Conservation agriculture machinery and their effect on carbon foot print

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ABSTRACT: Carbon balance in agriculture is important in terms of crop production. A study was conducted to assess the potential of carbon savings in rice-wheat production systems under conservation agriculture (CA) practices as compared to conventional practices (CP). A survey was carried out in four selected states (Punjab, Haryana, MP and UP) of India to assess the carbon foot print and farmers adoption of CA as well as CP. Carbon input and output for rice-wheat cropping system were analysed to quantify the total carbon consumption with CA and CP. The carbon output per unit carbon input was found significantly higher in CA practices as compared to CP in all four surveyed states. However, this ratio was found maximum in CA of Punjab (12.4) followed by CA of Haryana (12.0), CA of UP (10.8), CP of Punjab (9.2), CP of Haryana (8.6), CA of MP (7.8), CP of UP (7.7) and CP of MP (4.3). Maximum carbon productivity was observed in CA of Punjab (16.6 kg grain/kg CE) followed by CA of Haryana (15.4 kg grain/kg CE), CA of MP (13.7 kg grain/kg CE), CP of Punjab (12.4 kg grain/kg CE), CA of UP (11.8 kg grain/kg CE), CP of Haryana (10.9 kg grain/kg CE), CP of UP (8.5 kg grain/kg CE) and CP of MP (7.8 kg grain/kg CE). It is concluded from the results that the carbon use efficiency and productivity can be improved by adopting appropriate conservation agriculture practices supported with suitable agricultural machinery.

Key words: Agriculture machinery, conservation agricultural practices, carbon foot print

The impacts of global warming are likely to aggravate yield fluctuations of many crops thus causing adverse effect on food security. There are evidences already of negative impacts which have been projected with medium- term (2010-2039) climate change, e.g., yield reduction by 4.5 to 9 per cent, depending on the magnitude of warming. The increases in emissions of greenhouse gases cause rise in the Earth's temperature. The conclusion of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) is that the average global surface temperature will increase by 1.4 to 3°C above 1990 levels by 2100 for low emission scenarios and between 2.5 and 5.8 °C for higher emission scenarios of greenhouse gases and aerosols in the atmosphere (Mall *et al*., 2004). Total greenhouse gas emissions from agriculture are expected to increase, reaching 8.3 GtCE/year in 2030 (Smith *et al*., 2007). If food demand increases and dietary shift occurs, then annual agriculture emissions will rise further.

Agriculture involves off-farm or external input which are carbon (C)-based operations and products (Pimentel, 1992; Marland *et al*., 2003). Production, formulation, storage, distribution of these inputs and application with tractorized equipment lead to combustion of fossil fuel and use of energy from alternate sources, which also emits CO_2 and other greenhouse gases (GHGs) into the atmosphere. Thus, an understanding of the emissions expressed in kilograms of carbon equivalent (kg CE) for different tillage operations, fertilizers and pesticides use, supplemental irrigation practices, harvesting and residue management is essential to identify C-efficient alternatives such as bio-fuels and renewable energy sources for seedbed preparation, soil fertility management, pest control and other farm operations. Land use and land cover change and agricultural practices contribute about 20% of the global annual emission of carbon dioxide (CO_2) (IPCC, 2001). A significant part of the emission due to agricultural practices can be reduced by the worldwide adoption of Conservation Agriculture (CA) practices. Regarding C emissions; agricultural practices may be grouped into primary, secondary and tertiary sources (Gifford, 1984). Primary sources of C emissions are either due to mobile operations (e.g., tillage, sowing, harvesting and transport) or stationary operations (e.g., pumping water, grain drying). Secondary sources of C emission comprise manufacturing, packaging and storing fertilizers and pesticides. Tertiary sources of C emission include acquisition of raw materials and fabrication of equipment and farm buildings, etc. Therefore, reducing emissions implies enhancing use efficiency of all these inputs by decreasing losses, and using other C-efficient alternatives (Lal, 2004).

All over the world, the land is ploughed for seed bed preparation for planting a crop. When land is ploughed, the soil is inverted (turned over) so all of the old crop residue and other plant material is buried. The farmer then has bare soil, which is loose on the top (Esdail, 2009). Conventional tillage and erosion deplete soil organic carbon (SOC) pools in agricultural soils. Thus, soils can store C by conversion of the agricultural practices from till to no till or conservation tillage, by reducing soil disturbance, decreasing the fallow period and incorporation of cover crops in the rotation cycle. Eliminating summer fallow in arid and semi-arid regions and adopting no till with residue mulching improve soil structure, lower bulk density and increase infiltration capacity (Shaver *et al*., 2002). However, the benefits of no till on SOC sequestration may be soil/site specific, and the improvement may be inconsistent in fine textured and poorly drained soils (Wander *et al*., 1998). Some studies have also shown more N_2O emissions in no till. Similar to the merits of conservation tillage reported in North America, Brazil and Argentina (Lal, 2000; Sa *et al*., 2001) several studies have reported the high potential of SOC sequestration in European soils (Smith *et al*.,1998, 2000a,b). Keeping above facts in view, a comparative study of CA and Conventional practices (CP) was conducted in 4 states Punjab, Haryana, UP and MP of India. The purpose of the study was to compare carbon foot print in CA and CP.

MATERIALS AND METHODS

A pilot survey was conducted in four selected states namely Punjab, Haryana, Uttar Pradesh and Madhya Pradesh of India during year 2012-15. A total of 50 farmers of each four states (25 conservation agriculture and 25 conventional agriculture practicing farmers) were surveyed using a proforma to study the extent of use of conservation agriculture machines by farmers of northern states of India (Fig. 1, a, b, c &d). Carbon emission was also calculated, by assessing fuel consumption in tractor operation in conventional and CA practices for rice/soybean - wheat cropping system.

Details of some CA machinery

Happy Seeder

Development of the Happy Seeder (HS) machine was initiated at Punjab Agricultural University, Ludhiana in collaboration with Australian scientists and funded by the Australian Centre for international Agricultural Research (ACIAR) in 2002. There are three major prototypes developed till date, each being an improvement on the previous versions and having their own particular advantages. The first two versions helped cut and lift the standing stubble and loose straw ahead of the sowing tines so that they could engage in bare soil, and then deposit the stubble as mulch on the sown area behind the seed drill.

Fig.1 (a) Happy Seeder

Fig.1 (b) Bed maker-cum-seeder

Fig.1 (c) Seed-cum-ferti drill

Fig.1 (d) Zero till seed-cum-ferti drill

The third version of the Happy Seeder consists of a rotor for managing the paddy residues and a zero till drill for sowing wheat. Flails are mounted on the straw management rotor that cuts (hits/shear) the standing stubbles/loose straw encountered in front of the sowing tine and clean each tine twice in one rotation of rotor for proper placement of seed in soil. The rotor blades/flails guide the residue as surface mulch between seeded rows. Instead, the straw is chopped finely with the inclusion of fixed blades on the inside of the rotor volute and concave rotor blades in front of the improved design inverted-T sowing tines. All the furrow openers (tines) are now on the same bar and are curved so that there is only a very small clearance (15 mm) between the rotating flails and tines, which are swept clean twice with every revolution of the rotor and the straw is fed between the tines. As a result, the sowing lines are now more exposed, and visible. The rotor speed is only marginally higher than in Combo Happy Seeder (1300-1500 rpm). Moreover, the Turbo Seeder does not have a strip-till mechanism and the tines are on a single toolbar.

Bed maker-cum-Planter/Seeder

Bed planting system is referred to the planting and cultivation of crops on raised beds. Generally wheat and some other crops are sown on raised beds. Researchers from several organizations (DWR, Karnal; PAU, Ludhiana; CIAE, Bhopal; PDCSR, Modipuram; CCS, HAU, Hisar; RWC-IGP and CIMMYT etc.) have reported that planting wheat on raised beds has improved yield, increased fertilizer use efficiency, reduced herbicides dependence. Facilitated better weed management and mobility in the crops field for other intercultural operations, less lodging of crops and reduced seed rate. It also helps in better fertilizer and irrigation use efficiency. The total cost of production of raised bed in comparison to flat beds is found to be reduced marginally in the fresh beds but when beds are reused the reduction is about 25-35%. Bed planting system is gaining importance among farmers in different part of the country due to better benefit-cost ratio as compared to flat bed.

Zero Till Seed-cum-Ferti Drill

Zero-till drilling of wheat is becoming the most successful resource-conserving technology and an attractive alternative to the conventional tillage in sowing of wheat after rice. In Indo-Gangetic plains of Punjab, Haryana, Uttar Pradesh, and Bihar and in the irrigated zones of Madhya Pradesh and Rajasthan, farmers are shifting to direct drilling of wheat after the harvest of rice to maintain the timeliness in delayed wheat sowing conditions. Direct zero-till drilling offers the apparent advantage of timely planting at reduced time, fuel, labour and drastic reduction in tillage intensity, resulting in significant cost savings as well as potential gains in yield through earlier planting of wheat. Thus, reducing the drudgery involved in the task and reducing the cost of production. Moreover zero-till drilling carries special significance and has proved more cost effective in situations where late harvesting of rice compels delay in sowing of wheat.

In survey, the input data were recorded for major cropping systems of each state. Rice-wheat cropping system for Punjab, Haryana and UP and soybean-wheat cropping system for MP were selected for the study. During survey, the data of CA and CP for selected cropping system were recorded by enquiry. The field capacity and fuel consumption of CA machines were recorded during field operation. Fuel consumption and other chemical inputs were converted into equivalent carbon emission (kg CE/ha) using standard conversion factors (Table 1) (Pathak and Wassmann, 2007).

Agricultural Operations Followed under CP and CA Practices in Major Cropping System During survey of four northern India States (Punjab, Haryana, UP and MP) of India, the data of CP and CA practices, input and output carbon of rice-wheat cropping system of Punjab, Haryana, UP and Soybean-wheat cropping system of MP were recorded by consulting farmers. The agricultural operation in different states are given in Table 2.

Table 1: Carbon emission coefficients for different agricultural inputs and operations

S. N.	Fuel/chemical sources	Equivalent carbon e mission kg CE
(A)	One litre of fuel	
	Diesel	2.6
(B)	One kg of Fertilizers	
	Nitrogen	0.9-1.8
	Phosphorus	0.1-0.3
	Potassium	0.1-0.2
	Lime	0.03-0.23
(C)	One kg a.i. of Chemicals	
1.	Herbicides	
	2, 4-D	1.7
	Atrazine	3.8
	Glyfosate	9.1
	Paraquat	9.2
2.	Insecticide	
	Parathion	2.8
	Phorate	3.2
	Lindane	1.2
	Malathian	4.6
3.	Fungicide	
	Ferbam	1.2
	Maneb	2.0
	Captan	2.3
	Benomyl	8.0
4	Output from grain and straw	40% of grain and straw weight

Table 2: Agricultural operation followed by different surveyed states under CP and CA practices

Agricultural Operation	Crop	Punjab		Haryana		UP		MP	
		CP(T_1)	CA(T_2)	CP(T_3)	CA(T_4)	CP(T_5)	CA(T_6)	CP(T_7)	CA(T_8)
Major Soil Type of` surveyed state		Desent & Saline		Desent & Saline		Alluvium		Vertisols	
Seedbed preparation	Rice	1MB+2H+ 2C+ 2 PH	1H+1C	1H+1C+ 1R+2 PH*	—	3C*+1R	—	-	—
	Wheat	2H+2C	LLL*	3H+1C or 3R	LLL	3C or 3R	—	2H+1C	—
	Soybean	-	-	-	-	-	-	3H+2C	1H+1C
Sowing operation	Rice	TR*=225 labour/ha	DSR*= Zero till drill	TR*=225 labour/ha	DSR*= ZT*	TR*= 225 labour/ha	DSR* = ZT	-	-
	Wheat	seed-cum-ferti drill	Happy seeder	seed-cum-ferti drill	Happy seeder	seed-cum -ferti drill	ZT*	Seed drill	Seed-cum-ferti drill
	Soybean	-	-	-	-	-	-	Seed drill	Seed-cum-ferti drill
Intercultural operation	Rice	2CW	Herbicide	2CW	Herbicide	Mannual	Hebicide	Mannual	Herbicide
	Wheat	—	Herbicide	—	Herbicide	-	Herbicide	-	Herbicide
	Soybean	-	-	-	-	-	-	Peg type weeder	Peg type weeder

CP: Conventional practices; CA: Conservation agricultural practices
H: Harrow; C: Cultivator; MB=Mould board plough, R=Rotavator, DSR= Direct seeded rice, CW= Conoweeder, ZT= Zero-till drill, PH= Paddy Harrow, LLL= Laser land leveller, TR= Transplanting

Statistical Analysis

The surveyed data were statistically analyzed in a completely randomized block design with 8 treatments and three replications. Total 8 treatments T_1 (PCP=Punjab with conventional agricultural practice), T_2 (PCA= Punjab with conservation agriculture practice) like that T_3 (HCP), T_4 (HCA), T_5 (UCP), T_6 (UCA), T_7 (MCP) and T_8 (MCA) were made from four states (Punjab=P, Haryana=H, UP=U and MP=M) and two agricultural practices (Conventional=CP and Conservation=CA). Each replication had one village with mean of input and output data of 8 farmers. All inputs and output data for conventional and conservation agriculture practices were analysed using SPSS (V-10) and values arranged according to DMRT.

RESULTS AND DISCUSSION

The documentation on use of CA machinery was done based on survey of 200 farmers from four states of India. State wise commonly used CA machinery are given in Table 3.

Rice-wheat cropping system is the major cropping system in Punjab state. The machines used in Punjab for field preparation are laser land leveler, rotavator, cultivator, harrow and plough. However, CA practicing farmers used laser land levelers, zero till ferti seed drills, turbo happy seeder and raised bed planter in wheat and direct rice seeder in paddy crops.

Table 3: List of CA machinery being used in surveyed four states

S.N.	Machinery	States
1.	Zero-till drill	Punjab, Haryana, UP and MP
2.	Turbo happy seeder	Punjab and Haryana
3.	Laser land leveler	Punjab, Haryana and UP
4.	Direct rice seeder	Punjab and Haryana
5.	Straw reaper	Punjab, Haryana, UP and MP
6.	Raised bed planter	Punjab, Haryana and UP
7.	Rotavator	Punjab, Haryana, UP and MP
8.	Rototill drill	Punjab and UP

The major cropping system of MP is soybean - wheat cropping system. Most of the farmers of MP used cultivator for field preparation for wheat and soybean crops. However, a few farmers used rotavator for the same purpose. Conservation agricultural practicing farmers are also utilizing traditional seed drills without fertilizer application attachment.

The farmers of UP were very enthusiastic for adopting CA machines but availability of these machinery were limited. Most of the farmers are still using traditional practices. Rice-wheat cropping system is the major cropping system of UP. In traditional practice, sowing of wheat is done after field preparation using plough, harrow/ rotavator/cultivator. However, CA practicing farmers used zero till seed-cum-ferti drills and raised bed planters.

CA practices like zero tillage (ZT) can allow rice-wheat farmers to sow wheat immediately after rice harvest, so

Table 4: Effect of treatments on carbon input, output and output-input ratio

Trt	Input carbon, kg CE/ha	Rice yield (kg/ha)	Wheat yield (kg/ha)	Total Straw yield (kg/ha)	Output carbon, kg CE/ha	Output-Input ratio
T_1	911.6 ^{f}	4500^{g}	4527^{f}	11500^{e}	8211^{d}	9.0^{c}
T_2	679.0 ^{d}	4700^{h}	4972^{d}	11690^{e}	8545^{e}	12.6^{e}
T_3	863.9 ^{f}	3800^{f}	4662^{e}	9998^{cd}	7384^{c}	8.5^{bc}
T_4	611.3 ^{c}	3700^{e}	4704^{e}	9886^{c}	7316 ^{c}	12.0^{e}
T_5	769.9 ^{e}	3500^{d}	3034^{b}	8356^{bc}	5956 ^{b}	7.7^{b}
T_6	555.8 ^{bc}	3200^{c}	3715^{c}	8100^{b}	6006 ^{b}	10.8^{d}
T_7*	527.9 ^{b}	1250^{b}	2899^{a}	1456^{a}	2242 ^{a}	4.2^{a}
T_8*	300.1 ^{a}	1076^{a}	2962^{ab}	1422^{a}	2184 ^{a}	7.3^{b}

Note: Mean values of three replications, and Values followed by the same alphabet in the same column indicated data are not significantly different ($p<.05$).

*In treatments T_7 and T_8 soybean crop was taken in place of rice in MP state.

Table 5: Effect of treatments on energy and carbon productivity

Trts	Total input energy (MJ/ha)	Input carbon (kg CE/ha)	Grain output (kg/ha)	Energy Productivity (kg/MJ)	Carbon productivity (kg grain/kg CE)
T_1	55553	911.6	9027	0.16	9.90
T_2	46237	679	9672	0.21	14.24
T_3	50245	863.9	8462	0.17	9.80
T_4	42480	611.3	8404	0.20	13.75
T_5	38057	769.9	6534	0.17	8.49
T_6	30256	555.8	6915	0.23	12.44
T_7	20838	527.9	4149	0.20	7.86
T_8	16151	300.1	4038	0.25	13.46

the crop heads fills the grain before the onset of pre-monsoon hot weather. Field results of four surveyed states indicated that CA machines are increasingly being adopted by farmers in rice-wheat belt of IGP because of advantages of labor saving and early planting of wheat. During survey it was observed that Punjab and Haryana were using better CA machinery as compared to UP and MP. Significant yield gain under rice-wheat system in hot and water stressed condition was observed adopting CA machinery which minimized unfavorable environment impact especially in small and medium farm.

In India, almost 1.5 million hectare is under CA technologies (Jat *et al*., 2012). The CA technologies also bring many environmental benefits for instant using zero tillage for wheat on one hectare of land in the rice-wheat cropping system of IGP can save one million litres of irrigation water and 98 litres of diesel besides reducing carbon dioxide emissions by 0.25 mg. The RCTs in rice wheat system have pronounced effect on mitigation of GHG emissions and adaptation to climate change. In this study, it has emerged that global warming potential (GWP) in direct drill seeded rice and wheat on beds is 450 kg CO_2 equivalent/ha (kg CE/ha) as compared to 550 kg CO_2 equivalent/ha in conventional puddled transplant rice and tilled wheat.

Carbon balance in rice-wheat system

The input, output and output-input ratio obtained in eight treatments were analysed using SPSS (V-10) and values were arranged according to DMRT. Results obtained in Table 4 revealed that the carbon input in rice wheat production under conservation agriculture (CA) practices were significantly less as compared to CP of respective states. However, maximum carbon emission in rice-wheat production was observed under CP of Punjab in treatment T_1 (911.6 kg CE/ha) followed by T_3 (863.9 kg CE/ha), T_5 (769.6 kg CE/ha), T_2 (679.0 kg CE/ha), T_4 (611.3 kg CE/ha), T_6 (555.8 kg CE/ha) T_7 (525.9 kg CE/ha), and T_8 (300.1 kg CE/ha). Significant difference of carbon output per unit carbon input was observed between CP and CA practices under rice-wheat cropping system in Punjab, Haryana and UP and soybean-wheat cropping system in MP at 5% level of significance. Carbon output data revealed that difference of carbon output between CP and CA practices in different states were not significant. However maximum carbon output was observed in Punjab (8371-8385 kg CE/ha) followed by Haryana (7316 -7424 kg CE/ha), UP (5956-6006 kgCE/ha) and MP (2184 – 2242 kg CE/ha). Carbon output per unit carbon input was found maximum under CA practices of Punjab (12.36) followed by CA of Haryana (8.6), CA of MP (7.8), CV of UP (7.7) and CV of MP (4.25).

Energy and Carbon Productivity in Rice-Wheat System

The energy productivity for different treatments was calculated and listed in Table 5. Energy productivity under CA treatments T_2 (0.2436 kg/MJ), T_4 (0.2221 kg/MJ), T_6(0.2271 kg/MJ) and T_8(0.2539 kg/MJ) were found higher as compared to CP treatments T_1(0.2030 kg/MJ), T3(0.1900 kg/MJ),T_5 (0.1726 kg/MJ) and T_7 (0.2068 kg/MJ). However, maximum carbon productivity was observed in treatment T_2 (16.6 kg grain/kg CE) followed by T_4 (15.4 kg grain/kg CE), T_8 (13.7 kg grain/kg CE), T_1 (12.4 kg grain/kg CE), T_6 (11.8 kg grain/kg CE), T_3(10.9 kg grain/kg CE), T_5 (8.5 kg grain/kg CE) and T_7 (7.8 kg grain/kg CE). Maximum energy and carbon productivity of Punjab and Haryana indicated that better performance can be achieved by adapting appropriate CA practices supported with suitable machinery, since Punjab and Haryana uses almost all type of CA machinery available in India (Table 3).

CONCLUSIONS

i. The carbon output per unit carbon input under conservation agricultural practices were higher as compared to traditional practices in all four surveyed states. However, the ratios were higher in Punjab(12.6) and Haryana (12.0) state as compared to UP (10.8) and MP (7.3) due to use of appropriate CA machinery, though their input carbon were higher.
ii. Use of conservation agriculture practices equipped with suitable CA machinery like zero till seed-cum-ferti drill, happy seeder, raised bed planter, laser guided land leveler can prove a better option to increase the carbon productivity in agricultural operations.
iii. The higher carbon and energy productivity under CA practices shows it's sustainable potential.
iv. Variation in carbon and energy productivity not only depends on agricultural practices but also on use of suitable machinery either in CP or CA practices.

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