RESOURCE MANAGEMENT THROUGH CONSERVATION AGRICULTURE - A COMPLETE AGRICULTURAL SYSTEM

A.K.Singh[1] and P.P.Pal[2]

Inappropriate agricultural cultivation systems are one of the main reasons for the poverty and food insecurity faced by smallholders in most parts of the rural regions in developing countries. Unsustainable agricultural practices lead to an exhaustion of forest and soil resources, which results in reduced land productivity, land degradation, and a reduction in biodiversity. Conservation agriculture, which is mainly based on the three principles of minimum soil disturbance, permanent soil cover and crop rotation, has shown to improve, conserve and use natural resources in a more efficient way through integrated management of available soil, water and biological resources. It is now widely recognized as a viable concept of sustainable agriculture due to its comprehensive benefits in economic, environmental risks and to improve energy use efficiency has been well-documented. What is required is better understanding of its performance and requirements across wider geographic regions and environmental conditions to enable the diffusion of the technology. For its successful implementation in developing regions where it is needed most, the design and dissemination of cost-effective farming tools, access to herbicides and economic incentives will be required in addition to creating awareness.

In recent years, farmers interested in sustainable crop production systems have begun to adopt and adapt improved crops management practices, a step toward CA, which may be considered the ultimate solution. CA, which focuses on the complete agricultural system, involves major changes in farm cropping operations from the widely used, traditional tillage-based farming practices. Appropriate CA technologies encompass innovative crop production systems that combine the followings.

- Dramatic reduction in tillage- zero till or controlled till seeding for all crops in a cropping system if feasible.

- Rational retention of adequate levels of crop residues on the soil surface- surface retention of sufficient crop residues to protect the soil from water run-off and erosion; improve water infiltration and reduce evaporation to improve water productivity; increase soil organic matter and biological activity; and enhance long-term sustainability.

- Use of sensible crop rotations- employ economically viable, diversified crop rotations to help moderate possible weed, disease, and pest problems, enhance soil biodiversity; take advantage of biological nitrogen fixation and soil enhancing properties of different crops; reduce labor peaks; and provide farmers with new risk management opportunities.

- Farmer's conviction of the potential improved economic benefits and livelihoods from sustainable CA systems- secure farm level economic viability and stability. To achieve this will involve the development of innovation systems focused on the needs of farmers and will include multiple agents who will use their comparative advantages to adapt the principles of CA to the farmers' various biophysical and socioeconomic conditions.

1 Zonal Project Director, Zone-II, Kolkata 2 Senior Scientist, ZPD, Zone-II, Kolkata

The water resources available for irrigation are becoming increasingly scarce and irrigated systems are becoming more fragile, especially with respect to increases in soil salinity from poor irrigation management. Table 1 below illustrates how the use of a CA based, raised bed, furrow irrigated seeding system in northwest India resulted in both higher yields and significant irrigation water savings for a wide spectrum of crops, when compared to the traditional farmer practice of seeding on the flat with food irrigation.

Table1. Comparison of estimated irrigation water use for raised bed seeding with furrow, irrigation versus flat seeding with flood irrigation for different crops at the Directorate of Wheat Research (DWR), Karnal, Haryana, India.

Crops	Irrigation water use (cm)		% saving of irrigation water by furrow irrigation
	Raised bed seeding with furrow irrigation	Conventional seeding on the flat with flood irrigation	
Wheat	28	33	17
Maize	25	30	16
Pigeon pea	13	15	16
Soybean	17	20	16
Green gram	17	21	16
Vegetable pea	8	10	18
Mustard	9	11	17

The results in Table 1 contribute to the growing evidence that the use of furrow irrigation with raised bed seeding systems can provide striking increases in irrigation water use efficiency, especially permanent raised bed seeding systems where no tillage is used on top of the beds, but beds are reshaped as needed in the furrows. Farmers who used furrow irrigation are of the view that nearly 25 % of irrigation water could be saved through adoption of furrow irrigation method.

Results of experiments conducted for 11 years on effects of tillage and residue management practices on soil water aggregate stability, one of the more relevant soil physical properties indicated that the conventional tillage treatment with incorporation of all crop residues had a mean weight diameter of aggregates (a measure of aggregate stability) of only 65% of that for the permanent beds with all residues retained. However, the effect of residue retention of aggregate stability is also evident with the permanent bed system: the more residues that are left, the better the aggregate stability. The treatment with permanent beds in which all residues have been burned had a lower aggregate stability than the conventionally tilled practice.

Agricultural labor shortage are growing even in the two most populous Asian countries – China and India – and this is causing many farmers to consider the adoption of CA-based technologies which, under most situations, can reduce labor requirements. One of the major benefits that smallholder farmers perceive with CA is the labor savings (Wall 2007). In Asia, for example, hand transplanting of puddle rice after conventionally tilled, irrigate wheat has a high labor requirement that peaks in June and July (especially in northwest India). This creates serious labor shortages during the critical time, and has provoked farmer interest in technologies available for direct seeding rice without pudding. One of these technologies is direct (zero till) seeding of rice into dry soil after zero till wheat. Farmer interest is particularly keen in the lowland rice growing areas, where a major portion of the water used in rice production is provided by irrigation.

Experience has shown that dramatic labor reductions are possible with dry soil direct seeding and that substantial irrigation water savings are also possible under many situations. Achieving satisfactory weed control, however, is a challenge that is being resolved with different weed management practices. What is earnestly needed to advance dry soil direct seeded and zero tilled rice is serious efforts by rice breeders to breed and select new, appropriate rice cultivars for this system in the pertinent soil types. There are many positive experiences with direct seeding of rice into dry soil using the available cultivars that were developed under for transplanted conditions. Certainly, even better results will be achieved with cultivars selected and developed under this management system.

Along with reductions in labor, in mechanized systems CA results in a marked reduction in the use of tractors and equipment, all of which cuts fuel use, reducing both farmers' costs and GHG emissions. Generally, CA reduces tractors use by approximately 70%, depending on the intensity of tillage in the conventional system. The reduction in tractor use means that a single tractor can provide the required traction for a greater area. This provided for the expansion of the agricultural area using existing tractors but in the Indo-Gangetic Plains (especially in northwest India) it has meant that relatively large-scale farmers could become service providers to the smaller farmers in the community.

The increases in the prices of chemical fertilizer, as well as other inputs like herbicides, pesticides, and fuel in the last 18-24 months, have been astounding, especially in many developing countries. Farmers have access to only restricted amount of fertilizers through government rationing programs or have not been able to afford/acquire fertilizer. There is some concern that CA-based technologies using markedly reduced/zero till seeding systems combined with soil surface residue retention may lead to decreased fertilizer N-use efficiency, requiring the use of higher fertilizer rates to obtain similar yields as conventional till systems. When this has occurred, it has likely been due to factors associated with differing production situations. Obviously, suitable fertilizer management practices that are compatible with appropriate CA-based technologies may result in enhanced N-use efficiency.

Although, there are few reliable economic comparisons of dry seeded, zero till rice compared to transplanted, puddle rice, much more is known in relation to wheat. Economic comparison of conventionally tilled irrigated wheat and zero till wheat in the rice-wheat system indicated that variable costs are substantially lowered for zero till (partly due to reduced labor costs) along with higher gross and net benefits for the zero till wheat. These results are similar to most other examples where farmers have adapted suitable CA-based technologies.

Due to the escalating human population and the requirement of ever-increasing food supplies, soil erosion, water scarcity, and loss of biodiversity have gained recognition as prime environmental problems throughout the world. The main land degradation processes such as erosion, nutrient mining, carbon loss, etc. are caused or amplified by human activities, mainly agriculture. These processes are likely to become more severe as population grows and the demand for more land and food increases.

About 50% of the earth's land surface devoted to agriculture is more susceptible to erosion because of removal of vegetation before planting and frequent cultivation of the soils. As a result, soil erosion on agricultural land is estimated to be 75 times grater than erosion in natural forest areas, and about 75 billion tons of fertile soil is lost from world agricultural systems each year (Myers, 1993). Worldwide erosion on cropland averages about 30 t/ha-yr, with a range of 0.5 to 400 t/ha-yr (Pimental et al., 1995).

Soil nutrient mining occurs when extraction of useful nutrients from the soil by agriculture exceeds the rate of replenishment in the system. Nutrient depletion in soils adversely affects soil quality and reduces crop yield and consequently poses a potential threat to global food security and agricultural damage, and social and political instability. The degradation of soil in general and nutrient mining in particular is typically a creeping environmental problem which hinders the initiation of counterbalancing measures (Glantz, 1998; Martius et al., 2001).

In almost all countries of the world, food production is currently dependent on depleting large quantities of nutrients from soil reserves and this is likely to continue. Globally, soil nutrient deficits were estimated to accrue at an average rate (kg ha ^{1} yr^{1}) of 19 N, 5P and 39 K in the year 2000, respectively (Tan et al., 2005).

Soil carbon / organic matter is usually referred to as black gold because of its vital role in physical, chemical and biological processes within the soil system. Soil erosion results in the removal of organic matter and essential plant nutrients from the soil and the reduction of the soil depth. These changes not only inhibit vegetative growth, but reduce the presence of valuable biota and the overall biodiversity in the soil.

Since the mechanization of agriculture began a few hundred years ago, scientists estimate that some 78 billion metric tons of carbon once trapped in the soil have been lost to the atmosphere in the form of CO_2 (Lal, 2004). The mineralization rate of SOC may range from about 20% in 20 years in temperate climate to about 50% in 10 years in the topics.

The above evidence suggests that unsustainable exploitation of land resources is leading to widespread degradation of resources serious implications for food security and ecological integrity. The situation is not likely to improve in light of the increasing world population along with its increased demand for higher quantities and quality of food and water, a challenge being imposed on future generations.

Until the middle of last century, the increase in food production in most countries was achieved by bringing new land into agricultural production. However, reserves of potentiality arable prime agricultural land are dwindling and the remaining land is claimed for numerous purposes, including the provision of essential ecosystem services. There are also indications that the highly effective fertilizer and seed technologies introduced over the past four decades may be reaching a point of diminishing returns.

While conventional cultivation generally results in loss of soil C and nitrogen conservation agriculture has proven potential of converting many soils from sources to sinks of atmospheric C, sequestering carbon in soil as organic matter. In general, soil carbon sequestration during the first decade of adoption of best conservation agricultural practices is 1.8 tons CO_2 per hectare per year.

Leaving crop residue on the field is another practice which could have an important impact on the global carbon cycle. If 15% of C contained in the residue can be converted to passive soil organic carbon (SOC) fraction, this may lead to C sequestration at the rate of 0.2×10^{15} g/yr (Lal, 1997).

A study that assessed the impact of zero tillage in the rice-wheat system of India (Laxmi and Erenstein, 2006) showed that investment in zero-tillage was highly beneficial. Zero tillage technology is the most economical and attractive option for wheat cultivation. Crop yield using zero tillage (3410 kg/ha) was significantly higher than conventional method (3123 kg/ha) with significantly lower total cost of production.

In many cases, it may be difficult to explain the importance of CA adoption to farmers beyond its potential to reduce production costs, mainly by tillage reductions. It is therefore necessary to educate farmers on the links between excessive tillage and residue removal with soil sustainability problems, and how these problems can be alleviated through CA.

Conservation agriculture that involves an application of modern agricultural technologies to improve production, enable maximization of yields but also helps maintain ecosystem health and integrity unlike the traditional systems which mainly intend to maximize yields sometimes at the expensive of the environment Expansion of conservation agriculture can create a win-win situation through promoting more efficient crop production and reducing soil degradation while maintaining ecosystem integrity. As a result, the impacts of conservation agriculture have been markedly positive both in agricultural, economic and social terms.

Because of its significant contributions, the importance of conservation agriculture is growing worldwide where it currently spans over millions of hectares.

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