Conservation Agriculture: A System for Sustainable Food Production

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ABSTRACT

Conservation Agriculture (CA), defined as minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations, is more sustainable cultivation system for the future than those practiced these-days. Present tillage system is responsible for the degradation of natural resources and soils. CA can improve agriculture through improvement in water infiltration and reducing erosion, improving soil surface aggregates, reducing compaction through promotion of biological tillage, increasing surface soil organic matter and carbon content, moderating soil temperature, and suppressing weeds. CA also helps reduce cost of production, saves time, increase diversity, and reduces greenhouse gas emissions. Availability of suitable equipment is a major constraint to successful CA. National promotional program for this technology is needed in present Nepalese context.

INTRODUCTION

The demand for food is still increasing; not only to meet food security for a growing population, but also to provide more nutritious food that makes protein quality, vitamins, and some essential minerals (iron and zinc) more available. There is also increasing demand for meat products and hence the grains and fodder needed to feed livestock.

The land available to produce this extra food is shrinking because of urbanization and use of agricultural land for other purposes. The quality of this new land may be less than that already in use for agriculture. Most of the sources of productivity growth e.g. improved varieties, fertilizer and water are already being utilized. Competition for water resources, especially surface and ground water, will be more severe in future as domestic and industrial needs increase.

Costs of fossil fuels are increasing, causing higher production costs through higher diesel, fertilizer and other input costs. Greenhouse gas emissions such as carbon dioxide, methane, and nitrous oxide that have inherent warming effects on the atmosphere will increase with subsequent effects on climate causing drought and floods.

One obvious way for sustainable food production is to make more efficient use of the natural resources that are needed to produce food; this includes water, soil, air, solar radiation, inputs and labor.

MERITS AND DEMERITS OF TILLAGE

Tillage, an agricultural practice, has been used since over 10,000 years. Tillage is the act of soil manipulation with an implement powered manually or by animals or tractors. Other names for tillage include ploughing, cultivation, digging, etc. There are many reasons as given below for adopting tillage:

- It is used to incorporate the previous crop residues, weeds or amendments added to the soil, such as organic and inorganic fertilizers.

- It is the first step in the preparation of a seedbed, essentially the name for soil that is prepared to receive the seed of the planted crop.
- It helps aerate the soil organic matter (OM), which in turn helps release and make available to plants nutrients tied up in this important soil component.
- It is a recommended practice for controlling several soil- and residue-borne diseases and pests.
- It provides relief from compaction, albeit in some cases only temporarily, a physical property of soil that restricts root and water penetration and reduces yield.

Tillage has also detrimental effects on both the environment and farmers. Tillage costs money in the form of fuel for tractors, wear and tear on equipments, and the cost of the operator. If animals are used as power source, the cost of feeding and caring for the animals over a full year are also high. Greenhouse gas emissions from the burning of the diesel fuel add to global warming.

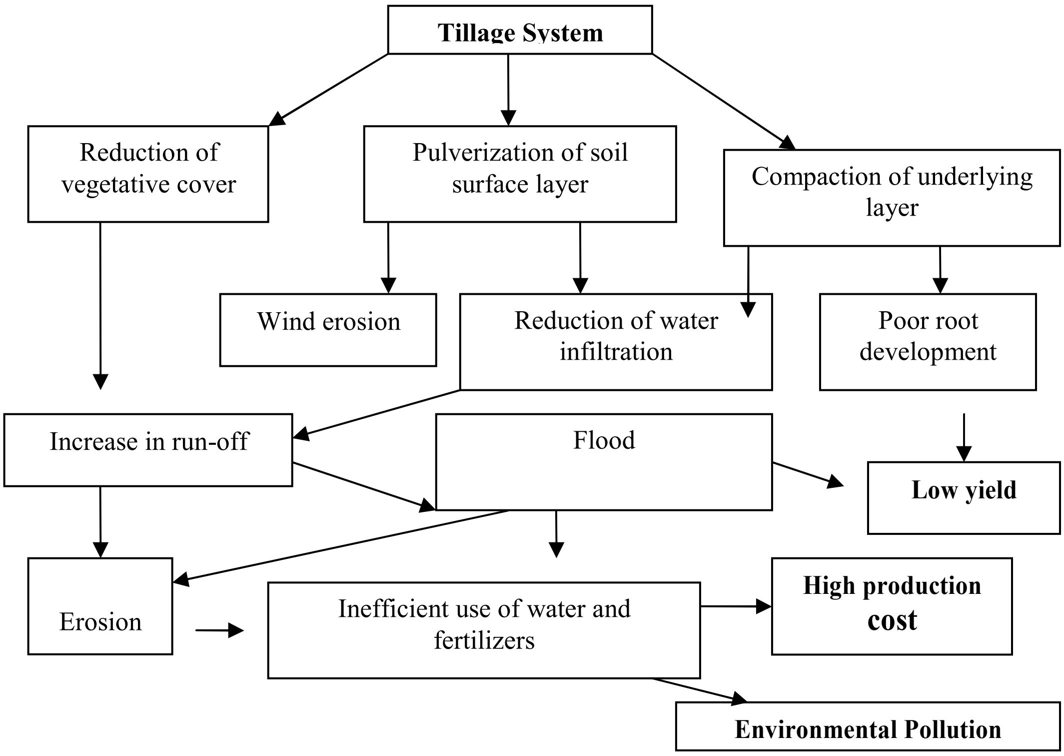

Fig.1 Effects of inappropriate tillage practices

Soil OM is oxidized when it is exposed to the air by tillage, resulting in a reduction in OM content, unless additional OM is returned to the soil as residues, compost, or other means. Tillage disrupts the pores left by roots and microbial activity. The bare surface exposed after tillage is prone to breakdown of soil aggregates as the energy from raindrops is dissipated; this results in clogging of soil pores, reduces infiltration of water and increased run-off, leading to soil erosion. When the surface dries, it crusts and forms a barrier to plant emergence. The bare surface after tillage is prone to wind erosion and tractor tires compact the soil below the surface. Figure 1 demonstrates the negative effects stemming from inappropriate tillage practices.

CONSERVATION TILLAGE AND CONSERVATION AGRICULTURE

Conservation tillage is the collective umbrella term commonly given to no-tillage, direct drilling, minimum tillage and or ridge tillage, to denote that the specific practice has a conservation goal of some nature. Usually, the retention of 0.3 surface cover by residues characterizes the lower limit of classification for conservation tillage, but other conservation objectives for the practice include conservation of time, fuel, earthworm, soil water, soil structure and nutrients. Thus residue levels alone do not adequately describe all conservation tillage practices (Baker et al 2007).

FAO mentions “Conservation tillage is a set of practices that leave crop residues on the surface which increases water infiltration and reduces erosion”. Conservation tillage practices can be transition steps towards Conservation Agriculture (Hobbs 2006).

Where, conservation agriculture defined by FAO is as follows; “Conservation agriculture (CA) 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 contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture (FAO 2006). FAO has characterized CA as follows: Conservation agriculture maintains a permanent or semi-permanent soil cover. This can be a growing crop or dead mulch. Its function is to protect the soil physically from sun, rain and wind and to feed soil biota. Therefore, zero or minimum tillage and direct seeding are important elements of CA. A varied crop rotation is also important to avoid disease and pest problem (FAO 2006).

In the rice-wheat areas of South Asia, no-till planting of wheat has increased rapidly over the past six years with more than 3.2 million ha reported in the 2005/06 wheat season in the Indo-Gangetic Plains (Rice-Wheat Consortium Research Highlights 2006). One of the major benefits of CA is that it costs less in terms of money and time (Hobbs and Gupta 2004). On an average, US$ 55 is saved on tillage costs, 50-60 liters diesel fuel is burned and crop yields have risen 247 kg/ha compared to normal tillage systems for wheat after rice. Since planting can be accomplished in one pass of the seed drill, the time needed for planting was also reduced, thus freeing farmers to do other productive work. Surveys of farmers concerning no-till wheat systems in India (Malik et al 2004) and Pakistan (Khan and Hashmi 2004) confirm these results and show that farmers who have adopted no till planting of wheat after rice have definite economic and social benefits occurring from this technology. Similarly, according to Sah et al (2005) farmers of Nepal who are adopting wheat cultivation after rice using minimum-till technique have obtained higher yields with lower production cost (Fig.2).

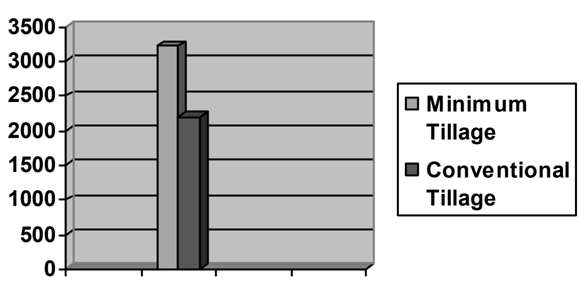

Fig. 2: Mean Wheat Grain Yield by Minimum Tillage over 1996/97-2006/07

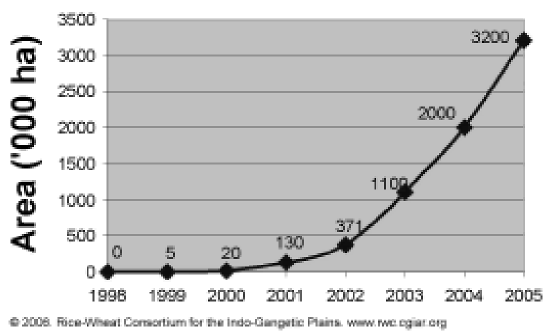

Fig.3: Adoption of Resource Conservation Technologies in the Indo-Gangetic Plains (1998-2005)

Water-use efficiency increased in the Rice-Wheat system because the first irrigation could often be eliminated, and when the first irrigation was given the water flowed faster across the field. Water savings of 15-50 percent have been calculated, with greater savings occurring when crops are planted on beds (Sayre and Hobbs 2004). Similar results were obtained in the trials at the Agricultural Implement Research Centre, Nepal (Sah et al 2007).

Mulch resulting from leftover residues is a key component of CA and helps promote more stable soil aggregates as a result of increased microbial activity and better protection of soil surface. Data from a 5-

year rice-wheat-moong bean trial at the AIRC, Nepal show higher grain yields with mulch, Table 1 (Sah et al 2007).

Table 1. Wheat grain yields (kg/ha) influenced by planting methods and mulching at AIRC, Birganj, Nepal during 2002/03-2006/07

Treatment	Year					
	2002/03	2003/04	2004/05	2005/06	2006/07	Mean
Flat + no mulch	3077	3848	4942	3192	3839	3780
Flat + mulch	3549	4189	5043	3399	4006	4037
Bed + no mulch	3220	4536	5187	3223	4013	4036
Bed + mulch	3684	4360	5324	3822	4734	4385
C. V. (%)						9.35
$LSD_{(0.05)}$						245

CA resulted in improved fertilizer efficiency (10-15%) in the RW system mainly as a result of better placement of fertilizer with the seed drill as opposed to broadcasting in the traditional system (Hobbs and Gupta 2004).

Table 2. Dry weed mass (g/m^2) influenced by planting methods and mulching at AIRC, Birganj, Nepal during 2002/03- 2004/05

Treatment	2003/03			2003/04			2004/05		
	Wheat	Moong	Rice	Wheat	Moong	Rice	Wheat	Moong	Rice
Flat + no mulch	123.8	141.1	5.8	181.7	234.1	117.6	117.2	234.1	64.3
Flat + mulch	42.3	101.1	6.0	77.5	182.4	101.1	108.6	182.4	24.2
Bed + no mulch	59.1	57.0	10.7	220.3	107.1	80.2	30.5	107.1	64.8
Bed + mulch	45.8	33.4	5.8	58.1	102.7	54.4	26.4	102.7	48.9

No-till uses less diesel fuel and thus results in lower carbon dioxide emissions, one of the gases responsible for global warming. In R-W systems, 40-60 litres of diesel fuel are saved because of farmers can forego the practice of ploughing many times to get a good seed-bed following puddling-degraded rice soils (Hobbs and Gupta 2004). A reduction of 50-60 percent has been shown in the germination of weeds in CA in R-W system, This is a unique weed situation in the R-W systems, the winter annual grassy weeds *Phalaris minor*, which is buried during the soil puddling exercise for rice, does not germinate during warm summer season and the buried seeds need to be exposed to the air by tillage to germinate in the cooler wheat season. Weed pressure was substantially reduced with the application of mulch in the R-W system in the trials at the AIRC, Nepal, Table 2 (Sah et al 2007). CA increases biotic diversity in the soil as a result of the mulch and reduced soil disturbance. It also produces higher surface soil organic carbon than when soils are tilled. The surface mulch also helps moderate soil temperatures and moisture, which is favorable for microbial activity. Groundcover also promotes an increase in biological diversity below and above ground; there are more beneficial insects where there is ground cover and mulch (Kendal et al 1995, Jaipal et al 2002) and these help control insect pests.

Less lodging was seen in no-till wheat in RW systems than with conventional tillage, especially on beds (Hobbs and Gupta 2004). No-till farmers need to adjust management to control diseases through sowing date, rotations and resistant cultivars to help shift the advantage from the disease to crop (Leakes 2003). More earthworms were found in no-till treatments in Australia (Table 3).

Table 3. Earthworm Populations under various tillage treatments with and without residue mulch in Australia (Chan and Heenan 1993)

Residue Management	Direct drilling (NT)	Reduced Tillage (RT)	Conventional Tillage (CT)
Retain straw residue	17	14	4
Burn straw residue	18	7	4

EQUIPMENT ISSUES

A major requirement of CA system is the development and availability of equipment that promotes good germination of crops planted into soil that is not tilled and where residue mulch occurs on the soil surface. It should also be able to place bands of fertilizers for increased efficiency. Recently, multi-crop, zero-till-cum- fertilizer drills fitted with inverted –T openers, disk planters trash-movers or roto-disc openers, minimum till drill (PTOS) have been developed for seeding into loose residues. This range of equipment means that small- and large-scale farmers can use this technology. In south Asia where land holdings are small and many farmers do not own a tractor, a system of rental or service providers make no-till available.

FARMER ADOPTION OF CA WORLDWIDE

Data reported by Derpsch (2005) indicate that the extent of no-tillage adoption worldwide is just over 95 million ha. This figure is a proxy for CA, although not all of this land is permanently no-tilled or has a permanent ground cover. Table 4 shows the extent of no-tillage by country. Six countries have more than 1 million ha of no-till. South America has the highest adoption rate and has more permanent no-till and permanent soil cover. Both, Argentina and Brazil had significant lag periods to reach 1 million ha in the early 1990s, and then expanded rapidly to the present day figure of 18.3 and 23.6 million ha, respectively (Derpsch 2005). Derpsch (2005) estimates that Brazil increased its grain production by 67.2 million tons in 15 years, with additional revenue of US$ 10 billion. Derpsch (2005) also estimates that at an average rate of 0.51 tons/ha/year, Brazil sequestered 12 million tons of carbon on 23.6 million ha of no-till land. Tractor use was also significantly reduced, saving millions of litres of diesel fuel. Similarly, Figure 3 shows the adoption rate of Resource Conserving Technologies in the Rice-Wheat Consortium for the Indo-Gangetic Plains (from 1998 to 2005). The adoption of this resource conservation technologies has not only produced an additional 0.5 million tons of wheat, but also saved a foreign exchange of US $ 80 million through reduced fuel consumption in tillage and irrigation operations in the region (RWC Research Highlights 2005/06). Though very low, the area under adoption of resource conserving technologies and their benefits in Nepal are presented in Table 5 and 6.

Table 4. Extent of no- tillage adoption worldwide

Country	Area under no tillage (million ha) 2004/05
USA	25.30
Brazil	23.60
Argentina	18.27
Canada	12.52
Australia	9.00
Paraguay	1.70
Indo-Gangetic Plains*	1.90
Bolivia	0.55
South Africa	0.30
Spain	0.30
Venezuela	0.30
Uruguay	0.26
France	0.15
Chile	0.12

Colombia	0.10
China	0.10
Others (Estimate)	1.00
Total	**95.48**

Source: Derpsch (2005); * includes area in India, Pakistan, Bangladesh and Nepal in South Asia.

Table 5. Adoption of Resource Conserving Technologies in Nepal, 2006/07

Technology	Area coverage (ha)
Zero- and Minimum tillage (ZTD & PTD)	678
Reduced tillage by Animal-drawn harrow (ADH)	944
Reduced tillage by Power tiller (PT)	15000
Total	**16622**

Table 6. Saving from different RCTs on wheat at National Wheat Research Program, Bhairahawa

Item	Percent saving /income increased
Saving in seed	10-13
Saving in land preparation and sowing cost	48-98
Saving in irrigation cost	22-44
Total cultivation cost	10-21
Production increase	5-25
Net income	33-60
Benefit cost ration against (0.95)	1.52-1.67

CHALLENGES TO ADOPTION OF CA

Probably, the first challenge faced was overcoming the mindset of the farmers in relation to changing the traditional way of farming, where tillage is considered essential. Farmers have to be convinced that it is possible to get good yields without tillage. A more practical way to convince the farmers is participatory system where they are provided with equipment and training to experiment with the technology and find out for them whether it works and what fine-tuning is needed to make it successful on their land. Other stakeholders, especially equipment manufactures, are also needed in order to modify the equipment as the farmers' requirement. Once this is done and the farmer is convinced that the CA methods are beneficial to him, he becomes the best extension agent for his village and neighboring farmers and adoption is accelerated. However, in order for accelerated adoption, farmers must also have easy access to machinery suitable for planting no-till crops into crop residues.

Since, many of the farmers in the village do not own tractor, another challenge is making equipment available to all farmers in a village once the farmers are convinced of the benefits of CA. At first, the tractor owners thought losing income from renting tractors out for plowing. Once the tractors owner was convinced to buy a no-till drill and provide the service with a fee to other farmers, this problem disappeared; whole villages were then able to adopt the technology.

Another challenge to the adoption of CA is related to the fact that the full benefits of CA take time to appear and, in fact, the initial transition years many present problems that influence farmers to abandon the technology. Weeds are the major initial problem that requires integrated weed management over time to get them under control. In the R-W system, weeds were actually fewer in the no-till wheat system than traditional tillage. In the rice phase, however, weeds are still the major constraint to using no-till or dry direct seeded rice; this problem must be solved before farmers will accept this practice for rice and allow the full benefits of CA for the entire annual cropping system. Soil physical and biological health also takes time to develop. It is hypothesized that it may take 3-7 years before physical and biological properties improve enough to be observed when the R-W system shifts from a puddle rice to a more aerobic system.

The last challenge encountered in this issue is delay in providing funds for research and development of CA and similar sustainable technology due to difficulty to convince the donors or government agencies. This means that the funding must be sustainable if CA-type technologies are to be successfully developed, introduced and adopted by farmers.

CONCLUSION

Crop production in the next decade should be increased from less land by making more efficient use of natural resources-and with minimal impact on the environment. Only by doing so can food- production keeps pace with demand, while the land's productivity is preserved for future generations. This is a significant challenge for agricultural scientists, extension personnel and farmers. Use of productive but more sustainable management practices described in the present paper can help solve this problem. Crop and soil management systems that improve soil health parameters (physical, biological and chemical) and reduce farmer's costs are essential. Development of appropriate equipment to allow these systems to be successfully implemented by farmers is a prerequisite for success. Overcoming traditional practices about tillage by promoting farmer experimentation with this technology in a participatory way will help accelerate adoption. Encouraging donors to support this long-term, applied research with sustainable funding is also urgent need.

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