Economics of Conservation Agriculture: An Overview

Singh, K.M. and Meena, M.S.

ICAR-RCER, Patna, Zonal Project Directorate, Jodhpur, India

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K. M. Singh[1] and M. S. Meena[2]

Abstract

Conservation agriculture / RCT offer a new paradigm for agricultural research and development different from earlier one, which mainly aimed at achieving specific food grains production targets. A shift in paradigm has become a necessity in view of widespread problems of resource degradation, which accompanied past strategies to enhance production with little concern for resource integrity. Integrating concerns of productivity, resource conservation and quality and environment is now fundamental to sustained productivity growth. Developing and promoting CA systems will be highly demanding in terms of knowledge base. This will call for greatly enhanced capacity of scientists to address problems from a systems perspective; be able to work in close partnerships with farmers and other stakeholders and strengthened knowledge and information-sharing mechanisms. CA offers an opportunity for arresting and reversing downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource-use-efficient, competitive and sustainable. 'Conserving resources-enhancing productivity' has to be new mission.

Key words: Economics of conservation agriculture, Conservation agriculture, Resource conservation technologies, Benefits of Conservation agriculture.

[1] Principal Scientist (Agricultural Economics) and Head, Division of Socio-Economic, Extension & Training, ICAR-Research Complex for Eastern Region, Patna- (Bihar) 800014, India.
Email: m.krishna.singh@gmail.com
[2] Principal Scientist (Agricultural Extension), Zonal Project Directorate, Jodhpur, India

Introduction

Conservation Agriculture (CA) is an approach for designing and management of sustainable and resource-conserving agricultural systems. It seeks to conserve, improve and make more efficient use of natural resources through integrated management of soil, water, crops and other biological resources in combination with selected external inputs. Such a technological package represents a resource saving and efficient agriculture that contributes to environmental conservation and at the same time enhances production on a sustainable basis. Elements of Conservation Agriculture, *inter-alia*, include improved on-farm water management, minimum tillage, organic soil cover, direct seeding through the crop residue and appropriate crop rotations to avoid disease and pest problems. Burning of crop residues, a common practice in many areas (e.g. rice-wheat cropping system) further causes pollution, Green house gas emission and loss of valuable plant nutrients. When crop residues are retained on the soil surface in combination with no tillage, it initiates processes that lead to improved soil quality and overall resource enhancement. CA has emerged as a new paradigm to achieve goals of sustainable agricultural production. It is a major step towards transition to sustainable agriculture. Therefore, benefits of CA are several folds. Direct benefits to farmers include (i) reduced cost of cultivation through savings in labor, (ii) time and farm power, and (iii) improved use efficiency resulting in reduced use of inputs. More importantly, CA practices reduce resource degradation. CA leads to sustainable improvements in efficient use of water and nutrients by improving nutrient balance and availability, infiltration and retention by the soil, reducing water loss due to evaporation and improving the quality and availability of ground and surface water.

1. Benefits of Conservation Agriculture

1.1 On-farm benefits

- Marked and rapid increase of organic matter content in upper layers of soil and increased biodiversity, number and activity (of earthworms, fungi, bacteria, etc.) in soil.

- Better soil structure and stability of soil aggregates; significantly higher infiltration rates; soil loss reduced by over 80 percent, runoff by 50 percent or more; more intensive but safe use of sloping areas made possible.
- Increase in nutrients stored, greater availability of P, K, Ca, Mg in root zone; less fertilizer needed for same result.
- Better germination and development of plants, better root development and to much greater depth; better resilience of crops in rainless periods due to increased water holding capacity.
- Yields often higher, typically + 20 percent for maize, + 37 percent for beans, + 27 percent for soybean, + 26 percent for onions; with less year-to-year yield variation;
- Reduced variations of soil temperature during day, with positive effects on plants' absorption of water and nutrients.
- Less investment and reduced use of machinery and animals in crop production; reduced costs for labor, fuel and machinery-hours perceptible within 2 years. Operational net margins per ha rose by between + 58 percent and + 164 percent, because of combination of lower cost of production and increase in yields, which provides greater resilience against falling market prices and bad weather.
- Greater flexibility in farm operations especially over optimum dates for planting; increasing possibilities for diversification into livestock, high-value and different crops, vertical integration into product processing and other activities; improved quality of life.

1.2 Off-farm benefits

- Flooding risks reduced by 30-60 percent due to greater rainfall infiltration and delays to overland flows. Extending time of concentration; better recharge of underground aquifers, improving groundwater reserves and dry season flow in springs and streams.
- Less herbicide use after first years; less pesticide use, more recycling of animal wastes; reduction of pollution and eutrophication of surface waters by agricultural

chemicals carried in surface runoff and eroded soil; less sedimentation and infrastructure damage, e.g. silting of waterways, large dams.

- Reduced water treatment costs due to less sediment, less bacterial and chemical contamination.
- Savings of up to 50 percent in costs of maintenance and erosion avoidance on rural roads.
- Reductions in fuel consumption of 50-70 percent or more and proportional reduction in greenhouse gas emissions.
- Reduced pressure on agricultural frontier and reduced deforestation by high-yielding, sustainable conservation agriculture and increased pasture carrying capacity through rotation with annual crops.
- Enhanced diversity and activity of soil biota.
- Reduced carbon emissions through less fuel use and enhanced carbon sequestration by not destroying crop residues and increasing, rather than losing, soil organic matter (FAO, 2001a).

2. World Wide Success of Conservation Agriculture

Conservation agriculture has emerged as an effective strategy to achieve goals of sustainable agriculture worldwide. It has the potential to address increasing concerns of serious and widespread problems of natural resource degradation and environmental pollution, while enhancing system productivity. According to current estimates, Resource Conservation Technology (RCT) systems are being adopted in some 80 million ha, largely in rain-fed areas and area is expanding rapidly. United States of America (USA) has pioneered research and development efforts and currently RCT is being practiced in more than 18 million ha of land. Other countries where RCT practices are being widely adopted include Australia, Argentina, Brazil and Canada. In many countries of Latin America, RCT systems are finding rapid acceptance by farmers. Many countries have now policy decision to promote CA / RCT. In Europe, France and Spain, it was being adopted in about 1 m ha area under annual crops. In Europe, the European Conservation Agriculture Federation, a regional lobby group uniting national associations in UK, France, Germany, Italy, Portugal and Spain, has been founded. RCT is also being adapted to varying extents in countries of Southeast Asia, viz. Japan, Malaysia, Indonesia, Philippines, Thailand, etc. A unique feature which has triggered widespread adoption of RCT systems in many countries is community-led initiative strongly supported by R&D organizations rather than as a result of usual research-extension system efforts.

3. Conservation Agriculture in India

In India, efforts to adopt and promote CA / RCT have been underway for nearly a decade, but it is only in past 4-5 years that technologies are finding acceptance by farmers. This effort has been spearheaded by Rice-Wheat Consortium for Indo-Gangetic Plains, a Consultative Group on International Agriculture Research (CGIAR) eco-regional initiative involving several CG centers and National Agricultural Research Systems of India, Pakistan, Bangladesh and Nepal. Concerns about stagnating productivity, increasing production costs, declining resource quality, declining water tables and increasing environmental problems are major forcing factors to look for alternative technologies, particularly in northwest region encompassing Punjab, Haryana and western Uttar Pradesh (UP). In eastern region covering eastern UP, Bihar and West Bengal, developing and promoting strategies to overcome constraints for continued low cropping system productivity have been the chief concern.

The primary focus of developing and promoting RCT practices has been the development and adoption of zero tillage cum fertilizer drill for sowing wheat crop in rice–wheat system. Other interventions being tested and promoted include raised-bed planting system, laser-aided land-leveling equipment, residue management alternatives, alternatives to rice-wheat cropping system in relation to RCT technologies, etc. The area planted with wheat adopting zero-tillage drill has been rapidly increasing. It is speculated that over past few years, adoption of zero-tillage has expanded to cover about 1 m ha. The processes, however, are slow and results are expected only with time. In India, CA / RCT is a new concept and its roots are only now beginning to find ground. Globally, RCT is being considered a route to sustainable agriculture and offers opportunities for moving to next phase in Indian agriculture.

4. Innovations in Conservation Agriculture

The resource conservation technologies that proved successful in India include watercourse improvement, laser land leveling, zero tillage technology, bed and furrow, irrigation system / bed planting, etc. These techniques have been promoted on pilot basis for efficient utilization of water and other inputs for crop production.

4.1 Laser Land Leveling

Precision land leveling is another resource conservation technology, initially, bucket type soil scrapers were used for precision land leveling, which have now been replaced by laser beam guided automatic scrapers for more precision of land leveling work. Impact assessment studies reveal significant benefits of precision land leveling (Table 1). Keeping in view benefits, it warrants that laser land leveling services are strengthened so that common farmers may harvest the fruits of this modern technique.

Table 1 Benefits of Laser Land Leveling

Sl. No	Particulars	(%)
1	Curtailment in irrigation application losses	25
2	Reduction in labor requirements	35
3	Enhancement in irrigated area	2
4	Increase in crop yield	20

4.2 Zero Tillage

One of main reasons for low yields of wheat in rice-wheat cropping system is delayed planting of wheat due to late maturing of preceding rice crop sown in region besides high cost of land preparations and other inputs. After rice harvest, sufficient residual moisture is generally available to establish new crop. Conventional tillage accelerates soil moisture evaporation and requires extra irrigation water to bring field back to semblance of a seedbed. This causes major delays in wheat sowing, which ultimately affects final crop yields. Decrease in wheat yield @ one percent per day after mid November is well documented due to delay in sowing. Zero tillage is an innovation that not only offers conservation of water and energy resources but also results in better crop yields. This technology had been in use since long in many parts of world and then it was introduced in India. Initial trials were confined to progressive and large farmers. Singh *et al*. (2007) found that farmers had favorable attitude towards zero tillage technology, but non adopters need to be motivated to adopt zero tillage technology. Zero tillage technology has been rapidly accepted by farmers due to its contribution in reducing cost of production, conservation of resources, and improving yields. Malik *et al.* (2005) was in view that a profit-driven advantage of zero tillage technology has allowed small and medium farmers to gain confidence in this technology. Considerable efforts were made to motivate the farmers to adopt zero tillage technology. A faction of experts / scientists has, however, shown its concern regarding negative effects of zero tillage on soil texture, carry over of insect pest on successive crop especially rice stem borer, and higher weed infestation in adopting technology at wider scale.

The situation warrants conducting evaluation studies on this technology for answering any such concerns. Similarly, socio-economic studies may also be conducted by involving farmers who have already tested and adopted zero tillage technology. Private farms with active participation of local community should also come forward to test and evaluate findings of such studies.

4.3 Bed and furrow planting

Bed and furrow planting technologies permit growing of crops on beds with less water. This technique has been tested for various crops and proved quite successful for wheat, maize, rice, etc. Advantages associated with bed and furrow technology of crop production are given below:

- Saving of about 30 percent irrigation water
- Less reduced chances of plant submergence due to excessive rain or over-irrigation
- Lesser crusting of soil around plants and, therefore, more suitable for saline and sodic soils
- Adaptable for various crops without changing basic design / layout of farm
- Enhanced fertilizer use efficiency due to local application
- Minimum chances of crop lodging

4.4 Developing Waste Lands through High Efficiency Pressurized Irrigation Systems

Water is a scarce input for agriculture, especially in rain-fed tracts and areas underlain with brackish groundwater. It must, therefore, be used most optimally for irrigation without wasting a single drop. In most of rain-fed regions, land is undulated and gravity irrigation from tube-wells and other sources is not possible. Likewise, at some locations in irrigated areas where soil is sandy, gravity irrigation results in colossal water wastage due to excessive seepage. If efficient irrigation system is provided under such conditions, crop production can be increased two to three folds.

4.4.1 Sprinkler irrigation technology

Sprinkler irrigation is one of four basic methods of irrigating crops. A sprinkler "throws" water through air to simulate rainfall whereas other three irrigation methods apply water directly to soil, either on or below surface. In certain areas of province fresh groundwater is available at a depth of 10 to 12 meters and soils are light textured. The portable rain gun sprinkler system is highly suitable in such areas. The system is quite simple and has been developed locally.

4.4.2 Drip / trickle irrigation

Under drip / trickle irrigation method, water is applied directly to plants through a number of low flow rate outlets placed at required intervals. Specially designed tricklers supply water to individual plants or to a row of plants from these points. Unlike sprinkler or surface irrigation, only soil near plant is watered rather than entire area. Trickle irrigation has been generally found feasible in more arid regions for irrigating high value crops, such as fruits / nut trees, grapes, sugarcane, flowers, vegetables, etc. It is, however, not yet well adopted for field crops. Drip irrigation can be a great aid for efficient use of water. A well-designed drip irrigation system practically loses no water to runoff, deep percolation, or evaporation. Irrigation scheduling can be precisely managed to meet crop demands, holding promise of increased crop yields and quality. Drip irrigation decreases water contact with crop leaves, stems, and fruits. The conditions, therefore, become less favorable for onset of diseases. Chemicals for controlling insect pests and diseases can be used more efficiently with drip irrigation. Since only crop root zone is irrigated, nitrogen already in soil is less subjected to leaching losses. Nitrogenous fertilizer that is added can also be used more efficiently. Where insecticides are labeled for application through drip irrigation, their lesser quantities may be required to control pests.

5. Management of Crop Residues

Majority of farmers consider crop residues, particularly their large amounts, as unwanted by-products. Time saving and easy handling are quoted as major reasons for burning of left over straw. The practice has, however, been seriously criticized as it significantly increases air pollution. Really, incorporation of stubbles / residues in soil eventually improves physical properties of soil e.g. infiltration rate, soil porosity and water holding capacity. Nitrogen is one of the most important nutrients that is lost through burning and same can be retained / added in soil through residue management. It is reported that nutrient loss due to burning of $1.41m^3$ of wheat stubbles is estimated to be 17.51, 3.69 and 4.15 kg of nitrogen, phosphate and sulfur, respectively. There are evidences that stubble retention increases microbial biomass, which has been correlated with increased nitrogen mineralization, non-symbiotic nitrogen fixation, and microbial diversity. The same in turn results in improved soil fertility / health.

The major losses / damages associated with burning of wheat residues are as under:

- Deterioration of general condition of soil
- Lowering of soil capability / fertility to produce high yields
- Burning of beneficial insects / micro-organisms in soil
- Endangers natural environment
- Considerable financial loss to farmers as residues removed from fields would be used for some other purpose e.g. fodder, straw sale, and kitchen fuel.

5.1 Benefits of Crop Residue Management

Major benefits of management of crop residues are as under:

- Better soil health and productivity
- Addition in organic matter contents

- Enhances infiltration rate
- Improves water and nutrients use efficiency
- Accelerates microbial activity
- Lowers weeds infestation
- Increases yield by 15-20 percent
- Reduces environmental pollution
- Removal of residues can provide additional income from grain recovery and straw sale and also dry feed for livestock.

6. Economics of Conservation Agriculture

CA is an essential part of profitable / successful agriculture. Growing crops represents a significant cost. This cost is affected by the choice of crops and how it is produced, harvested and by other factors. Sorrenson and Montoya, (1989) have narrated potential benefits to application of Residue-Based Zero Tillage Systems as.

- ***Cost of erosion****:* Considering losses of soil of 10 t/ha/year on the 6 million ha and the value of the macronutrients.
- ***Reduction in cost of fertilizers****:* The savings by applying less phosphorus in zero tillage systems.
- ***Elimination of costs of replanting****:* Saving costs of replanting after erosion.
- ***Savings in herbicides****:* The potential saving by planting black oats followed by soybean for weed suppression could be greater than US$5.7 million.
- ***Savings in fuel:*** The estimated reduction in costs of fuel required for soil preparation was greater than US$1.9 million in 1984.
- ***Costs of physical conservation works:*** The savings on constructing and maintaining terraces could reach US$1.2 million. The value of the added production resulting from more land being available because of the reduction in the number of terraces needed, is estimated at approximately US$3.2 million

- ***Increase in production:*** The value of additional production was estimated at a minimum of US$5.7 million in 1984 on the basis of the differences in crops' productivity between direct drilling and conventional cultivation observed in the experiments at IAPAR.
- ***Externalities:*** Eroded soil coming from cropped areas tends to sediment rivers, roads, etc. and increase water pollution.
- ***Analysis of cost-benefit ratio of soil conservation:*** Investments of US$19 million/year would provide a return of 20 percent per year with the widespread adoption of adequate practices (particularly zero tillage and crop rotations) over a time period of 20 years.

A perusal of Table-2 illustrates benefits of ZT in rice crop over conventional puddled rice. The findings of experiments carried out at farmer's field by ICAR-RCER, Patna suggest that despite an additional cash expenditure of Rs.3000 in weeding operations, ZT technology has proved more remunerative to farmers. The same trend can be observed in wheat crop too, and overall benefits accrued due to adoption of ZT technology over conventional methods was a handsome amount of Rs. 6617 per hectare (Table-3).

Table 2: Zero tillage and puddled broadcasted sowing in rice under heavy soils, Patna 2003, (Bihar)

Resource	Benefits Rs. / ha over conventional method (Puddled Transplanted)	
	ZT	Puddled broadcasted
Saving in nursery raising	1140	1140
Saving in land preparation puddling, bund making and nursery uprooting	2850	00
Saving in rice planting / sowing	1200	1800
Saving in weeding	(-) 3000	00
Increase income due to additional yield	2000 (4q / ha)	1000 (2q / ha)
Total gains	4190	3940
Source: Annual report (2003-04) of NATP on *Accelerating the adoption of RCTs for farm level impact on sustainability of Rice-Wheat systems of the Indo-gangetic plains.* Submitted to ICAR RCER, Patna, pp.1-11.		

Table 3: Salient features of zero tillage sowing in wheat under heavy soils, Patna (Bihar)

Sl. No.	Resource	Benefits rates over conventionally sown (Rs./ha)
1.	Land preparation cost including sowing	1200
2.	Saving in Seed	200 (20 kg/ha)
3.	Saving in 1st irrigation	267 (12 lit/ha)
4.	Saving in weeding	200
5.	Increase income due to additional yield	4950 (8q/ha)
6.	Total gains	6617
Source: Annual report (2003-04) of NATP on *Accelerating the adoption of RCTs for farm level impact on sustainability of Rice-Wheat systems of the Indo-gangetic plains.* Submitted to ICAR RCER, Patna, pp.1-11.		

Table 4: Pros and cons of zero tillage, surface seeding and conventional sowing in wheat under heavy soils, Patna, 2003 (Bihar)

Features	Zero tillage	Surface seeding	Conventional sowing
Land preparation cost included sowing (Rs./acre)	240	-	800
Cost of diesel (Rs./acre)	60	-	300
Seed rate (kg / acre)	50	64	60
Advancing sowing date over conventional (days)	10-12	15-22	-
Source: Annual report (2003-04) of NATP on *Accelerating the adoption of RCTs for farm level impact on sustainability of Rice-Wheat systems of the Indo-gangetic plains*. Submitted to ICAR RCER, Patna, pp.1-11.			

Table-4, compares three different technologies for planting wheat in plains of Bihar, a perusal of this table shows, savings in land preparation (Rs.560 per acre), saving in cost of diesel (Rs. 240 per acre), seed rate reduced by almost 10 kg/acre, and due to ZT technology, timely sowing of wheat could be possible, as the sowing date was advanced by almost 10-22 days by adopting CA techniques (ZT and SS). It was also observed by researchers that wheat yields using ZT technology was most remunerative when it was planted between Nov 30th to Dec 7th and yield per ha gradually declines as planting dates are advanced (Table-5). This establishes thinking that ZT technology helps in timely planting of Rabi crops (a non-monetary input) resulting in much higher yield and thereby ensuring higher returns to the farmers (monetary gains). In this way economics of wheat cultivation and rice establishment can be understand through the perusal of table 6 & 7, respectively.

Table 5: Wheat yield under Zero tillage at various sowing dates, Patna, 2002 (Bihar)

Sowing date	No. of villages	No. of Sites	Yield range		Mean yield (q/ha)
			Min.	Max.	
Nov.,30-Dec 07	6	16	33.5	58.2	53.1
Dec., 08-15	9	17	25.2	55.4	49.2
Dec., 16-23	16	68	20.8	51.1	44.2
Dec., 24-31	8	20	18.4	49.0	36.3
Jan 01-08	2	12	14.3	33.4	24.3
Jan 09-16	1	6	11.2	17.4	14.5

Source: Annual report (2003-04) of NATP on *Accelerating the adoption of RCTs for farm level impact on sustainability of Rice-Wheat systems of the Indo-gangetic plains*. Submitted to ICAR RCER, Patna, pp.1-11.

Table 6: Economics of Wheat Cultivation, Patna District (Bihar) India. 2003 (Rs. / acre)

Particular	Range (in Rs.)	Mean
Zero tillage		
Investment	2015-5152	4546
Return	3267-15200	7956
Profit / loss	1062-11800	4522
Conventional tillage		
Investment	1545-5951	3792
Return	2015-8550	4920
Profit / loss	-1136 - 4998	1139

Source: Annual report (2003-04) of NATP on *Accelerating the adoption of RCTs for farm level impact on sustainability of Rice-Wheat systems of the Indo-gangetic plains*. Submitted to ICAR RCER, Patna, pp.1-11.

Table 7: Economics of Rice establishment (Rs. / ha), Patna (2002), Bihar

Sl. No.	Particular	ZT	Direct sowing	Conventional
1.	Land preparation	-	800	800
2.	Nursery raising	-	-	1600
3.	Puddling	-	2000	2000
4.	Bund making	-	800	800
5.	Rice planting / sowing	700	200	600
6.	Weeding pre planting / sowing	800	00	00
7.	Weeding post planting / sowing	500	500	500
	Total	2000	4300	6300
Saving over conventional method		4300	2000	-
Source: Annual report (2003-04) of NATP on *Accelerating the adoption of RCTs for farm level impact on sustainability of Rice-Wheat systems of the Indo-gangetic plains*. Submitted to ICAR RCER, Patna, pp.1-11.				

7. Transition to Conservation Agriculture Will Not Be Easy

Conservation agriculture offers an opportunity and a mission to move into next phase in Indian agriculture in specific context. It is a challenge for all stakeholders, scientific community, farmers, extension agencies and industry to understand opportunities, and calls for strategies different from those we have adopted over past decades in conventional agriculture. The biggest challenge is to overcome past mindset according to which agriculture is nearly synonymous with practice of cultivating soil. CA paradigm will call for an innovation systems perspective to deal with diverse, flexible and context-specific needs of technologies and their management for specific locations. An innovation systems perspective involves understanding of organizations and individuals responsible for generation, diffusion, adaptation, use of knowledge of socio-economic significance and institutional context that governs the way these interactions and processes take place. Research and development for CA thus will need innovative features to address challenges.

7.1 Technological challenges

CA / RCT system constitutes a major departure from past ways of doing things. This implies that whole range of practices, including planting and harvesting, water and nutrient management, disease and pest control, etc. need to be evolved, evaluated and matched in context of new systems. The key challenge relates to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance; developing crop harvesting and management systems with residues maintained on soil surface and developing and continuously improving site specific crops, soil and pest management strategies that will optimize benefits from the new systems.

7.2 Technology adoption

Strategies to promote RCT will call for moving away from conventional compartmentalized and hierarchical arrangements of research that generates and perfects technologies, extension that delivers it and farmers who passively adopt it. There will be need to bring all involved stakeholders on a common platform to conceive end-to-end strategies. Institutionalizing role of research, extension and farmers in such a way that partnership among these stakeholders is strengthened right from beginning, and also enabling a sense of ownership among them.

7.3 Long-term perspective

CA practices, e.g. no tillage and surface-managed crop residues set in processes which initiate changes in soil physical, chemical and biological properties, which in turn affect crop yields. Understanding dynamics of these changes and interactions among physical, chemical and biological phases is basic to developing improved soil-water and nutrient management strategies. Similarly, understanding dynamics of qualitative and quantitative changes in soil biodiversity, disease causing organisms, including weeds in relation to altered management practices is fundamental to evolving control measures with minimum use of environmentally harmful chemicals.

7.4 Site specificity

Adaptive strategies for CA will be highly site-specific, yet learning across sites will be a powerful way in understanding why certain technologies or practices are effective in a set of situations and not effective in another set. This learning process will accelerate building a knowledge base for sustainable resource management. Developing and promoting a networking to share information amongst farmers, scientists and other stakeholders would be critical in advancing spread and continued up-gradation of CA/RCT systems. Understanding the diversity and context-specific nature of processes would be important in learning and changing for better. CA implies a radical change from traditional agriculture. There is need for policy analysis to understand how conservation technologies integrate with other technologies, policy instruments and institutional arrangements that promote or deter CA. Accelerated development and adoption of CA technologies will call for greatly strengthened monitoring and evaluation along with policy research. Understanding constraints in adoption and putting in place appropriate incentives for adopting CA systems will be important.

Conclusions

Conservation agriculture / RCT offer a new paradigm for agricultural research and development different from earlier one, which mainly aimed at achieving specific food grains production targets. A shift in paradigm has become a necessity in view of widespread problems of resource degradation, which accompanied past strategies to enhance production with little concern for resource integrity. Integrating concerns of productivity, resource conservation and quality and environment is now fundamental to sustained productivity growth. Developing and promoting CA systems will be highly demanding in terms of knowledge base. This will call for greatly enhanced capacity of scientists to address problems from a systems perspective; be able to work in close partnerships with farmers and other stakeholders and strengthened knowledge and information-sharing mechanisms. CA offers an opportunity for arresting and reversing downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource-use-efficient, competitive and sustainable. ‘Conserving resources-enhancing productivity’ has to be new mission.

- Availability of machinery / equipment for promotion of resource conservation technologies is a prerequisite for achieving targets of agricultural production. Availability of implement at economical cost is major constraint in promotion of bed planting of crops. Likewise, machinery is not available for crop residue management that is impeding acceleration of this practice.
- Organizing farmers’ days, holding of field demonstrations, cross-farm visits of extension experts and effective use of mass media i.e. print and electronic media for transfer of technology may play a major role in promotion of resource conservation technologies amongst farming community.
- Capacity building of farmers to acquire, test and adopt technologies through participatory approach will enable them to seek resource conservation technologies for their farms and thus they can reduce their production cost and combat production constraints.
- Improvement in coordination among various stakeholders (research, extension service, farmers, service providers, agricultural machinery manufacturers, etc.) for transfer of technologies will play a pivotal role in accelerating adoption of new interventions.

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