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SUBJECT II
CONSERVATION AGRICULTURE

Impact of Resource Conservation Technologies on Carbon Emission in Major Wheat Growing Regions of India

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I

INTRODUCTION

The demand for foodgrains in India is growing very fast due to increase in population coupled with rising economic status of the common people. To meet the fast growing demand of food-grains, farmers are using inputs for crop production in an intensive and unsustainable manner. The negative consequences of this are reduction in crop productivity and deterioration in the quality of natural resources. The crop cultivation with intensive management has a significant impact on the carbon and nitrogen cycle. Agricultural system contribute to carbon emission through several mechanisms, i.e., (a) direct use of fossil fuel in farm operations; (b) indirect use of embodied energy for producing agricultural inputs (fertiliser, pesticides etc.); and (c) loss of soil organic matter during cultivation of soils (Pretty and Ball, 2001). Every year, agriculture releases about 10 to 12 per cent of the total greenhouse gases (GHGs) emissions, which is accounted for about 5.1 to 6.1 Gt CO_2 (Cole *et al*., 1997). The negative consequences of climate changes might have significant impact on crop production (Reilly *et al*., 1996).

Agriculture has potential to reduce the emission of GHGs by crop management and agronomic practices. Normally, nitrogen application rate in organic farming are 60 to 70 per cent lower than the conventional agriculture, due to recycling of organic/crop residue and use of manures. In addition, the availability of limited nitrogen in organic system requires careful and efficient management (Kramer *et al*., 2006). Many researchers have reported that yield of crops grown under organic farming system are comparable to crop yield under conventional system. Efficient use of inputs and net income per unit cropped area is at par due to reduction in fertiliser and other inputs application (Pimentel *et al*., 2005; Mäder *et al*., 2002). Nemecek *et al*. (2005) have reported that GHGs emissions from organic farming were 36 per cent lower than conventional system of crop production.

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Past researchers have reported that the organic and no-till farming system has potential to improve soil fertility by retaining crop residues and reducing soil erosion (Reganold *et al*., 1987; Siegrist *et al*., 1998), reducing irrigation water and sequencing CO_2 (Niggli *et al.,* 2009). The organic matter has a stabilising effect on the soil structure, improves moisture retention capacity and protects soil against erosion (Reicosky *et al*., 1995; Fliessbach and Mäder, 2000; Six *et al*., 2000). Based on the long-term agricultural experiments conducted in Europe and North America it was found that significant quantity of organic matter and soil carbon has been lost due to intensive cultivation (Arrouays and Pélissier, 1994; Reicosky *et al*., 1995, 1997; RCEP, 1996; Sala and Paruelo, 1997; Rasmussen *et al*., 1998; Tilman, 1998; Smith, 1999; Robert *et al*., 2001). The combination of organic farming with zero tillage system of crop production, the sequestration rate on arable land could be easily increased by 3 to 6 quintal carbon per hectare per year (Pretty and Ball, 2001; Niggli *et al*., 2009). Reduced tillage techniques, increasingly and successfully applied to organic systems, enhance carbon sequestration rates considerably (Berner *et al*., 2008; Teasdale *et al*., 2007).

Globally, the total area under conservation agriculture was 45 million hectares in 1999 which increased to 95 million hectares by the year 2005. In 2008, total area under conservation agriculture was 105 million hectares. Out of this, the share of different continents was 49.58, 40.07, 12.16, 2.53, 1.15 and 0.37 million hectare for South America, North America, Australia and New Zealand, Asia, Europe and Africa, respectively (Derpsch and Friedrich, 2009). More than 90 per cent of the area under conservation agriculture globally, is cultivated in five countries, i.e., USA, Brazil, Argentina, Canada and Australia. In India, presently more than two million hectares area in Indo-Gangetic Plain under rice-wheat system is under resource conservation technology. The zero-tillage system using legume as green manure or cover crop can contribute significant amount of organic matter and carbon accumulation in the crop field (Reicosky *et al*., 1997; Drinkwater *et al*., 1998; Lal *et al*., 1998; WCCA, 2001). Dobbs and Smolik (1996) reported that 0.023 tonnes per hectare carbon can accumulate by using zero-tillage with crop rotation. Whereas, organic matter and soil carbon augments by 0.73 per cent and 0.39 tonne per hectare per year, respectively, under zero-tillage system (Smith *et al*., 1998). The quantity of soil carbon accumulation depends upon the climatic condition. Per year per hectare carbon accumulation can increase in humid-temperate (0.5-1.0 tonne) fallowed by humid tropics (0.2-0.5 tonne), and lowest in the semi-arid tropics with 0.1-0.2 tonne (Lal *et al*., 2000).

II

OBJECTIVES AND METHODOLOGY

The prime objective of the present study is to estimate and compare the CO_2 and carbon emission by direct use of fossil fuels in farm operations under the conventional and resource conservation systems in major wheat growing regions of India.

III

ANALYTICAL PROCEDURE

The present study is confined to major wheat growing Indian states. These states are (a) undivided Uttar Pradesh (presently Uttar Pradesh and Uttaranchal); (b) Punjab; (c) Haryana; and (d) undivided Bihar (presently Bihar and Jharkhand). The farmers of these states are allocating larger portion of their holding under wheat cultivation and also have begun adopting resource conservation technologies (RCTs). In 2005-06, total area under wheat crop in the country was 26.39 million hectares and share of these four states was 65.91 per cent. Out of this, the highest area allocated by the farmers under wheat cultivation was in Uttar Pradesh (9.56 million ha) followed by Punjab (3.47 million ha), Haryana (2.30 million ha), and lowest in Bihar with 2.06 million ha.

Singh and Sharma (2005) conducted field experiments for a period of six years (1998-1999 to 2003-2004) at the experimental farm of Project Directorate for Cropping Systems Research, Modipuram, Meerut, Uttar Pradesh, and they estimated per hectare direct fossil fuel use for sowing of wheat crop under conventional system and resource conservation system. The diesel used for sowing of wheat crop under conventional method, zero-till drill, strip-till drill, bed planter and rotary drill was 48.8, 7.1, 8.75, 8.6, and 16.1 litres per hectare respectively. Rautaray (2005) estimated the direct fuel (diesel) consumption for sowing wheat crop under conventional, zero-till drill, strip till drill and roto-till drilled was 34.62, 11.30, 17.50, 13.8 litre per hectare respectively. Jat *et al*. (2006) estimated that the use of one litre diesel will generate 2.6 kg of CO_2. Paustian *et al*. (2006) suggested that CO_2 can be expressed in terms of its carbon equivalent, and one kg CO_2 is equivalent to 0.27 kg of carbon. For the present estimation we used Singh and Sharma's (2005) estimation for diesel consumption on sowing of wheat crop under conventional system and resource conservation agriculture system.

Assumptions

The farmers are using mechanical power for land preparation, sowing, pumping irrigation water, harvesting and threshing for wheat. For the estimation of CO_2 emission from wheat crop, we consider only the land preparation and sowing operations. We assume that for the rest of the activities fossil fuel consumption for mechanical power would be the same in both cases, i.e., conventional and resource conservation agriculture system. To estimate CO_2 emission from the land preparation and sowing of wheat crop using mechanical power (tractor), we assume that out of the total area under wheat crop, 80 per cent area in Uttar Pradesh and Bihar and 90 per cent area in Punjab and Haryana, farmers are using mechanical power. The other assumptions are:

1. *Business-As-Usual Scenario*: Out of the total area under wheat crop, 80 per cent area was sown by the mechanical power using tractor in Uttar Pradesh and Bihar, whereas, in case of Punjab and Haryana it was 90 per cent;

2. *Scenario–I*: Out of the total wheat area using mechanical power, 90 per cent area would be under conventional system and 10 per cent area will be put under resource conservation agriculture system, i.e., zero-tillage;

3. *Scenario–II*: Out of the total wheat area using mechanical power, 80 per cent area would be under conventional system and 20 per cent area will be allocated for resource conservation agriculture system. Out of the total area under resource conservation agriculture system, the area under zero-tillage, strip till drill, bed planter and rotary till drill would be 14, 2, 2 and 2 per cent respectively;

4. *Scenario–III*: Out of the total wheat area under mechanical power, 75 per cent area would be under conventional system and 25 per cent area will be put under resource conservation agriculture system. Out of the total area under resource conservation agriculture system, the area under zero-tillage, strip till drill, bed planter and rotary till drill will be 15, 3, 4 and 3 per cent respectively; and

5. *Scenario–IV*: Out of the total wheat area using mechanical power, 50 per cent area would be allocated under conventional system and 50 per cent area would be under resource conservation agriculture system. Out of the total area under resource conservation agriculture system, the area under zero-tillage, strip till drill, bed planter and rotary till drill will be 25, 5, 10 and 10 per cent respectively.

IV

RESULTS AND DISCUSSION

4.1 *Business-As-Usual Scenario*

Under the business-as-usual scenario, state-wise use of fossil fuel, CO_2 and carbon emission is presented in Table 1. Besides land preparation and sowing of wheat crop, farmers are using fossil fuel operated mechanical power for pumping groundwater[1] for irrigation, crop harvesting using combine harvester, transportation of inputs and outputs, electricity generation using coal for farm use, thermal

TABLE 1. DIESEL CONSUMPTION, CO_2 EMISSION AND CO_2 EQUIVALENT CARBON EMISSION FROM WHEAT UNDER DIFFERENT METHODS OF SOWING

Method of wheat sowing	Diesel Consumption (million lts)					CO_2 emission (million kg)					Carbon emission (million kg)				
	Uttar Pradesh	Bihar	Haryana	Punjab	Total	Uttar Pradesh	Bihar	Haryana	Punjab	Total	Uttar Pradesh	Bihar	Haryana	Punjab	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
A. Business-as- usual scenario	373.18	80.49	101.19	152.31	707.17	970.27	209.27	263.10	396.02	1838.65	261.97	56.50	71.04	106.92	496.44
B. Scenario - I	341.29	73.61	92.54	139.30	646.75	887.36	191.39	240.62	362.18	1681.54	239.59	51.67	64.97	97.79	454.02
1. Conventional	335.86	72.44	91.07	137.08	636.46	873.24	188.34	236.79	356.42	1654.79	235.77	50.85	63.93	96.23	446.79
2. Zero-tillage	5.43	1.17	1.47	2.22	10.29	14.12	3.04	3.83	5.76	26.75	3.81	0.82	1.03	1.56	7.22
3. Strip till drill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Bed planter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5. Rotary drill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Scenario - II	311.26	67.13	84.40	127.04	589.84	809.28	174.55	219.44	330.31	1533.58	218.51	47.13	59.25	89.18	414.07
1. Conventional	298.54	64.39	80.95	121.85	565.74	776.21	167.42	210.48	316.81	1470.92	209.58	45.20	56.83	85.54	397.15
2. Zero-tillage	7.60	1.64	2.06	3.10	14.40	19.76	4.26	5.36	8.07	37.45	5.34	1.15	1.45	2.18	10.11
3. Strip till drill	1.34	0.29	0.36	0.55	2.54	3.48	0.75	0.94	1.42	6.59	0.94	0.20	0.25	0.38	1.78
4. Bed planter	1.32	0.28	0.36	0.54	2.49	3.42	0.74	0.93	1.40	6.48	0.92	0.20	0.25	0.38	1.75
5. Rotary drill	2.46	0.53	0.67	1.01	4.67	6.40	1.38	1.74	2.61	12.13	1.73	0.37	0.47	0.71	3.28
D. Scenario - III	296.36	63.92	80.36	120.96	561.60	770.54	166.19	208.94	314.50	1460.17	208.04	44.87	56.41	84.91	394.24
1. Conventional	279.88	60.37	75.89	114.24	530.38	727.70	156.95	197.32	297.01	1378.99	196.48	42.38	53.28	80.19	372.33
2. Zero-tillage	8.14	1.76	2.21	3.32	15.43	21.17	4.57	5.74	8.64	40.13	5.72	1.23	1.55	2.33	10.83
3. Strip till drill	2.01	0.43	0.54	0.82	3.80	5.22	1.13	1.42	2.13	9.89	1.41	0.30	0.38	0.58	2.67
4. Bed planter	2.63	0.57	0.71	1.07	4.99	6.84	1.48	1.85	2.79	12.96	1.85	0.40	0.50	0.75	3.50
5. Rotary drill	3.69	0.80	1.00	1.51	7.00	9.60	2.07	2.60	3.92	18.20	2.59	0.56	0.70	1.06	4.91
E. Scenario - IV	222.40	47.97	60.31	90.77	421.44	578.23	124.72	156.79	236.01	1095.75	156.12	33.67	42.33	63.72	295.85
1. Conventional	186.59	40.24	50.60	76.16	353.59	485.13	104.64	131.55	198.01	919.33	130.99	28.25	35.52	53.46	248.22
2. Zero-tillage	13.57	2.93	3.68	5.54	25.72	35.29	7.61	9.57	14.40	66.88	9.53	2.06	2.58	3.89	18.06
3. Strip till drill	3.35	0.72	0.91	1.37	6.34	8.70	1.88	2.36	3.55	16.48	2.35	0.51	0.64	0.96	4.45
4. Bed planter	6.58	1.42	1.78	2.68	12.46	17.10	3.69	4.64	6.98	32.40	4.62	1.00	1.25	1.88	8.75
5. Rotary drill	12.31	2.66	3.34	5.03	23.33	32.01	6.90	8.68	13.07	60.66	8.64	1.86	2.34	3.53	16.38

fertiliser, insecticide and pesticide producing plants, etc. If we consider all the activities related to farm production and for all the crops then carbon emission from agriculture would be much more than what we estimated.

Total fossil fuel used for the land preparation and sowing of wheat crop was worked out to be 707.17 million litres in 2005-06. Out of this, the share of Uttar Pradesh state was the highest (52.77 per cent) followed by Punjab (21.54 per cent), Haryana (14.31 per cent) and lowest for Bihar with 11.38 per cent. From total diesel consumption, CO_2 emission was 1.84 million tonnes. Out of this, share of Uttar Pradesh, Bihar, Haryana and Punjab was estimated to be 0.97, 0.209, 0.263 and 0.396 million tonnes respectively. The carbon emission from the burning of fossil fuel was estimated to be 0.496 million tonnes. Out of this, share of Uttar Pradesh, Bihar, Haryana and Punjab were estimated to be 0.262, 0.057, 0.071 and 0.107 million tonnes respectively (Table 1).

4.2 *Scenario – I*

Under the scenario-I, total diesel used was estimated to be 646.75 million litres (Table 1). Total CO_2 emission from the burning of fossil fuel was estimated to be 1.68 million tonnes and carbon emission would be 0.454 million tonnes. The state-wise estimation of CO_2 emission was highest in Uttar Pradesh (0.887 million tonnes) followed by Punjab (0.362 million tonnes), Haryana (0.241 million tonnes) and lowest in Bihar with 0.191 million tonnes. The state-wise carbon emission was estimated to be 0.24, 0.097, 0.065 and 0.052 million tonnes for Uttar Pradesh, Punjab, Haryana and Bihar respectively. Under scenario-I, the diesel consumption will be reduce by 60.43 million litres as compared to business-as-usual scenario. The CO_2 and carbon emission will be reduced with the tune of 0.157 and 0.042 million tonnes respectively as compared to business-as-usual scenario.

4.3 *Scenario – II*

Under scenario-II, total fossil fuel (diesel) used for land preparation and sowing of wheat crop was estimated to be 589.84 million litres. Total CO_2 emission from burning of fossil fuel was estimated to be 1.54 million tonnes, which is equivalent to 0.414 million tonnes carbon. State-wise fossil fuel used for land preparation and sowing of wheat crop was estimated to be 311.26, 127.04, 84.40 and 67.13 million litres for Uttar Pradesh, Punjab, Haryana and Bihar respectively (Table 1). The CO_2 emission from burning of fossil fuel was estimated to be 0.809, 0.33, 0.219 and 0.175 million tonnes for Uttar Pradesh, Punjab, Haryana and Bihar respectively, which is equivalent to 0.311, 0.127, 0.084 and 0.067 million tonnes carbon emission respectively. Under scenario–II, fossil fuel consumption will be reduced with the tune of 117.34 million litres as compared to business-as-usual scenario. The CO_2 and carbon emission would be reduced by 0.31 and 0.117 million tonnes respectively as compared to business-as-usual scenario. The reduction of fossil fuel consumption under RCTs was due to reduction in number of ploughing.

4.4 *Scenario – III*

Total fossil fuel use for land preparation and sowing of wheat crop was estimated to be 561.60 million litres under scenario–III (Table 1). The CO_2 and carbon emission from burning of fossil fuel would be 1.46 million tonnes and 0.394 million tonnes, respectively. State-wise fossil fuel use was estimated to be 296.36, 120.96, 80.36 and 63.92 million litres for Uttar Pradesh, Punjab, Haryana and Bihar respectively. The state-wise CO_2 emission from the burning of fossil fuel was estimated to be 0.771, 0.315, 0.209 and 0.166 million tonnes for Uttar Pradesh, Punjab, Haryana and Bihar respectively which is equivalent to 0.208, 0.085, 0.056, and 0.045 million tonnes carbon respectively. It is estimated that under Scenario–III, the diesel consumption and CO_2 and carbon emission would be reduce by 145.57 million litres, 0.379 and 0.102 million tonnes respectively as compared to business-as-usual scenario.

4.5 *Scenario – IV*

Under scenario–IV, total fossil fuel use in major wheat growing Indian states was worked out to be 421.44 million litres, whereas, total CO_2 and carbon emission would be 1.096 million tonnes and 0.296 million tonnes, respectively. The fossil fuel use in Uttar Pradesh, Punjab, Haryana and Bihar was worked out to be 222.40, 90.77, 60.31 and 47.97 million litres respectively (Table 1). The CO_2 emission from burning of fossil fuel was estimated to be 0.578, 0.236, 0.157 and 0.125 million tonnes for Uttar Pradesh, Punjab, Haryana and Bihar respectively, whereas, it would be equivalent to 0.156, 0.064, 0.042 and 0.034 million tonnes carbon, respectively. Under scenario–IV, the fossil fuel consumption would be reduced by 285.73 million litres as compared to business-as-usual scenario. This would help to reduce CO_2 and carbon emission to the tune of 0.743 and 0.201 million tonnes respectively as compared to business-as-usual scenario.

V

CAPITALISATION OF CARBON EMISSION REDUCTION IN CARBON CREDIT

Today, the whole world is talking about global warming, climate change and their effects on our planet. Various countries have developed several ways to reduce the global warming. One such effort towards this area is formation of the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC or FCCC). The basic objective of UNFCCC focuses on stabilisation of concentration of greenhouse gases in the atmosphere at a certain level, to prevent dangerous anthropogenic interference with the climate system. However, the Protocol allows for several "flexible mechanisms", such as emissions trading, clean development mechanism (CDM) and joint implementation, to allow Annex-I countries (industrialised countries) meet their GHG emission limitations by purchasing GHG emission reductions credits from other countries (Toth and Mwandosya, 2001). Rich countries can either buy the credits to count towards their emissions-cutting targets or to offset the effect of their activities on the climate. Each credit, known as a Certified Emission Reduction (CER), represents a tonne of carbon dioxide. The trading of such credits incur through financial exchanges, where Annex I countries buy the credits by investing in the emission reducing projects of the developing countries. Thus the CDM is one of the Kyoto Protocol's "project-based" mechanisms, as it is designed to promote the projects aimed at reducing emissions.

The CDM is based on the idea of emission reduction "production" (Toth and Mwandosya, 2001). These reductions are "produced" and then subtracted against a hypothetical "baseline" of emissions. The emissions baselines are the emissions that are predicted to occur in the absence of a particular CDM project. CDM projects are "credited" against this baseline, in the sense that developing countries gain credit for producing these emission cuts.

Investigations of adoption of Resource Conserving Technologies have shown that high cost of RCTs is the major constraint in its adoption. Marginal cost is incurred in adoption of any new technology during production process. As per economic principles, any producer will continue/adopt any new technology as long as its incremental cost (ICCT) is equal to or less than incremental revenue (IRCT). There may be following situations:

$$ICCT < IRCT \quad \text{....(1)}$$
$$ICCT = IRCT \quad \text{....(2)}$$
$$ICCT > IRCT \quad \text{....(3)}$$

Where;

ICCT = Incremental Cost of Resource Conservation Technology

IRCT = Incremental Revenue of Resource Conservation Technology

A rational producer will continue with the new technology only in the above two situations i.e., (1) and (2). Producer will not continue under situation (3) where incremental cost is greater than incremental revenue. Carbon emission reduction is quantified and converted into carbon credits at prevailing market price and reduction of diesel consumption is added to find out the incremental benefit. It is evident from Table 2 that incremental benefit[2] is highest (US$ 33.31) in zero tillage and lowest (US$ 26.12) in rotary drill. In all RCTs, incremental benefit (IRCT) is less than the incremental cost[3] (ICCT) resulting in slow adoption of RCTs. RCTs have other benefits like carbon sequestration, improvement of soil health and reduction in fertiliser requirement.

TABLE 2. CAPITALISATION OF CARBON EMISSION REDUCTION AND CARBON CREDITS

(per hectare)

Method of crop Cultivation (1)	Diesel consumption (liter/ha) (2)	Δ in Diesel consumption (liter/ha) (3)	Cost saving due to diesel reduction ($)* (4)	Equivalent Carbon reduction (Kg) (5)	Carbon Credit (@ 10$/ tonne) (6)	Carbon Credit (@ 30$/ tonne) (7)	Incremental benefit due to diesel saving and carbon credit ($) (8)	Incremental cost ($) (9)
Conventional	48.80							
Zero tillage dill	7.10	41.70	32.43	29.27	0.29	0.88	33.31	50.11
Strip-till drill	8.75	40.05	31.15	28.12	0.28	0.84	31.99	70.18
Bed planter	8.60	40.20	31.27	28.22	0.28	0.85	32.11	70.18
Rotary drill	16.10	32.70	25.43	22.96	0.23	0.69	26.12	70.18

One $ is equivalent to 45 INR.
Price of one liter diesel is equal to 35 INR.
One credit as being worth US $ 10-30.

It is revealed from Table 3 that under various scenarios, it is possible to reduce 0.157 million tonnes to 0.797 million tonnes of CO_2. So, using RCTs it is possible to produce 0.157- 0.797 million of carbon credits which is equivalent to 0.157 to 22.287 million US$ (Table 3) in India. It would bring credits for producing CO_2 emission cuts and offer opportunities to the industrialized countries (Annex I countries) to invest in these technologies for meeting their reduction commitment. There have been a number of studies that have attempted to quantify the marginal opportunity cost of sequestering carbon in agriculture. A study of the work by McCarl and Schneider (1999) suggested that agriculture could operate for as low as US $ 10-$ 25 per tonne.

TABLE 3. TOTAL CAPITALISATION OF CARBON EMISSION REDUCTION AND CARBON CREDITS IN DIFFERENT SCENARIO

(million US $)

(1)	Uttar Pradesh (2)	Bihar (3)	Haryana (4)	Punjab (5)	Total (6)
Scenario- I	0.839 – 2.487 (0.083)	0.179 – 0.536 (0.018)	0.225 – 0.674 (0.022)	0.338 – 1.015 (0.034)	0.157 – 0.471 (0.157)
Scenario- II	1.997 – 5.992 (0.200)	0.431 – 1.292 (0.043)	0.542 – 1.625 (0.054)	0.815 – 2.446 (0.082)	3.785 – 11.355 (0.379)
Scenario- III	3.920 – 11.761 (0.392)	0.085 – 2.537 (0.085)	1.063 – 3.189 (0.160)	1.600 – 4.800 (0.160)	7.429 – 22.287 (0.797)

Figures in parentheses represents total carbon reduction (million tonnes).

On the basis of the above findings, it is concluded that the adoption of RCTs is beneficial in the Indian context where it maintains the environmental cleanliness by reducing carbon emission, improving soil health through carbon sequestration on one hand and saves money on the other hand by reducing the fuel consumption and fertiliser requirements. The major constraint in the adoption of RCTs is the incremental cost. Therefore, it is suggested that Clean Investment Grant (CIG) should be mobilised to stimulate the development and adoption of innovative conservation approaches and technologies. It will protect the environment in conjunction with sustained agricultural production.

VI

CONCLUSION AND POLICY IMPLICATIONS

From the above discussion it is clear that, agronomic practices under resource conservation agriculture system have potential to reduce the direct fossil fuel consumption leading to reduction in carbon emission besides other benefits. Other benefits of resource conservation agriculture are improvement in soil fertility, reduction in soil erosion (Reganold *et al.*, 1987; Siegrist *et al.*, 1998), reduction in irrigation water use and enhancing sequencing CO_2 (Niggli *et al.*, 2009), reduction in fertiliser consumption, advancing in time of sowing of wheat crop after paddy, increase in crop production per unit area and consequently greater net income from crop production.

Figure 1 represents the reduction of direct fossil fuel consumption in major wheat growing Indian states, i.e., Uttar Pradesh, Punjab, Haryana and Bihar under different scenarios over business-as-usual scenario. Under scenario-I, II, III and IV, reduction in total fossil fuel consumption would be 60.43, 117.34, 145.57 and 285.73 million litres, respectively. This would help in saving of substantial amount of foreign exchange on import of diesel with the tune of US $ 42.30 million, US $ 82.14 million, US $ 101.899 million and US $ 200.01 million[4] per year under scenario – I, II, III and IV respectively over business-as-usual scenario. Beside economic benefits, the emission of carbon would be reduced to the tune of 0.042, 0.824, 0.102 and 0.201 million tonnes under scenario–I, II, III and IV, respectively.

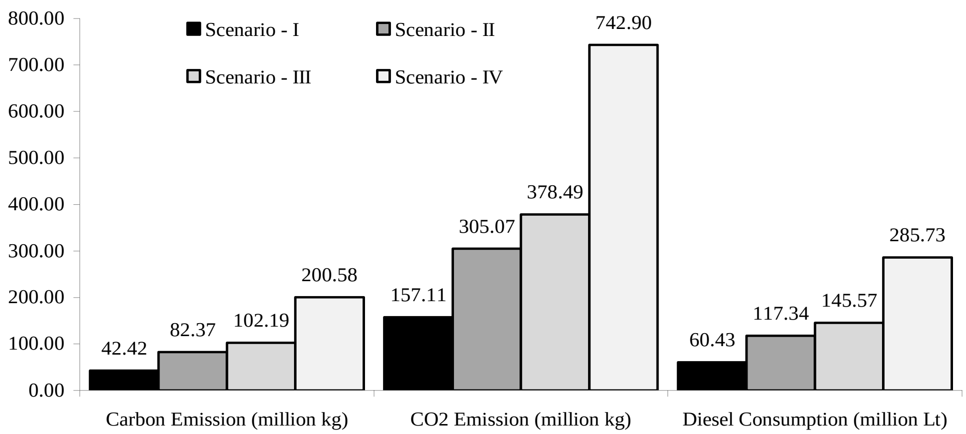

Figure 1. Reduction of Diesel Use, CO_2 and Carbon Emission Under Different Scenario

The farmers of the major wheat growing regions of India have already started adopting different options of resource conservation agriculture system, but the pace of adoption is very slow. The causes of slow adoption of resource conservation agriculture system of crop production are: (a) high cost of RCTs machineries, (b) non-availability of complete package of resource conservation agriculture for all the agro-climatic regions of India, as all agro-ecosystems are different, (c) non-availability of suitable varieties for resource conservation technology, (d) farmers of the study area are resource poor with small land holding size, (e) non-availability of skilled agricultural labourers to efficiently operate these machineries, (f) lack of extension services, (g) the other constraints like non-availability of bed planter on time on hire basis and repair of bed planter and difficulty in harvesting the crop, and

(h) the time lag in yield performance (FAO, undated; Joshi *et al*., 2005; Grover *et al*. 2005).

There is also an urgent need to tackle the problems associated with RCTs and provide incentives to farmers during the initial phase of adoption to compensate for initial yield reduction and financial support and subsidy for procurement of machinery associated with technology should be provided to harness its full potential. Based on the benefits of RCTs it is concluded that RCTs promotes sustainable agricultural development and therefore, it is suggested that these technologies should be subsidised. Since this subsidy will be in the form of Clean Investment Grant (CIG), it can not be perceived as a trade distorting subsidy. Adoption of RCTs should be scaled up to include greater area and more number of crops. Such technology promotes resource conservation not only at the farm level but also provides environmental benefits as evidence by reduced carbon emission.

NOTES

1. In the study area there is irregular and interrupted electricity supply to the farm sector which is 8-10 hours/day. The power supply to the farm sector during the peak period is lower than lean period. Besides this, power supply to the farm sector is scheduled in such a way that farmers get electricity sometimes in day and sometimes in the night. Most of the farm operations including irrigation cannot be efficiently done during night hours. Due to this, farmers are forced to use diesel pump for irrigation. The CO_2 emission from pumping groundwater can be reduced by regular power supply to the farm sector in day hours.

2. Incremental benefit was derived by adding the total cost saved due to reduction in the diesel consumption and equivalent carbon credit accrued due to reduced carbon emission.

3. Incremental cost is additional cost over conventional technology which was derived by assuming the life of the RCT equipments of 10 years and depreciation was calculated by straight line method based on actual cost of equipments (ranging from Rs. 30,000 to 60, 000) and average size of land holding is 1.33.

4. Assuming per litre price of diesel is Rs. 35.0 and 1 US$ = Rs. 50.00.

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