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CONSERVATION AGRICULTURE: IT'S IMPACT ON PRODUCTIVITY AND AGRO-ECOLOGICAL SYSTEMS

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Abstract: *The conventional mode of agriculture through intensive agricultural practices was successful in achieving goals of production, but simultaneously led to degradation of natural resources. The growing concerns for sustainable agriculture have been seen as a positive response to limits of both low-input, traditional agriculture and intensive modern agriculture relying on high levels of inputs for crop production. Sustainable agriculture relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes, such as nitrogen fixation, nutrient cycling, soil regeneration, and protection of natural enemies of pest and diseases as well as the targeted use of inputs. Agricultural systems relying on such approaches are not only able to support high productivity, but also preserve biodiversity and safeguard the environment. Conservation agriculture has come up as a new paradigm to achieve goal of sustained agricultural production. It is a major step toward transition to sustainable agriculture. Indian agriculture is entering a new phase. The major research and development efforts in the 'Green revolution' era focused on enhancing productivity of selected food grains and few other crops. The new challenges demand that efficient resource use and conservation receive high priority to ensure earlier gains can be sustained and further enhanced to meet the emerging needs. Issues of conservation have assumed importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Over the past three decades or so, internationally, rapid strides have been made to evolve and spread resource conservation technologies like zero and reduced tillage systems, better management of crop residues and planting systems, which enhance conservation of water and nutrients. Conservation agriculture (CA) which has its roots in universal principles of providing permanent soil cover (through crop residues, cover crops, agro forestry), minimum soil disturbance and crop rotations is now considered the principal road to sustainable agriculture: a way to achieve goals of higher productivity while protecting natural resources and environment. Conservation agriculture is currently practiced on more than 80 million ha worldwide in more than 50 countries and the area is expanding rapidly.*

I INTRODUCTION

Indian agriculture is entering a new phase. The major research and development efforts in the 'Green revolution' era focused on enhancing productivity of selected food grains and few other crops. The new challenges demand that efficient resource use and conservation receive high priority to ensure earlier gains can be sustained and further enhanced to meet the emerging needs. Issues of conservation have assumed importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Over the past three decades or so, internationally, rapid strides have been made to evolve and spread resource conservation technologies like zero and reduced tillage systems, better management of crop residues and planting systems, which enhance conservation of water and nutrients. Conservation agriculture (CA) which has its roots in universal principles of providing permanent soil cover (through crop residues, cover crops, agro forestry), minimum soil disturbance and crop rotations is now considered the principal road to sustainable agriculture: a way to achieve goals of higher productivity while protecting natural resources

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Conservation Agriculture (CA) is, to those who know it, the best bet for a sustainable and productive agriculture. People refer to CA as a win-win agricultural production system and it is successfully applied on more than 100 million hectares in so many different agro ecosystems and cropping systems that the reason and justification for soil tillage should become weaker and weaker. Good monsoon between 2005-06 and 2008-09 and the efforts of our farmers led to consistent increase in food production during the period and a record production of 233.88 million tones of food grains in 2008-09. Notwithstanding the fact that the south-west monsoon was the most deficient since 1972, by 23 per cent compared to the long period average (LPA), the overall agricultural gross domestic product (GDP) is estimated to have fallen by only 0.2 per cent in 2009-10 (advance estimates) as against the previous years growth rate of 1.6 per cent. Food grain area sown in kharif season declined by 6.5 per cent compared to last year and food production is expected to be short by 16 per cent compared to the fourth advance estimates of 2008-09. Rising food prices, spurred by expectations of shortfall in food production, have brought the issues of food security, food stocks management and need for improving food production and productivity to the forefront of national strategy.

II CONSERVATION AGRICULTURE - THE NEW PARADIGM

Over the past 2-3 decades globally, conservation agriculture has emerged as a way for transition to the sustainability of intensive production systems. The term 'Conservation Agriculture' (CA) refers to the system of raising crops without tilling the soil while retaining crop residues on the soil surface. Land preparation through precision land leveling and bed and furrow configuration for planting crops further enables improved resource management.

The key features which characterize CA include:

- **a)** minimum soil disturbance by adopting no-tillage and minimum traffic for agricultural operations,
- **b)** leave and manage the crop residues on the soil surface, and
- **c)** adopt spatial and temporal crop sequencing/crop rotation to derive maximum benefits from inputs and minimize adverse environmental impacts.

Conservation agriculture permits management of soils for agricultural production without excessively disturbing the soil, while protecting it from the processes that contribute to degradation e.g. erosion, compaction, aggregate breakdown, loss in organic matter, leaching of nutrients etc. Conservation agriculture is a way to achieve goals of enhanced productivity and profitability while protecting natural resources and environment, an example of a win situation. In the conventional systems, while soil tillage is a necessary requirement to produce a crop, tillage does not form a part of this strategy in CA. In the conventional system involving intensive tillage, there is a gradual decline in soil organic matter through accelerated oxidation and burning of crop residues causing pollution, green house gases emission and loss of valuable plant nutrients. When the crop residues are retained on soil surface in combination with no tillage, it initiates processes that lead to improved soil quality and overall resource enhancement.

Benefits of CA have been demonstrated through its large-scale adoption in many socioeconomic and agro-ecological situations in different countries the world over.

Benefits to Farmers

These include:

1. Reduced cultivation cost through savings in labour, time and farm power.
2. Improved and stable yields with reduced use of inputs (fertilizers, pesticides).
3. In case of mechanized farmers, longer life and minimum repair of tractors and less water, power and much lower fuel consumption.
4. Benefits of CA come about over a period of time and in some cases, might appear less profitable in the initial years.

Benefits to Natural Resources

These include:

1. Reduced soil degradation through reduced impact of rainfall causing structural breakdown, reduced erosion and runoff.
2. Gradual decomposition of surface residues leading to increased organic matter and biological activity resulting in improved capacity of soils to retain and regulate water and nutrient availability and supply.
3. Improved biological activity and diversity in the soil including natural predators and competitors.
4. Reduced pollution of surface and ground water from chemicals and pesticides, resulting from improved inputs use efficiency.
5. Savings in non-renewable energy use and increased carbon sequestration.

Conservation agriculture aims at reversing the process of degradation inherent to the conventional agricultural practices like intensive cultivation, and burning and/or removal of crop residues. Aggressive seed bed preparation with heavy machinery lead to declining soil fertility, biodiversity and erosion. Conservation agriculture leads to sustainable improvements in the efficient use of water and nutrients by improving nutrient balances, and availability, infiltration and retention by soils reducing water losses due to evaporation and improving the quality and availability of ground and surface water.

Attempts to promote CA globally are underway as reflected from developments worldwide. In this context, the Food and Agriculture Organization (FAO) of UN took an initiative to organize the First World Congress on Conservation Agriculture in Europe (Madrid, Spain) in 2001. The objective was to bring together farmers, scientists, private sector stakeholders and decision makers to share information and experiences and to encourage interaction for future research and development efforts. The Second Congress was held in South America (Brazil) in 2003 and third is scheduled to be held in Africa (Kenya) in 2005. In South Asia, initiatives to promote CA related activities are relatively recent. The aim of the National Conference on Conservation Agriculture was to take a stock of current status in the region and think of ways to move forward.

III CONSERVATION AGRICULTURE

Conservation agriculture has the potential to emerge as an effective strategy to address the increasing concerns of serious and widespread degradation of natural resources and environmental pollution, which accompanied the adoption and promotion of green revolution technologies since early seventies. The key challenge today is to adopt strategies that will address the twin concerns of maintaining and enhancing the integrity of natural resources and improved productivity, while improvement of natural resources taking a lead as it forms the very basis for long-term sustained productivity. Problems of resource degradation are widespread both in the irrigated and rain fed ecologies. While maintaining and further enhancing productivity in the well endowed areas without adversely impacting resource base and environment is the key issue, reversing resource degradation process and enhancing soil quality appears a pre-requisite for achieving significant productivity gains in majority of rain fed areas.

Resource degradation problems are manifesting in several ways. Declining water tables in many agriculturally important regions imply increasing pumping costs, replacement of shallow gravity tube wells with submersible pumps at huge cost, adverse effects on water quality and overall ecology of the region. Declining soil carbon and fertility are reflecting in declining soil bio-diversity, multiple nutrient deficiencies, need for increasing inputs use to maintain yields and implications for quality of produce and environment. Inefficient input use and management practices are leading to widespread contamination of surface and groundwater with connected health hazards. Rainfall runoff and erosion of surface soil remains a major factor for continued low productivity, more so in rain fed areas. That there is a strong connection between resource degradation, poverty and livelihood opportunities is now being understood and appreciated. The need for developing and promoting technologies which can reverse the processes leading to resource degradation is urgent. Conservation agriculture has emerged a major way forward from existing unsustainable mode of agriculture.

IV CONSTRAINTS TO CONSERVATION AGRICULTURE

Farmers in a country or region, where CA is not practiced, face a number of problems which make adoption difficult. These problems are of diverse nature, such as intellectual, social, biophysical and technical, financial, infrastructural and policy. Most farmers are facing several of these problems, if not all, at the same time to the effect that only very few bold pioneer farmers adopt CA. Farmers are not in the position to start with a blank sheet and to weigh objectively the merits and disadvantages of CA against conventional tillage farming. In all cases CA is the new unknown concept, while the default condition for more than 90% of the world's farmers is the conventional tillage-based practice which has worked for them so far.

Intellectual Constraints

New technologies that lead to immediate fast adoption often show obvious advantages resulting in fast acceptance and enthusiasm. In many cases this enthusiasm cools down, once the new technology is known and the downsides become visible. With CA it is just the opposite way: it contradicts so much of the knowledge a farmer has learned and been told that the benefits offered by CA are not obvious in the beginning. However, once the step-wise adoption begins, CA improves its performance over time. The more experience producers have with CA, the more convinced and positive is their opinion about it. The less practical experience people have with CA, the more critical and negative is their attitude towards it. A study carried out with European and American no-till farmers and agricultural experts came to similar conclusions. It was found that the experts, mostly without practical experience in CA, anticipated many problems for its adoption. In their perception actually the problems exceeded the benefits leading to an overall negative attitude. Farmers, however, who were actually practicing CA and had experience with the system, had an overall positive perception with the benefits clearly dominating and the problems being manageable (Tebrügge and Böhrnsen 2000).

CA has actually two intellectual barriers to overcome: the first is that CA concept and principals are counterintuitive and contradict the common tillage-based farming experience, which has worked for generations and which often has created cultural values and rural traditions; the second is the lack of experiential knowledge about CA and the mechanism to acquire it. Soil tillage, and particularly the plough, has in most countries become part of the culture of crop production. Ploughing, cultivation and tillage are often synonyms for growing a crop. Cropland is called “arable” land which is Latin for “ploughable” land. The plough has been part of the very early developments of agriculture and has the character of a brand symbol for what is ‘correct’. It is therefore difficult for people to accept that all of a sudden the plough is dangerous and that a crop can grow without tilling the land. Overcoming this “mental compaction” is often much more difficult than actually physically starting with no-till farming (Landers 2001). Unless a person has seen it happen, it is very difficult to imagine a soil becoming softer and better structured without being tilled.

The second intellectual impediment to adoption is simply the lack of sufficient experiential knowledge about it at all and the means of acquiring it. Globally some 7% of the agricultural land is under CA. The adoption is concentrated in some few countries, eventually reaching adoption levels beyond 50%, while in the rest of the world the adoption is at levels below 2%. This explains that most people have never seen a CA system in practice. Since it is also not yet represented in any labels or certification schemes or has any direct relevance to consumers, CA hardly appears in the media. CA is also not included in university curricula even in good agricultural universities. This explains that, despite having an adoption level more than twice that of organic farming, the public knowledge about CA is much lower than about organic farming. Even most agricultural professionals and many farmers have never heard about CA, and if they have, they have only vague ideas. Permanent no-tillage farming and CA are often simply not known and therefore not on the screen as an option for farmers. For actual adoption of CA the farmer would not only need to know about CA elements in general, she/he would need to know the details on how to implement CA elements under the specific conditions of an individual farm. This knowledge is generally not available as a standard technology package off-the-shelf. Worse, CA is a complex and management intensive farming concept in which crop management has to be planned ahead and is mostly proactive and not reactive, as in the standard tillage-based systems. Problems of soil compaction or uneven surface in tillage-based systems are corrected with tillage, in no-till systems they have to be prevented from occurring from the start. Weed and pest management in conventional tillage systems is often based on chemical or mechanical control as response to the incidence, while in CA the incidence of weeds and other pests is reduced by forward planning of crop rotations. This increased complexity requires a degree of experience and knowledge, which has to be acquired and learned. For early adopters this learning process and experiential knowledge has therefore involved a lot of trial and error until sufficient local experience and knowledge is accumulated to make the adoption easier. However, the solutions to these practical problems are best developed by the farmers themselves and not by scientists. Usually farmer's own adaptive "research and development" process leads to quicker and more applicable results than the so called 'Green Revolution' approach of leaving the development of a standard technology package "ready for adoption" to the scientific community.

To effectively cope with the diverse agro-ecological and socio-economic conditions of farming environments when considering system level alternatives and changes, *flexible* approaches to on-farm testing and dissemination are required. This is particularly so when knowledge-intensive, integrated practices involving the simultaneous management of several elements are being introduced as is the case with CA, and the elements concerned cannot be reduced to standardized technology package intended for wide applicability (Stoop *et al.*2008). The same accounts for other complex and management intensive concepts, such as integrated pest management (IPM), which has been successfully introduced by FAO through a network of Farmer Field Schools (FFS) first in Asia. (van den Berg and Jiggins, 2007) and more recently in Africa. Another more recent example is the System of Rice Intensification (SRI) with similar levels of complexity and need for local adaptation paired with the problem of being counterintuitive (Stoop *et al.* 2008). Thus, a relatively large variation in the implementation and performance of CA practices in farmers' fields is an obvious and logical consequence of this dissemination approach, partly also because the new balances and equilibrium as well as full benefits that such practices are expected to offer take time to establish. Therefore, economic assessments and adoption studies based on aggregated results over relatively short periods of time will further contribute to biased and/or pre-mature, generalised conclusions with regards to production potentials, agronomic feasibility and future prospects.

Social Constraints

Farming communities in the developing regions are mostly conservative and risk averse. Any farmer doing something fundamentally different from the others will therefore risk being excluded from the community. Only very strong and individually minded characters would take that step, which leads to social isolation and sometimes even to mocking.

Even if those individuals have visible success, the aversion created in the community and the peer pressure can result in other farmers not following. The pressure can be so bad that the community gets jealous of the success and instead of also adopting it, it leads to boycott including using 'black magic' and placing bad spells on the fields. For adoption of CA it is therefore not enough to find any progressive farmer who will prove the concept to work, but the farmer must have a socially important role, and be respected and integrated in the community. Ideally the community should be involved from the very beginning to avoid this kind of antagonism. Other problems can be traditional land tenure systems, where there is no individual ownership of land, which lowers the incentives of farmers to invest in the long term improvement of soil health and productivity. Also communal grazing rights, which often include the right to graze on crop residues or cover crops after the harvest of the main crop, create conflicts which make it difficult for the uptake of CA practices. These problems can be real impediments to the adoption of CA and conflicts arising, for example, from alternative uses of crop residues as mulch or animal feed cannot be solved by orders or directives. Even physical protective structures such as fences might not be the optimal solution, if they work against the traditional social values of the respective cultures. Much more important in the process is that the entire community first understands the issues and the changes and benefits involved in adopting CA and jointly looks for solutions.

Biophysical and Technical Constraints

Although the concept of CA is universally applicable, this does not mean that the techniques and practices for every condition are readily available. In most cases the actual CA practice has to be developed locally, depending on the specific farming situation and agro-ecological conditions. Especially the crop rotations, selections of cover crops, issues of integration of crop and livestock have to be discovered and decided upon by the farmers in each location. A diversity of problems arises, very often around weed management, residue management, equipment handling and settings, planting parameters like timing and depth, which all have to be discovered new. This creates the problem that extension agents and advisors in the beginning, when CA is newly introduced in a region, cannot give specific advice on practices, but have to develop these practices together with the farmers. On the other side such an approach, if correctly applied, is much quicker and more sustainable than the development of specific practices by scientists, since it uses the immense pool of experience and innovation potential of the farmers' community. In this way some cover crops have been developed from weeds, or practices such as growing paddy rice or potatoes under no-till in CA have been developed by farmers without the scientists even thinking of proposing such innovations. Another technical constraint is the simple unavailability of certain technologies or inputs, apart from the financial or other constraints. In many countries where farmers start with CA there are no seeds available for cover crops. Also the availability of equipment, especially no till direct seeding equipment, often is a problem. By now there are technologies available for most situations, somewhere in the world. However, in a specific location farmers might not be aware of these technologies or they simply have no way to access them. This is were usually external support such as knowledge sharing or eventually even the introduction of specific technologies, such as direct seeding equipment, is required.

Financial Constraints

Although the profitability of CA is usually higher than for conventional farming practice there are still financial hurdles to adoption, depending of the availability of capital to invest into this change of production system. These constraints exist at all farm size levels, though obviously to different degrees and for different purposes. Changing a production system to CA is a long term investment. In many cases the rationale for the change is the degradation of the natural resources, especially of soil and water, as a result of the previous tillage-based agriculture. In order to start with CA and to successfully create favourable conditions for the soil life and health to return, some initial investment into the land might be necessary, such as breaking existing compactions by ripping, correction of soil pH or extreme nutrient deficiencies, leveling and shaping of the soil surface for the cropping system foreseen under CA.

Especially for small subsistence farmers the capital for this kind of investment is not available. In addition to this, the farmer needs new equipment, while most of the existing equipment is becoming obsolete and will most likely not find an attractive second hand market for.. The larger the farmer, the more important is this hurdle, since a no-till seed drill for example is considerably more expensive than a conventional one. This conflict between the potential improved profit margin on one side and the very concrete and actual investment requirements on the other side often leads to the fact that farmers decide not to change to CA, even though they are convinced about the benefits. The provision of credit facilities for these cases is one solution, but sometimes also the availability of contractor services or technical advice on how to adapt and modify existing equipment as a low cost intermediate solution to start can help. The modification of existing equipment has, for example in Brazil and in Kazakhstan, provided an entry point for some farmers to start with CA and then, after benefiting from the higher profitability, making the investment into proper equipment at a later stage. Especially for small farmers the home made solutions for simple CA farm tools are an important element for CA adoption in Paraguay (Lange and Meza, 2004).

Infrastructural Constraints

As with any agricultural production system, CA also requires certain exogenous inputs to achieve intensive production levels. CA is capable of improving the soil and crop growth conditions for production and the efficiency of the natural resource and input use, but it is not a 'perpetual motion' process which would allow crop intensification from endogenous resources. If CA is therefore meant to sustainably intensify agricultural production, a suitable market and service infrastructure must be in place to provide inputs and to allow the processing and marketing of the produce. Without any external inputs, CA systems will still perform better than conventional tillage-based methods, but this will be at a much reduced level. Some of the inputs like the types of fertilizers will differ only marginally from the requirements of conventional tillage-based farming. Other inputs, however, such as herbicides, seeds for cover- and rotational crops and especially equipment for direct seeding, planting and residue management are often completely different to the traditionally used ones and have to be introduced to the markets. This requires not only a good input supply infrastructure, but also a proactive attitude of the supply sector, such as dealers and manufacturers. Otherwise a chicken-and-egg situation is created where the supply sector does not offer certain inputs because there is no market for them, but the farmers are also not demanding the items because they are not being offered. This deadlock often requires some external intervention mostly in stimulating the demand, but also in assisting the supply sector in making inputs commercially available. This includes, besides the collaboration with the farming sector, a close collaboration with the commercial input supply sector and some supportive policies.

Policy Constraints

Adoption of CA can take place spontaneously, but it usually takes a very long time until it reaches significant levels. Adequate policies can shorten the adoption process considerably, mainly by removing the constraints mentioned previously. This can be through information and training campaigns, suitable legislations and regulatory frameworks, research and development, incentive and credit programmes. However, in most cases policy makers are also not aware about CA and many of the actually existing policies work against the adoption of CA. Typical examples are commodity related subsidies, which reduce the incentives of farmers to apply diversified crop rotations, mandatory prescription for soil tillage by law, or the lack of coordination between different sectors in the government. There are cases where countries have legislation in place which supports CA as part of the programme for sustainable agriculture. If those countries, within the same Ministry of Agriculture, have then also a programme to modernize and mechanize agriculture, it usually happens that the first items introduced under such a mechanization programme are tractors with ploughs or disk harrows. This does not only give the wrong signal, but it works directly against the introduction and promotion of CA, while at the same time an opportunity is missed to introduce the tractors with no-till seeders instead of the plough, helping in this way to overcome this technology constraint.

Countries, with their own agricultural machinery manufacturing sector, also often apply high import taxes on agricultural machinery to protect their own industry. This industry often has no suitable equipment for CA available in the short term, but due to the high import taxes the importation of equipment from abroad is made impossible to the farmers who wish to adopt CA. In other cases the import tax for raw material might be so high that the local manufacturing of CA equipment becomes unfeasible. In all those cases regulations have to be revised even beyond the influence of the Ministry of Agriculture, which often proves very difficult. Policymakers and legislators must be made aware of CA and its ramifications to avoid such contradictory policies. Where farmers do not only farm their own land, but rent land from others, there are additional problems with the introduction of CA: the building up of soil organic matter under CA is an investment into soil fertility and carbon stocks, which so far is not recognized by policy makers, but increasingly acknowledged by other farmers. Farmers who still plough know that by ploughing up these lands the mineralization of the organic matter acts as a source of plant nutrients, allowing them to "mine" these lands with reduced fertilizer costs. This allows them to pay higher rent for CA land than the CA farmer is able to do. Such cases can be observed in "developing" African countries as well as in "developed" European ones. To avoid this some policy instruments are required to hold the land owner responsible for maintaining the soil fertility and the carbon stock in the soil, which in absence of agricultural carbon markets is difficult to achieve.

V CONSERVATION AGRICULTURE IN AGRO-ECOLOGICAL SYSTEMS

Rain fed Semi-arid and Arid Regions

Rain fed semi-arid and arid regions are characterized by variable and unpredictable rainfall, structurally unstable soils and low overall productivity. Results of most research station studies show that zero/ reduced tillage system without crop residues left on the soil surface have no particular advantage because much of the rainfall is lost as runoff due to rapid surface sealing nature of soils. It would therefore appear that no tillage alone in the absence of soil cover is unlikely to become a favoured practice. However, overall productivity and residue availability being low and demand of limited residues for livestock feed being high also poses a major limitation for residue use as soil cover in the arid and semi-arid regions. In the semi-arid regions there is wide variability in rainfall and its distribution and nature of soils. It would appear that there is need to identify situations where availability of even moderate amount of residues can be combined with reduced tillage to enhance soil quality and efficient use of rainwater. There appears no doubt that managing zero-tillage system requires a higher level of management vis-a-vis conventional crop production systems. Also there exists sufficient knowledge to show that benefits of CA mainly consist of reversing the process of degradation and that its advantage in terms of crop productivity may accrue only gradually.

Irrigated Ecosystems

In India efforts to promote CA technologies have largely been focused in the Indo-Gangetic plains covering the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. Over the decades of seventies and eighties rice followed by wheat has emerged the major cropping system extending to over 10 million ha, although a number of other crops are grown in spatial and temporal variations throughout the plains according to agro-climatic variations. Concerns of stagnating productivity, increasing production costs, declining resource quality, declining water table and increasing environmental problems are the major forcing factors to look for alternative technologies particularly in the north-west region encompassing the states of Punjab, Haryana and western UP. In the eastern region covering eastern UP, Bihar and West Bengal developing and promoting strategies to overcome the constraints responsible for continued low cropping system productivity have been the primary concern. It is in this context that the efforts aimed at developing and promoting CA technologies over the past decade or so must be viewed.

The primary focus of developing and promoting CA practices has been development and adoption of zero-till seed cum fertilizer drill for sowing wheat crop in the rice wheat system. Other interventions being tested and promoted include raised bed planting system, laser equipment aided land leveling, residue management alternatives, alternative to rice-wheat cropping system in relation to CA technologies, etc. The area planted with wheat adopting zero-till drill has been rapidly increasing over the past five to six years. A study from Kurukshetra district in Haryana showed that the number of zero-till cum fertilizer drills increased from 5 in 1997 to 1425 in 2003 and the corresponding area sown with wheat increased from 50 ha to 40,000 ha. The study also brought out that adoption of this technology was not limited to farmers with a large holding but the small holding farmers were adopting the technology through custom hiring (Rs 750 to 900 per ha for sowing wheat) while the farmers with bigger holding are purchasing the seed drill. In a sample study amongst farmers adopting zero-tillage it was observed that the area brought under zero-tillage visa- vis total area under wheat crop varied with an overall average of 45 percent under zero till system.

Another study summarized results of more than six hundred demonstrations over an area of 440 ha from 1998 to 2000. These and several other studies concluded that wheat yields in zero-till fields were invariably higher by 3 to 5 percent compared to planting in conventionally tilled fields. Increased yields were largely a result of timely planting of wheat when zero-till was used. Reduced cultivation costs to the tune of Rs 1500 to 2250 per ha resulting from reduced costs of diesel, labour and use of weedicides were other advantages cited by most studies presented. Reduced incidence of weeds, particularly Phlaris Minor and savings in water use were other benefits frequently cited by participants. In addition to zero-till planting of wheat, raised bed planting and laser land leveling are other technologies being increasingly adopted by farmers of the region. Farmers who have used laser land leveler reported positive effects in improving crop establishment, uniformity of crop maturity, increase in area available for cultivation (2 to 5 percent), improved efficiency of water application and increased water productivity resulting in large savings in irrigation water (up to 35 percent) and in improved use efficiency of applied nutrients. With increased availability of laser land leveling equipment, precision land leveling could become an important basal step for adopting CA systems.

Planting wheat and other crops on the raised beds is being increasingly adopted by farmers. The advantage cited by farmers include savings on inputs like seeds and fertilizers, significant savings in water and reduced use of plant protection chemicals while the labour requirements increased somewhat. The overall crop yields and net return increased. Bed planting systems also offered greater opportunity for crop diversification and were amenable to key elements of CA, zero tillage and residues managed on surface. Some efforts are also underway to adapt CA practices for rice crop in rice-wheat cropping system. The approach being tested is to grow rice under aerobic condition on raised beds under non-puddled conditions. Although some success has been reported, managing weeds is a major challenge. Edaphic requirements of growing rice do not permit zero tillage or surface retention of crop residues. The impact of CA practices on resource quality is gradual and significant only over a period of time. When rice is grown after 'zero' till wheat these benefits are not likely to accrue. The question therefore is: Is rice grown as apart of rice-wheat cropping system in the north-west an anti thesis of CA? Thus, if principles and practices of cultivating rice in the semi-arid north west achieved mainly through intensive irrigation contradicts the technological and institutional innovations that enable or form the basis for CA and sustainability, then alternate cropping systems that meet these challenges have to be evolved. The issues which are important, therefore, include: What are the alternate cropping systems for adapting and promoting CA; how do they balance productivity per unit water, vulnerability to leaching losses of applied nutrients, etc. The choice of cropping systems can have a strong influence on resource quality through processes such as nutrient depletion and/ or enrichment through underground biomass/ crop residues, need for external inputs, impact on environment etc. It would appear from the progress of CA related activities that while zero-till planting of wheat is catching up rapidly the benefits are largely related to ability to achieve timely planting. The concept of CA emerging globally stipulates least disturbance of soil (e.g. through zero-tillage) together with maintaining soil cover (e.g. through crop residue) as fundamental to resource improvement.

Impact of Conservation Agriculture Practices

The rapid adoption and spread of CA technologies particularly zero-tillage for wheat is attributed to multiplicity of benefits. These include:

a) ***Reduction in Cost of Production:*** This is a key factor contributing to rapid adoption of zero-till technology. Most studies show that the cost of wheat production is reduced by Rs.1500 to 2000 per hectare. Cost reduction is attributed to savings on account of diesel, labour and input costs, particularly weedicides.

b) ***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 use of weedicides.

c) ***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 crop.

d) **Increased Yields:** In properly managed zero-till planted wheat yields were invariably higher by 4 to 6 percent compared to traditionally prepared fields for comparable planting date.

e) **Environmental Benefits:** CA involving zero-till and surface managed crop residue systems are an excellent opportunity to eliminate burning of crop residues which contribute to large amount of green house gases like CO2, CO, NO2, SO2 and large amount of particulate matter. Burning of crop residues, also contributes 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

f) ***Crop Diversification Opportunities:*** Adopting CA system (includes planting on raised beds) offers opportunities for crop diversification. Cropping sequences/rotations and agro forestry systems when adopted in appropriate spatial and temporal patterns can further enhance natural ecological processes which contribute to system resilience and reduced vulnerability to yield reducing disease/pest problems. Limited studies indicate that a variety of crops like mustard, chickpea, pigeonpea, sugarcane, etc., could be well adapted to the new systems with advantage.

g) ***Resource Improvement:*** No tillage when combined with surface managed crop residues sets in 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, improve biological activity and provide more favourable environment for root growth, the benefits which are traditionally sought from tillage operations.

VI CONCLUSIONS AND POLICY SUGGESTIONS

Conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, diminishing factor productivity and decreasing cultivation costs making agriculture more resource use-efficient, competitive and sustainable. While R&D effort over the past decade have contributed to increasing farmer acceptance of zero tillage for wheat in rice-wheat cropping system, this has raised a number of institutional, technological and policy related questions related to technology generation, adaptation and further improvement, which must be addressed if CA practices have to be adopted on a sustained basis. The following recommendations and institutional arrangements represent an integrated view of focused group discussions to define R&D priorities for CA.

- Myopic 'food security' policy based on cereal production must now replace a well articulated policy goal for livelihood security and rural development in India, and other developing countries. A factor price support followed by mandatory procurement for the crops alternative to rice and wheat that do not overexploit natural resources and enabling policy mechanism and environment for other crops was stressed upon. Emphasis should be on selecting and developing crops and varieties which result in saving of inputs like water, electricity, fertilizers, etc.

- Promote CA as a theme ensuring effective linkages between R&D. Leverage funding mechanisms to permit multidisciplinary teams of scientists and farmers to work in a participatory mode and promote networking amongst farmers, scientists, farm machinery manufacturers to facilitate information exchange and learning.

- Adaptive strategies for CA will be site specific and call for initiation of R&D efforts under a range of situations which aim at exploring multiple benefits by building context specific partnerships to address key livelihood issues. Learning process across the sites will be a powerful way of understanding which technologies and why they are effective in a particular set of situations. This will greatly accelerate building acknowledge base for sustainable resource management. Developing and promoting networking to share information among partners will be critical in advancing spread and continuous improvement of CA systems.

- Promoting CA will call for moving away from the conventional compartmentalized and hierarchical arrangement of research that generates perfect technologies, extension that delivers it and farmers who passively adopt it. All the stakeholders involved would need to be brought together on a common platform to conceive end-to-end strategies. Institutionalizing the role of research, extension and farmers in such a way that the partnership among these stakeholders might be strengthened right from the beginning of the project, and building up sense or enabling of ownership among them.

- Conservation agriculture offers opportunities for diversified cropping systems in different agro-ecoregions. Developing, improving and 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 systems. 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.

- Impact of CA technologies on resource quality and environment is slow and significant changes may show up only over a period of time. There is a need to set up long term monitoring sites in representative agro-ecological situations to monitor resource quality, ecology and productivity with a view to continuously improve management options for sustained improvements. Evaluation and impact of CA practices therefore needs a longer term and broader perspective, which goes beyond yield increase studies.

- Conservation agriculture practices i.e., no tillage and surface maintained crop residues set in processes which initiate changes in soil physical, chemical and biological properties which, in turn, affect root growth and crop yield. Understanding the dynamics of these changes and interactions between physical, chemical and biological phases is basic to developing improved soil, water and nutrients management strategies. Similarly understanding the dynamics of qualitative and quantitative changes in soil biodiversity (flora and fauna), diseases and pest causing organisms including weeds in relation to altered management practices is fundamental to evolve control measures which involve minimum use of environmentally harmful chemicals.

- Conservation agriculture technologies bring about significant changes in the plant growing microenvironment. These include changes in moisture regimes, root environment, emergence of new pathogen populations and shifts in insect-pest scenario etc. The requirements of plant type suited to the new environment and to meet specific mechanization needs could be different. There is need to develop complementary crop improvement programme aimed at populations which are better suited to the new systems. Farmer-participation research approaches would appear promising for identifying and developing crop varieties suiting specific environments or locations.

- 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 incentive for adopting CA systems will be important. This will call for considerable strengthening of social science research.

- There is a need for generating 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. Inclusion of conservation and sustainability concepts in the course curricula with a suitable blend of biophysical and social sciences would be important.

Despite the obvious productivity, economic, environmental and social advantages and benefits of CA, adoption does not happen spontaneously. There are good reasons for individual farmers not to adopt CA in her/his specific farm situation. The origin of the hurdles ranges from intellectual, social, financial, biophysical and technical, infrastructural to policy issues. Knowing the respective bottlenecks and problems allows developing strategies to overcome them. Crisis and emergency situations, which seem to become more frequent under a climate change scenario, and the political pressures for more sustainable use of natural resources and protection of the environment on the one hand and for improving and eventually reaching food security on the other provide opportunities to harness these pressures for supporting the adoption and spread of CA and for helping to overcome the existing hurdles to adoption.

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