, and water, minimizing waste and maximizing yield. GPS-equipped machinery negotiates fields with unparalleled accuracy, optimizing operations and reducing environmental impact. Real-time monitoring of crop conditions through GPS-enabled sensors and drones allows for timely interventions, ensuring optimal crop health and resource utilization. Additionally, GPS facilitates the precise mapping of fields, aiding in boundary identification and compliance with regulations. Through its multifaceted applications, GPS has become an indispensable tool for modern agriculture, empowering farmers to enhance productivity while promoting sustainability. Geographic Information System (GIS) technology has revolutionized agriculture by providing farmers with powerful tools for spatial analysis and decision-making.

By integrating various data layers such as soil type, topography, weather patterns, and crop yields into a geographic framework, GIS enables farmers to identify spatial patterns and trends crucial for effective farm management. GIS helps in the creation of detailed maps that depict soil variability, water flow patterns, and crop health indicators, enabling farmers to make informed decisions about planting, irrigation, and resource allocation. Moreover, GIS facilitates the integration of data from multiple sources, including remote sensing imagery and on-farm sensors, providing a comprehensive view of agricultural landscapes. Through its ability to analyze spatial relationships and visualize complex data, GIS enhances precision agriculture practices, optimizing resource use, minimizing environmental impact, and ultimately improving farm productivity and sustainability.

12.3 Site-Specific Nutrient Management (SSNM):

Presently nutrient management recommendation process in India relies on response data gathered from broad geographical regions. Site-specific nutrient Management presents an alternative strategy that considers the inherent spatial variability in nutrient requirements. It entails monitoring all pathways of plant nutrient supply and emphasizes a balanced use of fertilizers, bio-fertilizers, organic manures, crop residues, and nutrient-efficient crop varieties for maintaining agricultural productivity. SSNM advocates for a targeted approach to fertilization, avoiding excessive and indiscriminate fertilizer application.

Instead, it empowers farmers to adjust fertilizer use dynamically based on the specific needs of nutrients in their crops and availability of nutrition from natural resources, organic sources, and irrigation water (Pasuquin *et al.*, 2014). The goal is to supply nutrition at an optimized rate and timing to obtain high yields to maximize nutrient use efficiency. This approach involves three key steps: setting achievable yield targets, utilizing existing nutrient sources effectively, and applying fertilizers to bridge the gap between crop nutrient demand and supply.

A. Reduced tillage, zero tillage:

Both reduced tillage and zero tillage are integral components of conservation agriculture, which aims to sustainably manage agricultural ecosystems while enhancing productivity and environmental stewardship. These practices help to make soil healthy, water conservation, reduced greenhouse gas, and mitigate the negative impacts of erosion and soil degradation. By minimizing soil disturbance and preserving soil structure, reduced and zero tillage contribute to more resilient and sustainable agricultural systems.

- **a. Reduced Tillage**: Reduced tillage involves minimizing the extent and intensity of mechanical soil disturbance compared to traditional tillage practices. Instead of fully inverting or disturbing the soil across the entire field, reduced tillage techniques disturb only a portion of the soil surface, typically leaving a significant amount of crop residue above the soil. This residue helps in protecting the soil from erosion, retain moisture, and improved soil structure. Conceptually, reduced tillage can be seen as a middle ground between conventional tillage and zero tillage. It aims to strike a balance between the benefits of soil conservation and the need for some level of soil disturbance for weed control, seedbed preparation, and nutrient incorporation.
- **b. Zero Tillage**: Zero tillage, also known as no-till farming, involves completely eliminating physical soil disturbance in the planting and cultivation process. In zero tillage systems, crops are planted directly into untilled soil, often through the residue left from the earlier crop. This method helps to maintain soil structure, preserve soil organic content, and considerably reduce soil erosion.

Conceptually, zero tillage represents a radical departure from traditional tillage practices. It prioritizes soil conservation and minimizes soil disturbance to the greatest extent possible. Instead of relying on mechanical tillage for weed control and seedbed preparation, zero tillage often utilizes alternative methods such as cover cropping, crop rotation, and the use of herbicides in a targeted manner.

B. Crop residue cover:

Crop residue cover (CRC) is a cornerstone of resource conservation technology (RCT) in agriculture, pivotal for soil health and sustainable land management. By preserving plant material on the soil surface after harvesting, CRC mitigates soil erosion, enhances moisture retention, and fosters nutrient cycling. RCT, including tools like remote sensing technology, facilitates accurate assessment and monitoring of CRC across agricultural landscapes. This technology enables producers to take informed decisions regarding tillage practices, crop rotation, and erosion-preventing measures. Maintaining adequate CRC not only safeguards soil structure and fertility but also contributes to improved quality of water and reduced environmental deterioration. In the phase of global climate change challenges, CRC and RCT play indispensable roles in promoting resilient and sustainable agricultural systems, ensuring the long-term viability of food production while conserving natural resources.

C. Cover crops:

Cover crops are crops grown basically for protecting and improving the soil health rather than for profitability. They are typically sown during the off-season or in between main crops for preventing erosion of soil, suppressing weeds, enhance soil fertility, and improve overall soil health. These crops can include various grasses, legumes, or other plants that have deep roots or dense foliage, which contribute to soil structure, nutrient retention, and moisture conservation. Common cover crops include clover, rye, vetch, and buckwheat.

Maintaining soil coverage stands as a fundamental tenet of conservation agriculture (CA). These cover crops serve various agronomic, ecological, and economic roles within CA systems, complementing the functions performed by primary commercial crops (Schipanski *et al.,* 2014). They compensate for the mineral nutrition of major crops by fixing atmospheric nitrogen by the legumes, mulch mineralization, or manures returning from animals which graze upon them. Additionally, the biological mass generated by cover crops may generate additional farm income, such as through extra food production for consumption or as supplementary fodder. Beyond their above-ground functions, cover crops play crucial roles below the soil surface. The roots help prevent or remediate compaction of soil, access moisture from deeper soil layers beyond the reach of main crop roots, and recycle nutrients like nitrates, potassium, calcium, and magnesium that are prone to leaching into deeper soil horizons (Ayub *et al.*, 2020). This vegetative cover not only shields the soil from the impact of raindrops but also provides shade and maintains optimal moisture levels.

D. Leaf Colour Chart:

The Leaf Color Chart (LCC), originally developed in Japan, serves as a non-destructive method to assess the nitrogen requirements of rice plants by measuring the intensity of green color in their leaves (Bhupen Chandra *et al.*, 2021). This tool is being standardized alongside chlorophyll meters for enhanced accuracy. Research findings have demonstrated the efficacy of LCC-based nitrogen management over locally recommended nitrogen application methods in both hybrid and inbred rice varieties. By applying nitrogen based on LCC readings, it has been possible to reduce nitrogen fertilizer application by 20-30 kg per hectare without compromising rice yield (Singh, 2014).

This approach not only optimizes nitrogen use but also contributes to sustainable agricultural practices by reducing input costs, and minimizing environmental impacts associated with excessive nitrogen application. Thus, Leaf Color Chart emerges as an important tool for improving nitrogen delivery strategies in rice cultivation, offering a practical and efficient means of enhancing crop productivity while promoting resource efficiency.

E. Laser land leveling:

Laser land leveling is a precise technique used to flatten land surfaces with an accuracy of around ±2 cm from the average elevation, achieved through the use of laser-equipped drag buckets. This method, also known as precision land leveling, aims to create a uniform slope ranging from 0 to 0.2% across the fields. It employs high-powered tractors and soil-moving equipment fitted with advanced technologies such as global positioning systems (GPS) and laser guidance systems. These systems enable precise manipulation of soil, either through filling or cutting, for achieving a slope which is desired or level of the land. By optimizing land surface uniformity and water distribution, laser land leveling contributes to improved water efficiency and enhanced agricultural productivity. This technology represents a significant advancement in new era agriculture, presenting farmers with the means to achieve greater precision in land management and resource utilization, ultimately leading to better, profitable and sustainable farm practices.

F. Crop rotation and cropping system:

Crop rotation is an agricultural practice in which various crops are grown in the same region successively throughout time. Instead of planting the same crop in the same field year after year, farmers rotate through a variety of crops, usually in a predetermined order. The purpose of crop rotation is to enhance soil health, manage pests and diseases, improve nutrient cycling, and maintain or increase crop yields. Each crop in the rotation may have different nutrient requirements, growth patterns, and interactions with diseases and pests. Rotating crops can help farmers break the life cycles of pests and diseases, reduce soil erosion, optimize soil fertility, and promote overall sustainability in agricultural systems. Beside this, cropping system refers to the management and arrangement of crops within a specific agricultural area over time. It encompasses crop selection, planting, cultivation, and harvesting practices, influenced by factors like climate, soil type, and market demands, to optimize productivity, sustainability, and resource utilization. A well-planned crop rotation within a cropping system not only enhances crop productivity and soil fertility but also enhances water use efficiency by suppressing weeds, creating favourable microclimates for plant growth, moderating soil temperatures, and improving soil physical properties. An effective cropping system plays an integral role in sustaining agriculture.

G. Integrated Farming Systems:

Integrated Farming Systems necessitate harmonious integration of various farm activities like field cultivation, livestock rearing, aquaculture, and agroforestry within a single farming operation. IFS aims to maximize resource utilization, enhance per-hectare yield, and promote sustainability by leveraging synergies between different components.

By recycling organic matter, nutrients, and energy, IFS minimizes waste, reduces environmental impact, and increases overall farm resilience. This holistic approach offers diversified income streams, food security, and ecological benefits while optimizing land and labour efficiency.

12.4 Direct Seeded Rice (DSR):

Direct Seeded Rice (DSR), sometimes known as the 'broadcasting seed technique,' is a water-efficient rice production technology. This approach involves drilling seeds directly into the soil. Unlike the typical water-intensive approach of transplanted rice seedlings from a nursery, this method conserves underground water level. This procedure requires no nursery preparation or transfer. The increased scarcity of labour and water, combined with concerns about soil fertility, has prompted renewed interest in switching from traditional puddled and transplanted rice growing methods to Direct Seeded Rice (DSR) (Kaur and Singh 2017). According to studies conducted in Northwest India, DSR in unpuddled soils saves 35% to 57% of water (Bhatt and Kukal, 2017). Additionally growing DSR and transplanted rice on raised beds has shown reduced water usage by twelve percent to sixty percent compared to flooded, transplanted rice in the Indo-Gangetic Plains (Kumawat *et al.*, 2019).

12.5 System of Rice Intensification (SRI):

System of Rice Intensification (SRI) is a unique method of cultivation of rice focused on optimizing plant growth and productivity while minimizing inputs. It involves transplanting young rice seedlings at wider spacing, maintaining soil moisture through alternate wetting and drying, and promoting healthy root growth. By emphasizing organic practices and reducing chemical use, SRI enhances soil health, conserves water, and increases rice yields, offering a sustainable approach to rice production with environmental and economic benefits.

A. Drip irrigation:

Drip irrigation, often known as trickling irrigation, is a method of delivering water to soil at very low rates, typically ranging from 2 to 20 litres per hour, via a network of small-diameter plastic pipes fitted with emitters or drippers. This technology ensures that water is supplied directly to the root zone of plants, reducing waste and increasing water use efficiency (WUE).

Unlike surface and sprinkler irrigation, which saturate the entire soil profile, drip irrigation targets specific areas, wetting only the soil around plant roots. One key advantages of drip irrigation is its suitability for row crops, offering precise water delivery tailored to the needs of individual plants. Additionally, drip irrigation systems are highly adaptable, and capable of being implemented on farms with varying slopes.

With an impressive water use efficiency ranging from 85% to 90% (Malhotra, 2016), drip irrigation stands out as a sustainable and effective method for optimizing water resources while promoting crop growth and productivity.

12.6 Furrow Irrigated Raised Beds (FIRB):

Furrow Irrigated Raised Beds (FIRB) involve creating raised beds with 15cm row spacing and 55cm width, with a 30cm wide furrow between them. This method optimizes water usage, resulting in water savings of approximately 20-30% (Sushil *et al.*, 2012). By elevating the planting beds and incorporating furrows, FIRB facilitates efficient water distribution to the root zones of crops while minimizing water loss through runoff or evaporation. This approach enhances water conservation efforts while promoting optimal growing conditions for crops.

A. Nano fertilizers:

Nano fertilizers are designed to provide nutrients to crops through various methods: encapsulation within nano-materials like nano-tubes or nano-porous materials, coating with thin protective polymer film, or delivered as particles or emulsions of nanoscale dimensions. This approach enables slow, targeted, and efficient release of nutrients. Additionally, nanoparticles may directly contribute to nutrient delivery in certain instances.

B. Happy Seeder Technology:

The Happy Seeder Technology represents a machinery innovation capable of simultaneously sowing seeds and fertilizer precisely without disturbing the soil through tilling. It efficiently handles various crop residues, supporting loads of 10-12 tonnes effortlessly. With nine times, it can sow nine rows in a single operation. Utilizing a minimum 45HP double clutch tractor, it weighs approximately 750kg. This versatile machine can cover an area of 10-15 hectares (Mooventhan *et al.*, 2018).

12.7 Constraints and Challenges in Adopting RCTs:

Despite evidenced and recorded benefits in both research and field demonstrations, conservation agriculture programs and resource-conserving technologies adoption by the farmers is low. Many identified constraints are observed that pose hindrances large-scale adoption of RCTs:

- Many of the conservation agriculture-based resource conservation technologies are practiced by mechanisations of specific types. Such implements are not available across many locations and are also unaffordable. Successful adoption of RCTs also calls for developing, standardizing, and promoting and mobilization of supply to the new areas suiting to new crops and cropping sequences. In a country with 82% of the farmers being small and marginal category (www.fao.org), affordability of specialized equipment and mechanization are beyond reach along with implied periodic maintenance charges.

- RCT strategies involving those under site-specific management and needing a lot of research involving field experiments and repeated testing across the sites to validate in other locations becomes a time and money-consuming process.

For example, surface crop residues as mulch helps in maintaining soil temperature in a region by reducing soil water evaporation and which may again acts as an source of decomposable organic matter or may harbour undesirable pest populations in some other regions (Gupta and Jat, 2010).

- Initial investments into the land are necessary such as breaking existing soil compactions by ripping, addition of organic matter into soil, zero-till seeding, use of supplemental source of nutrients over inorganic fertilizers, leveling and shaping of the soil surface. These are important requisites to successfully change a production system with RCTs, but small subsistence farmers cannot make such capital available (Knowler and Bradshaw, 2007).
- India which obtains protein from diary in a big way and absence of forage in the lean seasons, predominantly under rainfed tracts, traditionally crop residues are used in a very large scale to make up for forage shortages and also as fuel; there exists competition between conservation practice and livestock feeding for crop residues (Bhan and Behera, 2014).
- Owing to the unaffordability and reasons cited for forage and fuel use farmers resort to large-scale residue burning of the previous crop, mainly rice and wheat instead of machinery sowing under CA. This practice in long term results in environmental pollution and corresponding health hazards for the region.
- While initially after the introduction of conservation agriculture practices predominance of annual grassy and broad-leaved weeds posed a big problem that over the years yielded into heavy infestation of perennial weeds with repeated and continuous practice of zero-tillage.

  This is because the selective herbicides fail to address the perennial weed management properly; further repeated application of non-selective herbicides cause in environmental pollution.
- Small and fragmented land holdings are a typical character of Indian Agriculture where technologies like happy seeder, laser land leveler, or zero-till-drill have limitations for use.
- Unlike conventional cultivation, RCT practices, e.g. zero-tillage, crop residue retention on the land surface, direct seeded rice, etc result in resource improvement gradually over time. In many cases, benefits in terms of yield improvement may not be seen immediately or in the early years of implementing conservation practices. This is the basic mindset among resource-poor farmers that restricts the implementation of RCT (Hobbs and Govaerts, 2010).
- In site-specific nutrient management, Soil Test Crop Response equations have been developed for specific crops and varieties in a specific location and the same equations can't be applicable for a wide range of soils or crops. Limitations for the use of leaf colour charts emerge from the fact that different varieties have varying levels of greening, and this misleads the management of nitrogen.
- Precision farming based RCTs are not taking off as variable rate technologies can't be calibrated across a predominance of small holdings with wide variations in soil fertility and moisture conditions.
- Development of appropriate technical packages and skilling extension agents with training of state of art technologies, unto better adoption of RCTs, are also very much lacking.

12.7.1 Future Thrust:

- Low tillage, crop rotation, residue management, control of weeds through herbicides, direct seeded rice, site-specific nutrient management, etc. are the key components of resource conservation strategies.
- Therefore, these priorities must be studied in a comprehensive way and tested and validated under diversified soil and agro-climatic conditions across the country on a long-term basis.
- Utmost necessity to create awareness, especially among the resource-poor farming communities about the importance of soil health, water conservation, addition of organic matter in soil, and conventional practices like residue burning, intensive tillage, and rampant use of inorganic nutrient sources need to be discouraged.
- For proper implementation of conservation practices, it is indispensable to identify a precised set of packages of practices of suitable strategies based on exquisite research for each agro-ecological region.
- Another aspect of conservation farming to cut down the input use from off-farm sources such as fertilizers and plant protection chemicals can be strengthened by integrated nutrient and pest management approach.
- The issues regarding the development of eco-friendly practices for tillage and proper residue management for specific combinations of soil-agro climatic situations and cropping systems to increase water and nutrient use efficiency need to be fine-tuned.
- Inter-disciplinary research programs must be carried out to develop, standardize, and promote congenial equipment and machines for zero-till seeding, residue establishment, harvesting, water and nutrient application and other inter-cultural operations across locations.
- Comprehensive experiments and validations are needed for the incorporation of tillage dynamics, the extent of residue retention, soil-physical properties, site-specific nutrient management, water conservation, etc. different in crop-growth simulation models for the ultimate projection of crop yields under various cropping systems following conservation practices across locations.
- Research and experiments in conservation practices must go with long-term aspects as the advancement in resource growth, especially soil health and yield comes gradually over time which provides the perception of the dynamics of interactions and changes in soil Physico-chemical and biological environments under various water and nutrient management approaches (Abrol and Sangar, 2006).
- Resource management systems provide ample scope for scientists of various disciplines to discourses various difficulties from a system perspective to set research priorities and allocate resources in close partnerships and active participation with the farmers, extension agents and other stakeholders in an integrated way for developing and promoting new technologies on a large scale.
- Active participation of farmers in various training and demonstration programs and information-sharing mechanisms is needed to strengthen their knowledge, improve basic management skills regarding various technologies, and also to overcome their traditional mind-set toward conventional practices.

12.7.2 Policy Implications:

Adoption of resource conservation technologies and conservation agriculture principles are seldom in India and it needs the policy support, public, involvement of various private sectors institutions. Policy and institutional corroborations are crucial to boost proper implementation and rapid adoption of technologies and for that all stakeholders must be encouraged to work together toward a common goal.

Since this domain calls for a paradigm shift, we need to further understand its interaction with existing technology of conventional agriculture and varying terrain and agro climates and how agreements of policy can foster or deter conservation strategies (Raina *et al*., 2005). Some of the important consideration regarding policy implications for conservation are discussed below.

- Educated and skilled agents can guide for technical assistance to the farmers who are unaware of the technology or profitability to implement it, in areas where resource conservation is profitable is a big area to work upon In India. There is also a need to incentivize and transfer costs/ subsidies to farmers to encourage RCT-based cultivation where conservation is yet to be perceived as profitable.
- Training and demonstration programs must be organized and supervised on resource conservation for capacity building through policy interventions. It must be laid out for all new and existing extension personnel at every level in the respective departments.
- Despite efforts for on-farm evaluation, training and demonstration of conserving technologies are being carried out in India through network research projects, a farmer’s participatory research should be laid out to obtain refinement of technologies and their demonstrations in the initial years followed by large scale implementation in the subsequent years.
- A more participatory action is required to train the farmers with the equipment to conduct various experiment with conservation practices on themselves in their respective farming conditions and contemplate things for themselves. Learning, improving, and standardizing equipment for seed sowing, fertilizer application, irrigation and harvesting with a pledge of minimum soil disturbance through residue management for different agro-ecological conditions will call for successful accomplishment of conservation practices.
- RCT and CA-driven technologies also foster crop diversification that help in knocking off risk, enrichment of biodiversity, diversify income sources through employment generation, and sustaining resource allocation across agro-ecological regions. Such diversification should draw attention from “food security” to “soil, environmental, and livelihood security” i.e. towards an integrated approach.
- The cultivation practices must switch from heavy machinery to conservation-based machinery or equipment that causes minimum soil disturbance. Here comes the crucial need of policy interventions to manufacture these machines at the local level to ensure availability to the small and marginal farmers of the country.
- The government should initiate steps to provide credit support to farmers and FPOs for purchasing various equipment, machinery, and other inputs with reasonable interest rates. The unaffordable farmers should be made inclusive through custom hiring mechanisms or cooperative support.

12.8 Conclusion:

Resource conservation agriculture or RCTs offers a new footstep for sustainable agricultural research and development, as it is less labor-intensive, energy efficient and input responsive, cut down greenhouse gas emission and provides sustainable yields to the farmers without eroding natural resource base and environmental health. Sole application of Resource-conservation technologies may have several advantages as well as drawbacks. However, drawbacks of any single technology can be dispelled by combining different RCTs and the benefits of the technologies may be appreciated for long run. Different RCTs have been successfully applied under different cropping systems and ecological situations around the world giving away sustainable production without much negative environmental alterations. Despite of having certain specific constraints, in recent years its adoption has shown an increment in implementation in the farmer's field across regions and in making available of the equipment and machineries to the small and marginal farmers of the country. The change in traditional mind-set regarding conventional agriculture not only by farmers but also by scientist, extension workers, stakeholders, and policy makers in developing as well as developed countries is a must needed perspective for associated with the development, diffusion and subsequent adoption of appropriate conservation technologies. Developing and promoting conservation systems should be highly the knowledge and skill base which will call for scientists from several disciplines to discourses various difficulties from a system perspective to set research priorities and allocate resources in close partnerships and active participation with the farmers, extension agents and other stakeholders and strengthened knowledge and information-sharing mechanisms. The challenges and constraints for adoption also needs government integrated policy interventions, involvement of private sectors and financial support from them. However, if the development, adoption and diffusion of different RCTs are done properly on a large scale, it will offer farmers and society both possibilities and bring the second green revolution in India.

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