Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2016, Volume 29, Issue 1, Page 18-23

Strengths-Weaknesses-Opportunities-Threats (SWOT) Analysis of Conservation Agriculture

Dibyendu Chatterjee

ICAR-National Rice Research Institute, Cuttack 753 006, Odisha

ARTICLE INFO

Article history:
Received 4 December 2015
Revision Received 20 December 2015
Accepted 21 December 2015

Key words:
Conservation agriculture, reduced tillage, minimum tillage, no-tillage, cover crop

ABSTRACT

Conservation agriculture is an option that attempt to achieve profits with high and sustained production levels while conserving the natural resources and environment. It is based on three principles *viz.* permanent soil cover, minimum soil disturbance and crop rotations. Maintaining a soil cover is necessary to protect the soil physically from sunlight, rain and wind and to feed soil biota. Conservation tillage can reduce erosion, increase organic matter content and improve physical, chemical and biological properties of soil. Soil surface can be covered either by mulch or by cover crops. Crop rotation is also essential to offer a diverse food to the soil microorganisms and to increase farm incomes. Conservation agriculture proved beneficial on long term basis in many ways, *viz.* reduction in cost of production, decreasing energy input, saving of nutrients and increased yields. However, problem like short term yield decline, weed infestation *etc*. under conservation agriculture have also been reported in India. There is need to discuss critically different aspects of this alternative management approach so as to find out its feasibility under Indian conditions.

1. Introduction

Conservation agriculture (CA) is a management system that strives to achieve acceptable profits with high and sustained production levels while conserving the natural resources and environment (FAO, 2006). It relies on three principles *viz.* permanent soil cover, minimum soil disturbance and crop rotations. Maintaining a permanent or semi-permanent organic soil cover is necessary to protect the soil physically from sun, rain and wind and to feed soil biota (FAO, 2006). Conservation tillage reduces soil erosion, increase organic matter content and improve physical, chemical and biological soil properties. Soil surface can be covered either by mulch or by cover crops. Crop rotation is also essential to offer a diverse diet to the soil microorganisms and to increase farm income. Conventional agricultural practices when adopted continuously for long time may have significant negative impact on physical, chemical and biological properties of soil, whereas CA proved beneficial on long term basis in many ways, *viz.* reduction in cost of production, decreasing energy input, saving of nutrients and increased yields. Nonetheless, problem like short term yield decline, weed infestation *etc*. under CA have also been reported in India. There is need to discuss critically different aspect of this alternative management approach so as to find out its feasibility under Indian conditions.

Concept of Conservation Agriculture

The realistic implementation of the idea of sustainable agriculture requires a specific tool that would change efficiently from a conventional agro-technology that exploits the soil and may hamper its natural ecosystem functions, to a conservationist approach that conserves, and even restores the soil properties and the ecological processes and functions of the soil and its biota.

Corresponding author: dibyenducha@gmail.com

This technical tool is called "conservation agriculture" (FAO, 2001). Conservation agriculture is based on 3 principles, which are linked and must be considered together for appropriate design planning and implemention process: *(a)* permanent soil cover is important to protect the soil against the deleterious effects of exposure to rain and sun, *(b) minimal soil disturbance:* because of this there will be enhanced soil biological activity that produces stable aggregates and various sizes of pores, allowing the air and water to infiltrate and *(c) crop rotations:* the rotation of crops is required to explore nutrients from different soil layers.

There are different means of CA like conservation tillage, soil cover, crop rotation, or use of specialized equipments. *(a) Conservation tillage:* thetillage or sowing system which preserves at least 30 per cent of the soil surface covered with residues after sowing so as to reduce erosion by water (Unger *et al.*, 1995).Before introducing conservation tillage soil limitations such as hard pan, levelling, surface crusting or compaction should be corrected. Actually the tillage system is classified on the basis of the degree of soil disturbance and on the residue cover as shown in Figure 1. *(b) Soil cover:* providing soil cover could be another viable option which can be achieved by two ways, *viz.,* mulching and multi-purpose cover crops. *(c) Crop rotation:* it should be designed in such a way so that, shallow rooted crops are rotated with deep rooted crops to mine nutrients not only from surface, but also from deeper layers and legumes are to be incorporated in rotation.

(d) *Specialized equipments:* that will allow good germination and minimizing soil disturbance and sowing the seed and banded fertilizer into loose and anchored stubbles. Recently, disc planters, punch planters, multicrop zero-till ferti-seed drills fitted with inverted T openers, trash movers or roto-disc openers are adopted.

SWOT Analysis

Strengths

For technology adoption, it needs to have benefits and advantages that attract a broad group of farmers. Therefore the benefits of CA can be considered as its strengths. These benefits can be grouped as:

(a) ***Economic benefits***

Conservation agriculture can improve the production efficiency through saving time, reducing labour requirement, increasing energy use efficiency, and reducing costs of cultivation.For instance, utilizing different methods of field preparation and drilling or broadcast sowing of wheat, Sharma *et al.,* (2004b) reported that the maximum cost was Rs 1637 for broadcast sown wheat followed by drill sown (Rs 1413) and minimum was for zero tillage, which was only Rs 179 ha^{-1}. The total energy required for various tillage options varied from 20279 MJ/ha for zero tillage to 23631 MJ/ha for broadcast sown wheat. The benefit cost ratio was highest for zero and the lowest for broadcast sown wheat, whereas, the specific energy (energy spent per kg of biomass production) requirement was the lowest for zero and the highest for broadcast sown wheat after conventional field preparation (Table 1).

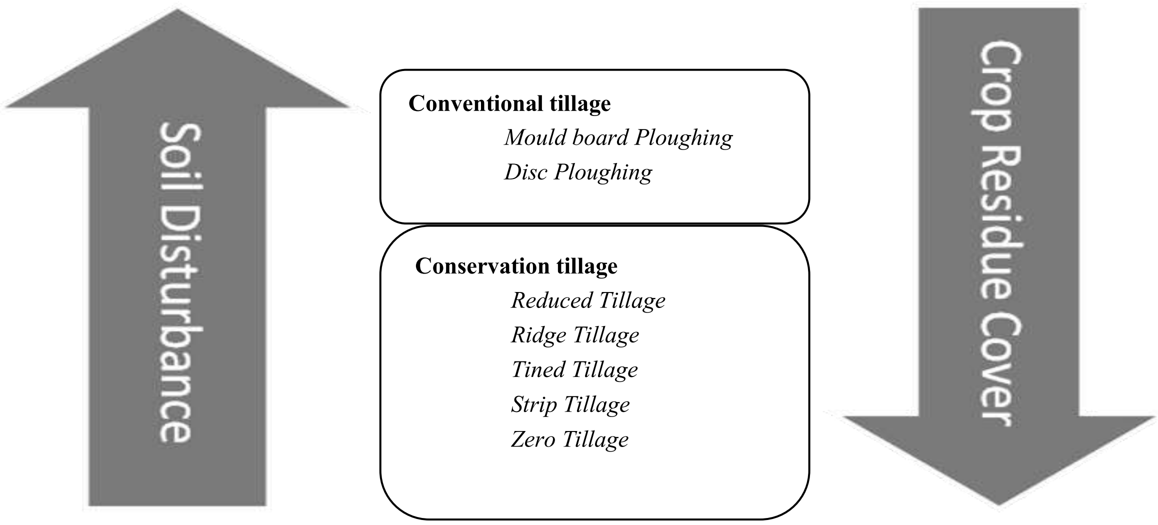


Figure 1. Tillage systems classification according to the degree of disturbance to the soil and the surface cover of residues.

Table 1. Comparative energy and economics of zero tillage verses conventional tillage (Sharma *et al.,* 2004b)

Parameter	Zero tillage	Conventional tillage	Conventional tillage broadcasting
Energy requirement (MJ ha^{-1})	20279	23136	23631
Tillage cost (Rs ha^{-1})	179	1413	1637
Gross income (Rs ha^{-1})	43251	43732	42405
Cost of production (Rs ha^{-1})	26023	27578	27860
Net income (Rs ha^{-1})	17228	16154	14545
Benefit cost ratio	1.66	1.59	1.52
Specific energy (MJ kg^{-1})	1.41	1.58	1.68

*b) **Agronomic benefits***

It includes the improvement of soil productivity through organic matter increase, soil water conservation, improvement of soil structure *etc*. In support of this point, (Figure 2). an example showing the performance of rice and wheat under different tillage operations are worth mentioning. The productivity was highest in rotary tillage for both rice and wheat crops. In rice, the mean yield for rotary puddling was 6.13 t ha^{-1} compared to 5.64 t ha^{-1} for conventional field preparation and puddling with a gain of more than 8%. In wheat, the yield recorded in various tillage options varied from 5.05 t ha^{-1} in farmers' practice of broadcast sowing after conventional field preparation to 5.63 t ha^{-1} for rotary tillage. The yield gain in wheat with rotary tillage was 7-12% over other tillage options. Comparing various tillage options with the broadcast sowing, a yield increase of 3.8, 1.1 and 11.6% was observed in conventional drill sowing, zero tillage and rotary tillage, respectively (Sharma, 2007).

(*c*) ***Environmental benefits***

This is achieved through reduction in soil erosion, improvement of water and air quality, biodiversity increase and carbon sequestration. A field trial was established to compare two cropping systems (continuous soybean and maize/soybean, soybean/maize rotation) under no tillage and reduced tillage. The number of culturable microorganisms varied with the crop management practice used (Figure 3). Populations of *Trichoderma* spp., *Gliocladium* spp. and total fungi were significantly higher when maize or soybean was under zero tillage, compared with reduced tillage, independently of the crop sequence. However, actinomycetes were not influenced by the tillage system (Gil *et al.,* 2009).

Figure 2. Productivity of rice and wheat under different tillage operation (Sharma, 2007)

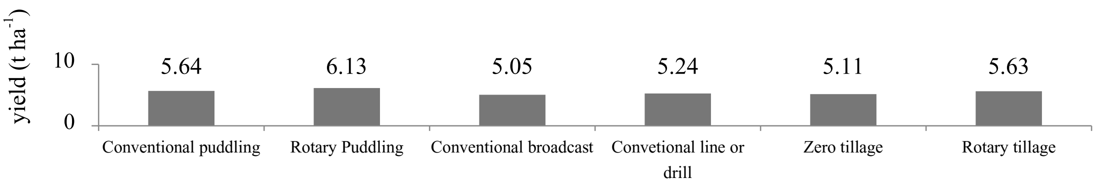
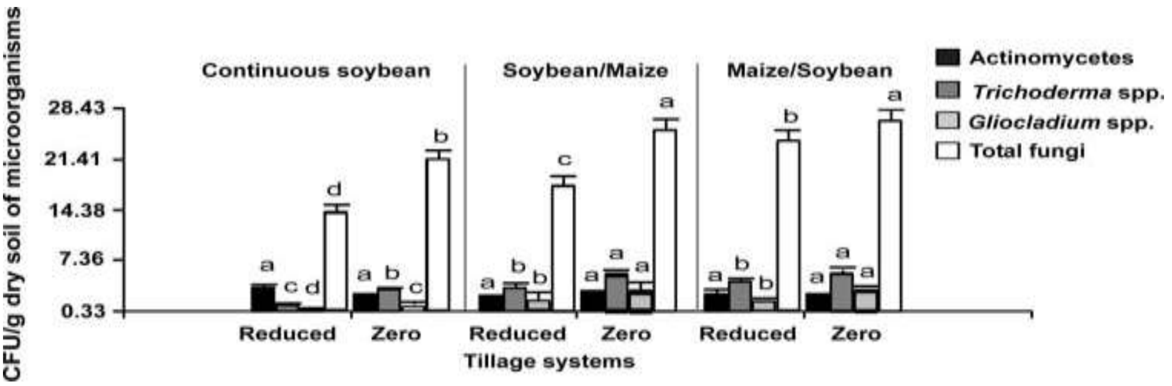


Figure 3. Populations of *Actinomycetes*, *Trichoderma* spp., *Gliocladium* spp., and total fungi under different tillage systems and crop rotation (Gil *et al.,* 2009)



Weaknesses

i. Conservation agriculture is a knowledge intensive system but small and marginal farmers are generally poorly connected to knowledge and information systems.This system integrates a new package of practices including seed bed preparation, planting, harvesting, water and nutrient management, diseases and pest control *etc*. which are to be evaluated and harmonized with Indian systems. However, there is no single outline of CA available for all agro-ecosystems.
ii. Use of herbicides is required, especially in the first few years. Adoption of CA may increase herbicide use and that successively will lead to increased contamination of water by herbicides.
iii. Formation of hard pan after 5-7 yearsdue to zero tillage.
iv. To build up a permanent cover with green manure or crop residues is problematic in a tropical country like India due to accelerated rate of residue decomposition which is mediated by high temperature. A complete ground cover is difficult to achieve in dry regions of India due to low biomass production, grazing and competition with food crops for soil moisture. Residual moisture after food crop harvest is not sufficient for growing cover crops. Access to cover crop seeds is difficult, as long as only a few farmers practice this technique.
v. Machineries are not widely available in all regions and although it is good in terms of saving money and fuel, more water use efficiency, time saving but, somehow it may be costly for small and marginal farmers. However alternate options are available. For *i.e.* direct drill seeding equipment having manual, animal or small tractor power sources. They can also use those machinaries on rent basis.
vi. New mix of insects, diseases and weeds may occur. *Phalaris minor,* a major weed for wheat which was no longer remained as major where zero tillage was followed. Rather, there were increased incidences of broad-leaved weeds (*Rumex spp., Malva spp*.), grasses (wild oat) and perennials (*Cynodon dactylon, Paspalum distichum*) and damage of wheat seedlings by pink stem borer of rice were also reported.
vii. Need for short-term benefits are vital for small farmers. Many of the benefits of CA are accumulated over time.
viii. It may also result in low yields in the initial years.

A research on the effect of tillage on termite incidence and yield of wheat showed that furrow-irrigated raised-bed planting system (FIRBS), which is a reduced tillage method where crops are sown on raised beds, had significant termite damage during both the years of a two years experiment (Table 2). This can be attributed to the fact that in FIRBS, irrigation was applied to the furrow and the top of the raised bed remain comparatively dry throughout the growing period, thus favouring the survival of termite. Yield is highest in rotary tillage followed by zero and conventional tillage and lowest in FIRBS. The highest yield in rotary tillage may be because of better pulverization leading to better aeration and lower bulk density of soil, which is reflected in better root and shoot growth early in the season that ultimately leads to better harvest at the end of the season (Sharma *et al.,* 2004a).

Major obstacles to broader adoption of conservation tillage as identified by the farmers included lack of information, concerns that it doesn’t work with certain crop rotations, and lack of interest in changing current practices (Mitchell *et al.,* 2007).

Table 2. Effect of tillage on termite incidence and yield of wheat (Sharma *et al.,* 2004a)

Tillage options	**Damaged tiller (No. m^{-2})**		**Yield (t ha^{-1})**	
	2000-2001	**2001-2002**	**2000-2001**	**2001-2002**
Zero tillage	9.67	6.33	5.95	6.41
Rotary tillage	19.67	4.33	6.18	6.72
FIRBS	82.33	37.67	5.38	6.04
Conventional tillage	12.33	10.25	6.17	6.31
LSD ($P \leq 0.05$)	20.49	7.44	0.15	0.31

Opportunities

Conservation agriculture can be adopted widely like: dryland and irrigated conditions, sea level to 3000 m msl, soils with 84% clay (Brazil) to 94% sand (Zimbabwe), equator to 60°N (Finland) and wide range of crops like wheat, maize, rice, cotton, soybeans, sunflower, even potatoes and cassava.

The opportunities of CA can be understood through an example by comparing of levelling by conventional and laser leveller (Table 3). Since the fields are cultivated regularly, minor undulations are created here and there when tillage operations are carried out.Therefore, precision land levelling by laser leveller not only saved water but also increased profit and reduce pumping requirement (Ambast, 2007).

Table 3. Comparison of conventional leveling and laser levelling (Ambast, 2007)

Parameters	**Conventional Leveling**	**Laser Leveling**
Leveling index (cm)	>1.5	<1.5
Pumping requirement per irrigation (hr ha^{-1})		
Paddy	25-27	20-22
Wheat	15-17	9-11
Water productivity (kg m^{-3})		
Paddy	0.37	0.47
Wheat	1.50	2.44
Profit over conventional (Rs ha^{-1})		
1st year	-	1000-1200
2nd year onwards	-	4000-5000

FAO (1997) reported that although the total farm income is less in first year of cultivation, it becomes higher at tenth year. However return on capital is always higher in CA (Table 4).

Table 4. Comparative short- and long-term economic return in Paraguay FAO (1997)

Incomes and costs (US $)	**First year**		**Tenth year**	
	CVA	**CA**	**CVA**	**CA**
Total farm income	77031	75010	68632	93762
Total variable costs	53484	51467	53026	48166
Total fixed costs	18618	14974	18618	14454
Net farm income	4929	8569	-3013	31142
Return on capital (%)	1.8	3.2	-1.1	13.3

CVA: Conventional Agriculture; CA: Conservation Agriculture

There are some opportunities to the Indian farmers to adopt conservation agriculture in wheat as listed by Singh (2007) are as follows:

i. *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 herbicides.

ii. *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 levelled and bed planted crop.

iii. *Resource improvement:* soil structural improvement and increased recycling and availability of plant nutrients.

iv. *Reduction in cost of production:* This is a key factor contributing to rapid adoption of zero-tillage technology. Cost reduction is attributed to savings on account of diesel, labour and input costs, particularly herbicides.

Threats

Some malpractices that threatened conservation agriculture are any kind of excessive tillage, burning of plant residues, uncontrolled grazing, over population, poor socio-economic conditions, poor land use policy enforcement *etc.* Excessive tillage of soils may affect in short term increases in fertility, but in long term it will aggravate soil structure degradation, loss of organic matter, erosion and declining biodiversity. Burning crop residues destroy an important source of plant nutrients and soil improvement potential. The phytosanitary motives for burning and ploughing can better be achieved by integrated pest management practices and crop rotations. There is a competition between crop residues cover maintaining and cover crops required for conservation agriculture and the demand from the livestock food. Therefore, uncontrolled and unplanned grazing of livestock may lead to destroy conservation agriculture venture. Due to the increasing pressure of population, efforts are on to produce more to feed them. This has also led to growing more food crops based on market demand not to save natural resources. Most of the Indian farmers are marginal and poor. For them it is very difficult to follow conservation agriculturebecause of its adverse effect on yield and more requirementof herbicide in the initial stage of adaption. Conservation policy like Conservation Security Program (CSP) and Conservation Reserve Program (CRP) was implemented in USA where farmers receive income support to maintain or enhance the soil, water and air quality through conservation technologies. In India no such programme is initiated.

Conclusion

Problems like short term yield decline, weed infestation *etc.* under CA have also been reported in India, but this technology can be adopted by improving awareness to change the mind set up of the stakeholders. They are confused the conservation tillage with CA. But the complete benefits of CA can be obtained only when the all three components are practiced. Refinement of technology is highly solicited. Whatever the technologies developed in abroad require modification before applying to the Indian condition. There is need to discuss critically different aspect of this alternative management approach so as to find out its feasibility under Indian conditions.

References

Ambast S.K, (2007). Design and construction procedures for OFD works with emphasis on laser land levelling. Pp. 47-56. In: National Training Course On-Farm Land and Water Management, CSSRI, Karnal.

FAO (2006). Conservation agriculture website. http://www.fao.org/waicent/faoinfo/agricult/ags/AGSE/agsee/genegen/object.htm.

FAO website: http://www.fao.org/ag/ca.

FAO (1997). TCI occasional paper series no. 9. Investment Centre Division, FAO, Rome.13.

FAO (2001). Conservation agriculture – case studies in Latin America and Africa. FAO Soils Bulletin 78**:** 58-59.

Singh G, (2007). Conservation agriculture for managing soil and water resources. Pp. 1-8. In: National Training Course On-Farm Land and Water Management, CSSRI, Karnal.

Sharma R.K, Chhokar, R.S, Chauhan D.S, (2004b). Zero-tillage technology in rice-wheat system-retrospect and prospects. *Indian Farmin*g 54: 12-17.

Sharma R.K, (2007). Resource conservation technologies for the sustainability of rice-wheat system. Pp. 135-144. In: National Training Course On-Farm Land and Water Management, CSSRI, Karnal.

Sharma R.K, Babu K.S, Chhokar R.S, Sharma A.K, (2004a). Effect of tillage on termites, weed incidence and productivity of spring wheat in rice-wheat system of North Western Indian plains. *Crop Protection* 23: 1049-1054.

Unger P.W, Jones O.R, Laryea K.B, (1995). Sistemas de labranza y prácticas de manejo de suelos para diferentes condiciones de tierras y climas. Pp. 82-117. In:Memorias de la segunda reunión bienal de la Red Latinoamericana de Labranza Conservacionista, Eds. I. Pla Sentís and F. Ovalles, Guanare, Acarigua, Venezuela, *RELACO*

Mitchell J.P, Klonsky K, Shrestha A, Fry R, DuSault A, Beyer J, Harben R, (2007). Adoption of conservation tillage in California: current status and future perspectives. *Australian Journal of Experimental Agriculture* 47: 1383–1388.

Gil S.V, Meriles J, Conforto C, Figoni G, Basanta M, Lovera E, March G.J (2009). Field assessment of soil biological and chemical quality in response to crop management practices. *World Journal of Microbiology and Biotechnology* 25: 439–448.