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Conservation agriculture in India – Problems, prospects and policy issues

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Abstract

Conservation agriculture (CA) technologies involve minimum soil disturbance, permanent soil cover through crop residues or cover crops, and crop rotations for achieving higher productivity. In India, efforts to develop, refine and disseminate conservation-based agricultural technologies have been underway for nearly two decades and made significant progress since then even though there are several constraints that affect adoption of CA. Particularly, tremendous efforts have been made on no-till in wheat under a rice-wheat rotation in the Indo-Gangetic plains. There are more payoffs than tradeoffs for adoption of CA but the equilibrium among the two was understood by both adopters and promoters. The technologies of CA provide opportunities to reduce the cost of production, save water and nutrients, increase yields, increase crop diversification, improve efficient use of resources, and benefit the environment. However, there are still constraints for promotion of CA technologies, such as lack of appropriate seeders especially for small and medium scale farmers, competition of crop residues between CA use and livestock feeding, burning of crop residues, availability of skilled and scientific manpower and overcoming the bias or mindset about tillage. The need to develop the policy frame and strategies is urgent to promote CA in the region. This article reviews the emerging concerns due to continuous adoption of conventional agriculture systems, and analyses the constraints, prospects, policy issues and research needs for conservation agriculture in India.

Key Words: Conservation agriculture, Conventional agriculture, Constraints, Prospects and policy of CA adoption, Resource use efficiency, Zero tillage

1 Introduction

Attaining food security for a growing population and alleviating poverty while sustaining agricultural systems under the current scenario of depleting natural resources, negative impacts of climatic variability, spiraling cost of inputs and volatile food prices are the major challenges before most of the Asian countries. In addition to these challenges, the principal indicators of non-sustainability of agricultural systems includes: soil erosion, soil organic matter decline, salinization. These are caused mainly by: (i) intensive tillage induced soil organic matter decline, soil structural degradation, water and wind erosion, reduced water infiltration rates, surface sealing and crusting, soil compaction, (ii) insufficient return of organic material, and (iii) monocropping. Therefore, a paradigm shift in farming practices through eliminating unsustainable parts of conventional agriculture (ploughing/tilling the soil, removing all organic material, monoculture) is crucial for future productivity gains while sustaining the natural resources. Conservation agriculture (CA), a concept evolved as a response to concerns of sustainability of agriculture globally, has steadily increased worldwide to cover about ~8% of the world arable land (124.8 M ha) (FAO, 2012). CA is a resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with three interrelated principles, along with other good production practices of plant nutrition and

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pest management (Abrol and Sangar, 2006).

Traditional agriculture, based on tillage and being highly mechanized, has been accused of being responsible for soil erosion problems, surface and underground water pollution, and more water consumption (Wolff and Stein, 1998). Moreover, it is implicated in land resource degradation, wildlife and biodiversity reduction, low energy efficiency and contribution to global warming problems (Boatmann et al., 1999). Hence, conservation agriculture (CA) is a way to cultivate annual and perennial crops, based on no vertical perturbation of soil (zero and conservation tillage), with crop residue management and cover crops, in order to offer a permanent soil cover and a natural increase of organic matter content in surface horizons. The main environmental consequences of this method have been investigated worldwide with the objective of presenting a synthesis of the available studies and documents to the farmers and scientific communities. It stresses the very beneficial impacts of a conservative way of cultivation on the global environment (soil, air, water and biodiversity), compared to traditional agriculture (Derpsch et al., 2010; Derpsch et al., 2011). Further, it also presents the actual gaps or uncertainties concerning the scientists' positions on these environmental aspects.

CA promotes most soils to have a richer bioactivity and biodiversity, a better structure and cohesion, and a very high natural physical protection against weather (raindrops, wind, dry or wet periods). Soil erosion is therefore highly reduced, soil agronomic inputs transport slightly reduced, while pesticide bio-degradation is enhanced. It protects surface and ground water resources from pollution and also mitigates negative climate effects. Hence, CA provides excellent soil fertility and also saves money, time and fossil-fuel. It is an efficient alternative to traditional agriculture, attenuating its drawbacks.

2 Conservation agriculture definition and goals

Conservation agriculture is a management system that maintains a soil cover through surface retention of crop residues with no till/zero and reduced tillage. CA is described by FAO (http://www.fao.org.ag/ca) as a concept for resource saving agricultural crop production which is based on enhancing the natural and biological processes above and below the ground. As per Dumanski et al. (2006) conservation agriculture (CA) is not "business as usual", based on maximizing yields while exploiting the soil and agro-ecosystem resources. Rather, CA is based on optimizing yields and profits, to achieve a balance of agricultural, economic and environmental benefits. It advocates that the combined social and economic benefits gained from combining production and protecting the environment, including reduced input and labor costs, are greater than those from production alone. With CA, farming communities become providers of more healthy living environments for the wider community through reduced use of fossil fuels, pesticides, and other pollutants, and through conservation of environmental integrity and services. As per FAO definition CA is to i) achieve acceptable profits, ii) high and sustained production levels, and iii) conserve the environment. It aims at reversing the process of degradation inherent to the conventional agricultural practices like intensive agriculture, burning/removal of crop residues. Hence, it aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It can also be referred to as resource efficient or resource effective agriculture.

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

Table 1 Some distinguishing features of conventional and conservation agriculture systems

Conventional agriculture	Conservation agriculture
● Cultivating land, using science and technology to dominate nature	● Least interference with natural processes
● Excessive mechanical tillage and soil erosion	● No-till or drastically reduced tillage (biological tillage)
● High wind and soil erosion	● Low wind and soil erosion
● Residue burning or removal (bare surface)	● Surface retention of residues (permanently covered)
● Water infiltration is low	● Infiltration rate of water is high
● Use of e*x-situ* FYM/composts	● Use of *in-situ* organics/composts
● Green manuring (incorporated)	● Brown manuring/cover crops (surface retention)
● Kills established weeds but also stimulates more weed seeds to germinate	● Weeds are a problem in the early stages of adoption but decrease with time
● Free-wheeling of farm machinery, increased soil compaction	● Controlled traffic, compaction in tramline, no compaction in crop area

Continued

Conventional agriculture	Conservation agriculture
● Mono cropping/culture, less efficient rotations	● Diversified and more efficient rotations
● Heavy reliance on manual labor, uncertainty of operations	● Mechanized operations, ensure timeliness of operations
● Poor adaptation to stresses, yield losses greater under stress conditions	● More resilience to stresses, yield losses are less under stress conditions
● Productivity gains in long-run are in declining order	● Productivity gains in long-run are in incremental order

Source: Sharma et al., 2012.

3 Principles of conservation agriculture

Conservation agriculture practices perused in many parts of the world are built on ecological principles making land use more sustainable (Wassmann, 2009; Behera et al. 2010; Lal, 2013). Adoption of CA for enhancing Resource use efficiency (RUE) and crop productivity is the need of the hour as a powerful tool for management of natural resources and to achieve sustainability in agriculture. Conservation agriculture basically relies on 3 principles, which are linked and must be considered together for appropriate design, planning and implementation processes. These are:

3.1 *Minimal mechanical soil disturbance*

The soil biological activity produces very stable soil aggregates as well as various sizes of pores, allowing air and water infiltration. This process can be called "biological tillage" and it is not compatible with mechanical tillage. With mechanical soil disturbance, the biological soil structuring processes will disappear. Minimum soil disturbance provides/maintains optimum proportions of respiration gases in the rooting-zone, moderate organic matter oxidation, porosity for water movement, retention and release and limits the re-exposure of weed seeds and their germination (Kassam and Friedrich, 2009).

3.2 *Permanent organic soil cover*

A permanent soil cover is important to protect the soil against the deleterious effects of exposure to rain and sun; to provide the micro and macro organisms in the soil with a constant supply of "food"; and alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. In turn it improves soil aggregation, soil biological activity and soil biodiversity and carbon sequestration (Ghosh et al., 2010).

3.3 *Diversified crop rotations*

The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro organisms, but also for exploring different soil layers for nutrients that have been leached to deeper layers that can be "recycled" by the crops in rotation. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna. Cropping sequence and rotations involving legumes helps in minimal rates of build-up of population of pest species, through life cycle disruption, biological nitrogen fixation, control of off-site pollution and enhancing biodiversity (Kassam and Friedrich, 2009; Dumanski et. al., 2006).

4 Status of conservation agriculture in India and abroad

Globally, CA is being practiced on about 125 M ha (Table 2). The major CA practicing countries are USA (26.5 M ha), Brazil (25.5 M ha), Argentina (25.5 M ha), Canada (13.5 M ha) and Australia (17.0 M ha). In India, CA adoption is still in the initial phases. Over the past few years, adoption of zero tillage and CA has expanded to cover about 1.5 million hectares (Jat et al., 2012; www.fao.org/ag/ca/6c.html). The major CA based technologies being adopted is zero-till (ZT) wheat in the rice-wheat (RW) system of the Indo-Gangetic plains (IGP). In other crops and cropping systems, the conventional agriculture based crop management systems are gradually undergoing a paradigm shift from intensive tillage to reduced/zero-tillage operations. In addition to ZT, other concept of CA need to be infused in the system to further enhance and sustain the productivity as well as to tap new sources of growth in agricultural productivity. The CA adoption also offers avenues for much needed diversification through crop intensification, relay cropping of sugarcane, pulses, vegetables etc. as intercrop with wheat and maize and to intensify and diversify the RW system. The CA based resource conservation technologies (RCTs) also help in integrating crop, livestock, land and water management research in both low-and high-potential environments.

Table 2 **Global adoption of conservation agriculture systems**

Country	Area (M ha)	% of Global Area
USA	26.5	21.2
Brazil	25.5	20.4
Argentina	25.5	20.4
Australia	17.0	13.6
Canada	13.5	10.8
Russian Federation	4.5	3.6
China	3.1	2.5
Paraguay	2.4	1.9
Kazakhstan	1.6	1.3
Others	5.3	4.2
Total	124.8	100.0

Source: FAO, 2012.

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

Spread of these technologies is taking place in the irrigated regions of the Indo-Gangetic plains where the rice-wheat cropping system dominates. The focus of developing and promoting conservation technologies has been on zero-till seed-cum fertilizer drill for sowing of wheat in rice-wheat system. Other interventions include raised-bed planting systems, laser equipment aided land leveling, residue management practices, alternatives to the rice-wheat system etc. It has been reported that the area planted with wheat adopting the zero-till drill has been increasing rapidly (Sangar et al., 2005), and presently 25% – 30% of wheat is zero-tilled in rice-wheat growing areas of the Indo-Gangetic plains of India. In addition, raised-bed planting and laser land leveling are also being increasingly adopted by the farmers of the north-western region.

5 Potential benefits of CA

Adoption and spread of ZT wheat has been a success story in North-western parts of India due to (1) reduction in cost of production by Rs 2,000 to 3,000 ha^{-1} ($ 33 to 50) (Malik et al., 2005; RWC-CIMMYT, 2005); (2) enhancement of soil quality, i.e. soil physical, chemical and biological conditions (Jat et al., 2009a; Gathala et al., 2011b); (3) enhancement, in the long term C sequestration and build-up in soil organic matter constitute a practical strategy to mitigate Green House Gas emissions and impart greater resilience to production systems to climate change related aberrations (Saharawat et al., 2012); (4) reduction of the incidence of weeds, such as *Phalaris minor* in wheat (Malik et al., 2005); (5) enhancement of water and nutrient use efficiency (Jat et al., 2012; Saharawat et al., 2012); (6) enhancement of production and productivity (4% – 10%) (Gathala et al., 2011a); (7) advanced sowing date (Malik et al., 2005); (8) reduction in greenhouse gas emission and improved environmental sustainability (Pathak et al., 2011); (9) avoiding crop residue burning reduces loss of nutrients, and environmental pollution, which reduces a serious health hazard (Sidhu et al., 2007); (10) providing opportunities for crop diversification and intensification-for example in sugarcane based systems, mustard, chickpea, pigeonpea etc. (Jat et al., 2005); (11) improvement of resource use efficiency through residue decomposition, soil structural improvement, increased recycling and availability of plant nutrients (Jat et al., 2009a); and (12) use surface residues as mulch to control weeds, moderate soil temperature, reduce evaporation, and improve biological activity (Jat et al., 2009b; Gathala et al., 2011b). Because of the ZT wheat benefits, the CA based crop management technologies have been tried in other cropping systems in India (Jat et al., 2011), but there are large knowledge gaps in CA based technologies which indicates there is a need to develop, refine, popularize and disseminate these technologies on a large scale.

Zero tillage is a technology where the crop is sown in a single tractor operation using a specially designed seed-cum-fertilizer drill without any field preparation in the absence of anchored residue at optimum to slightly wetter soil moisture regimes. Experiences from several locations in the Indo-Gangetic plains showed that with zero tillage technology farmers were able to save on land preparation costs by about Rs. 2,500 ($41.7) per ha and reduce diesel consumption by 50 – 60 litres per ha (Sharma et al., 2005). Zero tillage allows timely sowing of wheat, enables uniform drilling of seed, improves fertilizer use-efficiency, saves water and increases yield up to 20%. Success has also been achieved in bed planting of wheat, cotton and rice. This has resulted in savings in irrigation water, improved fertilizer use and reduced soil crusting.

6 Prospects of conservation agriculture

The direction that Asian countries take to meet their food and energy needs during the coming decades will have profound impacts on natural resource bases, global climate change and energy security for India, Asia and the world. These challenges draw attention to the need and urgency to address options by which threats to Indian/Asian agriculture due to natural resource degradation, escalating production costs and climate change can be met successfully. A shift to no-till conservation agriculture is perceived to be of much fundamental value in meeting these challenges. Asian farmers/researchers will continue to need assistance to reorient their agriculture and practices for producing more with less cost through adoption of less vulnerable choices and pathways. Therefore, business as usual with conventional agriculture practices does not seem a sustainable option for sustainable gains in food-grain production, and hence CA-based crop management solutions adapted to local needs will have to play a critical role in most ecological and socio-economic settings of Asian Agriculture. The promotion of CA under Indian/Asian context has the following prospects:

(i) Reduction in cost of production – This is a key factor contributing to rapid adoption of zero-till technology. Most studies showed that the cost of wheat production is reduced by Rs. 2,000 to 3,000 ($ 33 to 50) per hectare (Malik et al., 2005; RWC-CIMMYT, 2005). Cost reduction is attributed to savings on account of diesel, labour and input costs, particularly herbicides.

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

(iii) Saving in water and nutrients – Limited experimental results and farmers experience indicate that considerable saving in water (up to 20% – 30%) and nutrients are achieved with zero-till planting and particularly in laser leveled and bed planted crops. De Vita et al. (2007) stated that higher soil water content under no-till than under conventional tillage indicated the reduced water evaporation during the preceding period. They also found that across growing seasons, soil water content under no-till was about 20% greater than under conventional tillage.

(iv) Increased yields – In properly managed zero-till planted wheat, yields were invariably higher compared to traditionally prepared fields for comparable planting dates. CA has been reported to enhance the yield level of crops due to associated effects like prevention of soil degradation, improved soil fertility, improved soil moisture regime (due to increased rain water infiltration, water holding capacity and reduced evaporation loss) and crop rotational benefits. Yield increases as high as 200 – 500 kg ha^{-1} are found with no-till wheat compared to conventional wheat under a rice-wheat system in the Indo-Gangetic plains (Hobbs and Gupta, 2004). Review of the available literature on CA provides mixed indications of the effects of CA on crop productivity. While some studies claim that CA results in higher and more stable crop yields (African Conservation Tillage Network, 2011), on the other hand there are also numerous examples of no yield benefits and even yield reductions particularly during the initial years of CA adoption.

(v) Environmental benefits – Conservation agriculture involving zero-till and surface managed crop residue systems are an excellent opportunity to eliminate burning of crop residue which contribute to large amounts of greenhouse gases like CO_2, CH_4 and N_2O. Burning of crop residues, also contribute to considerable loss of plant nutrients, which could be recycled when properly managed. Large scale burning of crop residues is also a serious health hazard.

(vi) Crop diversification opportunities – Adopting Conservation Agriculture systems offers opportunities for crop diversification. Cropping sequences/rotations and agroforestry systems when adopted in appropriate spatial and temporal patterns can further enhance natural ecological processes. Limited studies indicate that a variety of crops like mustard, chickpea, pigeonpea, sugarcane, etc., could be well adapted to the new systems.

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

7 Constraints for adoption of conservation agriculture

A mental change of farmers, technicians, extensionists and researchers away from soil degrading tillage operations towards sustainable production systems like no tillage is necessary to obtain changes in attitudes of farmers (Derpsch, 2001). Hobbs and Govaerts (2010) however, noted that probably the most important factor in the adoption of CA is overcoming the bias or mindset about tillage. It is argued that convincing the farmers that successful cultivation is possible even with reduced tillage or without tillage is a major hurdle in promoting CA on a large scale. In many cases, it may be difficult to convince the farmers of potential benefits of CA beyond its potential to reduce production costs, mainly by tillage reductions. CA is now, considered a route to sustainable agriculture. Spread of conservation agriculture, therefore, will call for scientific research linked with development efforts. The following are a few important constraints which impede broad scale adoption of CA.

- Lack of appropriate seeders especially for small and medium scale farmers: Although significant efforts have been made in developing and promoting machinery for seeding wheat in no till systems, successful adoption will call for accelerated effort in developing, standardizing and promoting quality machinery aimed at a range of crop and cropping sequences. These would include the development of permanent bed and furrow planting systems and harvest operations to manage crop residues.
- The wide spread use of crop residues for livestock feed and fuel: Specially under rainfed situations, farmers face a scarcity of crop residues due to less biomass production of different crops. There is competition between CA practice and livestock feeding for crop residue. This is a major constraint for promotion of CA under rainfed situations.
- Burning of crop residues: For timely sowing of the next crop and without machinery for sowing under CA systems, farmers prefer to sow the crop in time by burning the residue. This has become a common feature in the rice-wheat system in north India. This creates environmental problems for the region.
- Lack of knowledge about the potential of CA to agriculture leaders, extension agents and farmers: This implies that the whole range of practices in conservation agriculture, including planting and harvesting, water and nutrient management, diseases and pest control etc. need to be evolved, evaluated and matched in the context of new systems.
- Skilled and scientific manpower: Managing conservation agriculture systems, will call for enhanced capacity of scientists to address problems from a systems perspective and to be able to work in close partnerships with farmers and other stakeholders. Strengthened knowledge and information sharing mechanisms are needed.

8 Challenges in conservation agriculture

Conservation agriculture as an upcoming paradigm for raising crops will require an innovative system perspective to deal with diverse, flexible and context specific needs of technologies and their management. Conservation agriculture R&D (Research and Development), thus will call for several innovative features to address the challenge. Some of these are:

(a) Understanding the system – Conservation agriculture systems are much more complex than conventional systems. Site specific knowledge has been the main limitation to the spread of CA system (Derpsch, 2001). Managing these systems efficiently will be highly demanding in terms of understanding of basic processes and component interactions, which determine the whole system performance. For example, surface maintained crop residues act as mulch and therefore reduce soil water losses through evaporation and maintain a moderate soil temperature regime (Gupta and Jat, 2010). However, at the same time crop residues offer an easily decomposable source of organic matter and could harbour undesirable pest populations or alter the system ecology in some other way. No-tillage systems will influence depth of penetration and distribution of the root system which, in turn, will influence water and nutrient uptake and mineral cycling. Thus the need is to recognize conservation agriculture as a system and develop management strategies.

(b) Building a system and farming system perspective – A system perspective is built working in partnership with farmers. A core group of scientists, farmers, extension workers and other stakeholders working in partnership mode will therefore be critical in developing and promoting new technologies. This is somewhat different than in conventional agricultural R&D, the system is to set research priorities and allocate resources within a framework, and little attention is given to build relationships and seek linkages with partners working in complementary fields.

(c) Technological challenges – While the basic principles which form the foundation of conservation agriculture practices, that is, no tillage and surface managed crop residues are well understood, adoption of these practices under varying farming situations is the key challenge. These challenges relate to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance, developing crop harvesting and management systems.

(d) Site specificity – Adapting strategies for conservation agriculture systems will be highly site specific, yet learning across the 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.

(e) Long-term research perspective – Conservation agriculture practices, e.g. no-tillage and surface-maintained crop residues result in resource improvement only gradually, and benefits come about only with time. Indeed in many situations, benefits in terms of yield increase may not come in the early years of evaluating the impact of conservation agriculture practices. Understanding the dynamics of changes and interactions among physical, chemical and biological processes is basic to developing improved soil-water and nutrient management strategies (Abrol and Sangar, 2006). Therefore, research in conservation agriculture must have longer term perspectives.

9 Policy issues

Conservation agriculture implies a radical change from traditional agriculture. There is need for policy analysis to understand how CA technologies integrate with other technologies, and how policy instruments and institutional arrangements promote or deter CA (Raina et al., 2005). CA offers an opportunity for arresting and reversing the downward spiral of resource degradation, diminishing factor productivity, decreasing cultivation costs and making agriculture more resource – use-efficient, competitive and sustainable. While R&D efforts over the past decade have contributed to increasing farmer acceptance of zero tillage for wheat in rice-wheat cropping systems, this has raised a number of institutional, technological, and policy related issues which must be addressed if CA practices are to be adopted in large scale in the region on a sustained basis. The following are some of the important policy considerations for promotion of CA.

- Scaling up conservation agriculture practices: Efforts to adapt the CA principles and technological aspects to suit various agro-ecological, socio-economic and farming systems in the region started a few decades ago. Greater support from stakeholders including policy and decision makers at the local, national and regional levels will facilitate expansion of CA and help farmers to reap more benefits from the technology. In India much research work on CA has been conducted for more than a decade, mostly at the *Indian Agricultural Research Institute.* However, its percolation to farmers is very limited. There is a need to think about the problems faced at the implementing level and devise a strategy involving all who are concerned. Most cases, where changes in favour of CA have occurred, are limited in success. FAO (2001) have reported that this is partly because policy environments are not favorable. One of the reasons for poor percolation of the technology to the farmers was the past bias or mindset about tillage by the majority of farmers (Hobbs and Govaerts, 2010). Under such situations, farmers participatory on-farm research to evaluate/refine the technology in initial years followed by large scale demonstration in subsequent years is needed. In India, efforts are being initiated through a network research project for on-farm evaluation and demonstration of CA technology for its promotion.
- Shift in focus from food security to livelihood security: Myopic “food security” policy based on cereal production must now replace a well-articulated policy goal for livelihood security. This will help the

diversification of dominant rice-wheat cropping systems (occupying about 10.5 million ha) in the Indo-Gangetic Plains, the cultivation of which in conventional tillage practice has overexploited the natural resources in the region. The nature of cropping patterns and the extent of crop diversification are influenced by policy interventions. The government policies that directly or indirectly affect crop diversification are: pricing policy, tax and tariff policies, trade policies and policies on public expenditure and agrarian reforms (Behera et al., 2007).

- CA offers opportunities for diversified cropping systems in different agro-ecoregions. Developing, improving, standardizing equipment for seeding, fertilizer placement and harvesting ensuring minimum soil disturbance in residue management for different edaphic conditions will be key to success of CA. For many situations for example, in hilly tracts, for small land holders bullock drawn equipment will have greater relevance. Ensuring quality and availability of equipment through appropriate incentives will be important. In these situations, the subsidy support from national or local government to firms for developing low cost machines will help in the promotion of CA technologies.
- CA technologies bring about significant changes in the plant growing micro-environment. These include changes in moisture regimes, root environment, emergence of new pathogens and shift in insect-pest scenario etc. The requirement of plant types suited to the new environment, and to meet specific mechanization needs could be different. There is a need to develop complementary crop improvement programmes, aimed at developing cultivars which are better suitable to new systems. Farmers-participatory research would appear promising for identifying and developing crop varieties suiting to a particular environment or locations.
- There is a need for generating a good resource database with agencies involved complementing each others' work. Besides resources, systematic monitoring of the socio-economic, environmental and institutional changes should become an integral part of the major projects on CA.
- Policy support for capacity building by organizing training on CA is needed. Availability of trained human resources at ground level is one of the major limiting factors in adoption of CA. Training on CA should be supported at all levels. Efforts to adequately train all new and existing agricultural extension personnel on CA should be made in relevant departments. Consideration of extension approaches such as the 'Lead Farmer Approach' should also be made as a way to mitigate extension shortages at the local level. In the long term, CA should be included in curricula from primary school to university levels, including agricultural colleges. Inclusion of conservation and sustainability concepts in the course curricula with a suitable blend of biophysical and social sciences would be important for sustainable resource management.
- Institutionalize CA: CA has to be mainstreamed in relevant ministries, departments or institutions and supported by adequate provision of material, human and financial resources to ensure that farmers receive effective and timely support from well trained and motivated extension staff. Key local, regional and national institutions should have dedicated CA champions among their staff who will help to ensure that relevant plans, programmes and policies embrace CA. In the short to medium term, policy makers could support activities of national and regional CA working groups to ensure that relevant thematic (research, technical, extension, training, education, input and output markets, policy) areas are covered by various CA programmes. Institutionalizing CA into relevant government ministries and departments and regional institutions is required for sustainability of the technology. Local, national and regional policy and decision makers could spearhead and support the formulation and development of strategies and mechanisms for scaling up the technology. CA could be integrated into interventions such as seed, fertilizer and tillage and draft power support programmes as a way of further enhancing productivity.
- Support for the adaptation and validation of CA technologies in local environments: Adaptive research is required to tailor CA principles and practices to local conditions. This should be done in collaboration with local communities and other stakeholders. Issues that should be addressed include crop species, selection and management of crop and cover crop and rotations, maintenance of soil cover and CA equipment. The resource poor and small holder farmers in India do not have economic access to new seeds, herbicides and seeding machineries etc. (Sharma et al., 2012). This calls for policy frame work to make easily available critical inputs.
- Support the development of CA equipment and ensure its availability: While some countries produce

CA equipment, most of the available implements and equipment are imported. In the short term, consideration could be made on removing or reducing tariffs on imported CA equipment and implements to encourage and promote their availability. In the medium to long run, local manufacture of these will increase availability, ensure that equipment is adapted to local conditions, increase employment opportunities and reduce costs. The larger and more complex equipment is expensive and users may have to hire it. There is an opportunity to develop a local hire service industry by providing equipment, and training on machine maintenance and business skills. Where governments support land preparation schemes using ploughs, there is scope to change the equipment to rippers or direct seeders to reduce the cost and align the schemes to CA approaches. In India, significant efforts have been made in developing, refining and promoting the second generation zero-till multi-crop planters, but quality control assurance on standards and their availability at the local level with after-sale services and spare parts is still an issue. The new machineries, viz. happy seeder, turbo seeder, laser land leveler etc. are found useful for CA practices, but these machines are more suitable for rich and medium to large farmers groups. These machines need more horse power (>50) for smooth functioning in field conditions. Small and marginal farmers having small holdings and economic limitations are unable to afford for such heavy machines. They need smaller versions of these machines which needs policy support for manufacturing at the local level.

- Promote payments for environmental services (PES) and fines for faulty practices: Adopters of CA improve the environment through carbon sequestration, prevention of soil erosion or the encouragement of groundwater recharge. It provides ecosystem services, thus, farmers could be rewarded for such services, which have a great impact on the quality of life for all.

  Continuous rice-wheat (RW) cropping in an area of 13.5 million ha with intensive tillage has resulted in over exploitation of resources, a decline of productivity, loss of soil fertility and biodiversity, and a decline of resource use efficiency in the Indo-Gangetic plains of South Asia. This has led to un-sustainability of agriculture in the region. Additionally, burning of huge quantities of crop residues has adverse environmental impacts. In a prosperous state like Punjab in India, 81% of the rice straw (crop residue) is burnt, leading to the loss of a huge quantity of nutrients and pollution of the environment (Yadvinder-Singh et al., 2005). Incorporation of crop residues is being considered as an alternative to burning and alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations (Yadvinder-Singh et al., 2005). There is a need for a strong policy intervention for prohibiting such an unscientific practice by imposing a fine.

- Building partnership: CA systems are very complex and their efficient management needs understanding of basic processes and component interactions which determine the system performance. A system perspective is the best to build working in partnership with farmers, who are at the core of farming systems and best understand this system. Scientists, farmers, extension agents, policy makers and other stakeholders in the private sector working in partnership mode will be important in developing and promoting new technologies. As FAO (2005) reported, the challenge is for would-be advisers to develop a sense of partnership with farmers, participating with them in defining and solving problems rather than only expecting them to participate in implementing projects prepared from outside. Instead of using a top-down approach where the extension agent places CA demonstrations in farmer fields and expects the farmer to adopt, a more participatory system is required where the farmers are enabled through provision of equipment and training to experiment with the technology and find out for themselves whether it works and what fine-tuning is needed to make it successful on their land.
- Credit and subsidy: The other important thing for successful adoption of CA is the need to provide credit to farmers to buy the equipment, machinery, and inputs through banks and credit agencies at reasonable interest rates. At the same time government need to provide a subsidy for the purchase of such equipment by farmers. For example, the Chinese government in recent years adopted a series of policy and economic measures to push CA techniques in the Yellow River Basin and is providing a subsidy on CA machinery and imparting effective training to farmers (Yan et al., 2009). This resulted in a considerable increase in area under CA. Currently in Shanxi, Shandong and Henan provinces over 80% area under maize cultivation depends on no till seeder.

10 Conclusion

Conservation agriculture offers a new paradigm for agricultural research and development different from the conventional one, which mainly aimed at achieving specific food grains production targets in India. A shift in paradigm has become a necessity in view of widespread problems of resource degradation, which accompanied the past strategies to enhance production with little concern for resource integrity. Integrating concerns of productivity, resource conservation and soil quality and the environment is now fundamental to sustained productivity growth. Developing and promoting CA systems will be highly demanding in terms of the 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. Conservation agriculture offers an opportunity for arresting and reversing the 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 the new mission.

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