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Impact of Zero-tillage on Environment and Farmers' Livelihood Sustainability in Western Plain Agro-Climatic Zone of Uttar Pradesh, India

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Abstract

Zero-tillage playing an important role in enhancing wheat productivity and it leads to enhance economic and environmental benefits. Looking the importance of technology, present study was an attempt to find out the impact of zero-tillage on environment and farmers' livelihood sustainability in Western plain agro-climactic zone of Uttar Pradesh. Present study was based on primary data and it was conducted in two villages of Ghaziabad district. Study suggests that after adoption of zero-tillage, the cost of cultivation of wheat crop was reduced as compared to conventional method of wheat cultivation. After adoption of zero-tillage, the incremental wheat yield i.e. grain and bhusa was found to be 6.21 and 6.18 quintal respectively. The economic benefit due to the adoption of zero-tillage was estimated to be Rs.18662.96 per hectare. Due to adoption of zero-tillage carbon emission was reduced by 23.93 kg per hectare and irrigation water was saved by 1347.50 m^3 per hectare.

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Introduction

Rice and wheat are the two important stable food-grains which consumed by larger population of the South Asia. The irrigated rice-wheat cultivation system provides employment, income and livelihoods of millions of population residing in the region (Ladha et al., 2003). The sustainable production and productivity of both rice and wheat crops are threatened by insufficient use of inputs, increasing scarcity of natural resources *viz.*, land and water, climate change, changing cropping pattern towards water efficient high valued crop and changing food consumption basket (IRRI, 2009). The conventional method of rice-wheat cultivation needs to be improved or replaced by resource conservation technology (RCTs). The resource conserving technologies are those that enhance the crop productivity and profitability by making more efficient use of inputs of crop production, reducing cost of inputs and escalating crop yield per unit of scare resources and inputs. RCTs assist farmers to enhance input-use efficiency and farm profitability on a sustainable basis (Gupta and Seth, 2006).

Under the conventional method of wheat sowing, seeds are broadcasted manually in thoroughly land prepared using 4-5 ploughing by tractor and after broadcasting of seed on more ploughing and planking is required to mix seeds into the soil. This required high energy and tillage cost, high seed rate and late sowing of wheat crop. Among the different options of RCTs, sowing of wheat crop using zero-till-drill-seeded wheat machine is more popular in those areas where soils are heavy (clay loam, loam) low land and high water retention capacity. These soils required relatively more time to dry-up for land preparation for sowing of wheat crop. In such situation farmers were using zero-till-drill-seeded wheat machine for sowing wheat crop just in one pass after harvesting of rice crop. Sowing of wheat crop using zero-till-drill-seeded machine helps farmers to reduce the cost of land preparation, reduction in use of other inputs and timely sowing of wheat crop. Sowing of wheat by using zero-till-drill seeded machine with crop residue management in the soil helps farmers to overall reduction in cost of cultivation and enhance wheat yield on sustainable basis. Many past researchers reported that after adoption of zero-tillage, the cost of cultivation of wheat crop was reduced and enhanced wheat yield as compared to conventional method of wheat cultivation (Laxmi et al., 2007; Kumar et al., 2005; Singh et al., 2011; Pal et al., 2010; Singh and Meena, 2013). Present study was an attempt to find out the impact of zero-tillage on environment and farmers' livelihood sustainability in Western plain agro-climactic zone of Uttar Pradesh. The specific objectives of the present study was: [a] to compare cost of cultivation of wheat crop under zero-tillage and conventional method; [b] to estimate the economic and environmental benefits of zero-tillage; [c] to determine the factors influencing adoption of zero-tillage; and [d] find out the constraints associated with adoption of zero-tillage.

Data and analytical procedure

Sampling procedure

Western plain agro-climatic zone of Uttar Pradesh consists of seven districts viz., Saharanpur, Muzaffarnagar, Meerut, Bagpat, Ghaziabad, Gautam Budha Nagar and Buland Shahar. Out of these districts, Ghaziabad district was purposively selected on the basis of highest adoption of zero-tillage. District has four development blocks viz., (1) Muradnagar, (2) Bhojpur, (3) Rajapur, and (4) Hapur. Out of these development blocks, two development blocks viz., Rajapur and Bhojpur was selected purposively on the basis of highest and lowest adoption of zero-tillage, respectively. From selected development block, Matiyala village from Rajapur and Tahlata village from Bhojpur development block was selected purposively on the basis of availability of zero-tillage adopters and non-adopters. From each village, 10 zero-tillage adopters and 10 non-adopters were selected using snowball sampling method. Thus, altogether, 40 respondents were finally selected from two villages.

Analytical procedure

Cost of cultivation: The cost of cultivation was estimated by using methodology developed by the Commission for Agricultural Cost and Prices. The different cost was calculated as:

Cost A_1: All the input cost + depreciation on implements and farm buildings+ land revenue, cesses and other taxes+ interest on working capital+ miscellaneous expenses.

Cost B_1: Cost A_1 + interest on value of owned fixed capital assets (excluding land).

Cost C_1: Cost B_1 + rental value of owned land+ rent paid for leased-in land.

Cost C_2: Cost C_1 + imputed value of family labour.

Cost C_3: Cost C_2 + 10 per cent of cost C_2 as account for managerial input of the farmer.

Economic and environment benefits

The economic benefits of RCT_S were worked out using economic surplus model as suggested by the Alston et al. (2005). The model is given below:

$$\Delta\ CS = PQ\ Z\ (1 + 0.5\ Zn)$$

$$\Delta\ PS = PQ\ (K - Z)\ (1 + 0.5\ Z\eta)$$

$$\Delta\ TS = \Delta CS + \Delta PS = P\ QK\ (1 + 0.5\ Z\eta)$$

Where,
$Z = K\ \varepsilon / (\varepsilon + \eta)$; K is vertical shift in supply function as proportion of initial price; η is elasticity of demand (absolute); and ε is elasticity of supply.

The environmental benefits realized by adoption of zero tillage are reduction in carbon emission. To find out the reduction of carbon emission, first of all diesel saving on farm operations was quantified and multiplied by the one litre equal to 2.6 kg of CO_2 (Jat et al., 2006) and one kg CO_2 is 0.27 kg of carbon (Paustian et al., 2006).

Irrigation water saving is also an environmental benefit. The farmer of the study area was using groundwater for irrigating wheat crop. For the quantification of irrigation water used for irrigation purposes, following formula was used:

$$Pd_{(m^3/Hr)} = \frac{HP \ x \ 75 \ x \ Pe}{1000 \ x \ DW} \ x \ 3600$$

Where,
Pd is pump discharge rate measured in m^3 per hour; *HP* is the pump capacity; *Pe* is the pump efficiency; and *DW* is depth to water level plus head of delivery pipe measured in meter.

Factors influencing adoption of zero-tillage

For identification of relative importance of various factors influencing adoption of RCT_S in different Agro-climatic zone was worked out by using binary logit model (Mallada, 1992). The algebraic form of model is given below:

$$p_i = \frac{1}{1+e^{-Z_i}}$$

Where, p_i is a probability of adoption of conservation tillage technology for the i^{th} farmer and ranges from 0 to 1. e^{-Zi} represents the base of natural logarithms and Z_i is the function of a vector of n explanatory variables and expressed as follows.

$$Z_i = \beta_0 + \sum \beta_i X_i$$

Where β_0 is the intercept and β_i is a vector of the relationship between p_i and X_i, which is non-linear, can be written as follows:

$$pi = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n)}}$$

Finally, the logit model is obtained by using the logarithm.

$$L_i = L_n\left[\frac{p_i}{1-p_i}\right] = Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots.. + \beta_n X_n$$

Identification of constraints

The Garret Ranking was used to rank the constraints associated with the zero tillage adoption. The percentage of each rank thus obtained was converted into scores by referring to the table given by Henry Garret. The score of all the factors were arranged in order of their ranks.

$$Percent\ Position = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where,
R_{ij} is the rank given for i^{th} item j^{th} individual and N_j is the number of items ranked by j^{th} individuals.

Results and discussion

Socio-economic profile of respondents

The respondents of the study area were doing crop production along with livestock rearing. In case of zero-tillage adopters, 75 per cent sample farmers were engaged in crop production and remaining 25 per cent farmers were involved in crop and livestock production, whereas in case of zero-tillage non-adopters, 50 per cent sample farmers were involved in crop production only and remaining 50 per cent involve in crop and livestock production. The average age of zero-tillage adopters was less (52.15 years) than the zero-tillage non-adopters (53.15 years). The average farming experience for zero-tillage adopters was found to be 27.55 years which was quite higher than zero-tillage non-adopters (27.00 years). The educational level of zero-tillage adopters was almost similar as zero-tillage non-adopters.

The average size of family member for zero-tillage adopter was 10.15 persons per family which were larger than the zero-tillage non-adopter (9.85 persons). Out of total family members, about 42.86 and 39.59 per cent family members for zero-tillage adopters and non-adopters respectively were belonging to children having age of less than 18 years and remaining family members were belonging to group of adult. The average size of land holding for zero-tillage adopter and non-adopter in Ghaziabad district was found to be 6.09 and 4.76 hectares respectively. All the agricultural land posed by the sample farmers in the study area were irrigated in all the season and major source of irrigation was groundwater.

Cost of cultivation

Per hectare cost of cultivation for wheat crop for zero-tillage adopter was lower (Rs.51315.21) than the zero-tillage non-adopter (Rs.57269.99) in the study area. The share of inputs cost for zero-tillage adopters and non-adopters were estimated to be 84.64 and 88.96 per cent respectively of total cost of cultivation (Table 1). Per hectare contribution of rental value of own land and leased-in land to total cost of cultivation (Cost C_3) was estimated to be 10.28 and 5.78 per cent for zero-tillage adopter and non-adopter respectively in the study area. The share of imputed value of family labour was 6.74 and 7.57 per cent for zero-tillage adopters and non-adopters to cost of cultivation respectively. The contribution of chemical fertiliser to total cost of cultivation was estimated to be 6.95 and 6.95 per cent for zero-tillage adopters and non-adopters respectively. The share of expenditure on irrigation water for wheat crop was estimated to be 4.73 and 7.06 per cent to total cost of cultivation for zero-tillage adopters and non-adopters respectively.

Table 1. Cost of cultivation of wheat (` /Ha).

Particulars	RCTs adopter			RCTs non-adopter		
	Physical unit	Amount (Rs.)	% to (C_3)	Physical unit	Amount (Rs.)	% to (C_3)
1. Human labour						
a. Family labour – Male	11.53	3458.78	6.74	14.45	4334.09	7.57
c. Hired labour – Male	4.57	1372.34	2.67	6.61	1984.09	3.46
c. Hired labour - Female	1.44	430.85	0.84	1.08	322.73	0.56
2. Machine labour (Hrs)	5.01	2506.65	4.88	11.83	5914.77	10.33
3. Seed (Kg)	124.92	3997.45	7.79	145.98	4671.52	8.16
4. Manure (Qts)	244.02	7320.48	14.27	229.55	6886.36	12.02
5. Fertilizer (Kg)		**3565.86**	**6.95**		**3977.47**	**6.95**
a. Nitrogen	152.33	1066.29	2.08	115.98	811.89	1.42
b. Phosphetic	94.41	2157.38	4.20	125.00	3000.00	5.24
c. Potassic	6.74	88.99	0.17	9.21	95.81	0.17
d. NPK	12.23	244.68	0.48	1.21	2.91	0.01
e. Zn	2.13	8.51	0.02	5.97	66.86	0.12
6. Insecticides and pesticides	-	307.50	0.60	-	335.00	0.58
7. Irrigation (Hrs)	63.07	2428.26	4.73	101.09	4043.64	7.06
8. Harvesting and threshing		14470.74	28.20		14500.00	25.32
Sub-Total		***43424.76***	84.62		***50947.14***	88.96
9. Interest on working capital		1519.87	2.96		1783.15	3.11
10. Total Working Capital		***44944.63***	87.59		***52730.29***	92.07
11. Land revenue		-	-		-	-
12. Rental value of own land		4241.37	8.27		2639.70	4.61
13. Rental Value of leased-in land		1030.05	2.01		671.11	1.17
14. *Cost* A_1		*37920.00*	73.90		*44418.73*	77.56
15. *Cost* B_1		*37920.00*	73.90		*44418.73*	77.56
16. *Cost* C_1		*43191.42*	84.17		*47729.54*	83.34
17. *Cost* C_2		*46650.19*	90.91		*52063.63*	90.91
18. *Cost* C_3*/ Cost of cultivation*		***51315.21***	**100.00**		***57269.99***	**100.00**

Income from crop production

Per hectare average yield of main and by-product (wheat *bhusa*) of wheat crop for zero-tillage adopters was worked out to be 49.88 and 49.88 quintal respectively, whereas in case of zero-tillage non-adopters it was 43.67 and 43.70 quintal per hectare for main and by-product respectively. The average market price received by the sample farmers in the study area was found to be Rs.1442.50 and Rs 348.50 per quintal for wheat (grain) and by-product (wheat *bhusa*) respectively (Table 2). Per hectare average gross income obtained by the zero-tillage adopter and non-adopters was estimated to be Rs.89335.65 and Rs.78217.56 respectively. In case of zero-tillage adopters, per hectare net income over cost C_3 was estimated to be Rs.38020.44, whereas in case of zero-tillage non-adopter it was Rs.20947.57. Per hectare net income over cost C_2 (cost of all the inputs including imputed value of family labour) was found to be Rs.42685.46 and Rs.26153.93 for zero-tillage adopters and non-adopter respectively.

The benefit cost ratio (B-C ratio) for wheat production for zero-tillage adopters was estimated to be 1.74 over cost C_3 which was higher than the zero-tillage non-adopter i.e. 1.37. The B-C ratio over cost C_2 was found to be 1.92 and 1.50 for zero-tillage adopters and non-adopter respectively. Per quintal average cost of wheat grain production was estimated to be Rs.1028.77 and Rs.1311.53 for zero-tillage adopter and non-adopter respectively which was lower than the market price received by the sample farmers for wheat in the study area i.e. Rs.1442.50 per quintal. The per quintal cost of production of wheat crop over cost C_2 (all inputs cost plus imputed value of family labour and rental value of own land) was estimated to be Rs.935.24 and Rs.1192.30 for zero-tillage adopters and non-adopter respectively. It is clear from the above discussion that the zero-tillage adopter was fetching more income as compared to zero-tillage non-adopter.

Table 2. Income from wheat production.

Particulars		Zero-tillage adopter	Zero-tillage non-adopter
1. Crop yield (Qts/Ha)	a. Main product (Wheat grain)	49.88	43.67
	b. By-product (Wheat *bhusa)*	49.88	43.70
2. Market price (Rs./Qt)	a. Main product (Wheat grain)	1442.50	1442.50
	b. By-product (Wheat *bhusa)*	348.50	348.50
3. Gross income (Rs./Ha)		89335.65	78217.56
4. Net income over (Rs.)	a. Cost A_1	51415.65	33798.84
	b. Cost B_1	51415.65	33798.84
	c. Cost C_1	46144.24	30488.02
	d. Cost C_2	42685.46	26153.93
	e. Cost C_3	38020.44	20947.57
5. Input-output ratio over (Rs.)	a. Cost A_1	2.36	1.76
	b. Cost B_1	2.36	1.76
	c. Cost C_1	2.07	1.64
	d. Cost C_2	1.92	1.50
	e. Cost C_3	1.74	1.37
6. Cost of production (Rs./Qt)	a. Cost A_1	760.22	1017.22
	b. Cost B_1	760.22	1017.22
	c. Cost C_1	865.90	1093.04
	d. Cost C_2	935.24	1192.30
	e. Cost C_3	1028.77	1311.53

Economic benefit of zero-tillage

After adoption of zero-tillage sample farmers in the study area was getting higher yield of main and by-product of wheat crop. Per hectare average wheat grain and *Bhusa* for zero-tillage adopters was 49.88 and 49.88 quintal respectively, whereas in case of non-adopters it was 43.67 and 43.70 quintal respectively. The incremental grain yield benefit due to adoption of zero-tillage was estimated to be 6.21 quintal per hectare over non-adopters. Per hectare incremental yield of by-product of wheat was found to be 6.18 quintal per hectare.

The prevailing price of haring labour in the study area was Rs.300 per day, tractor charges was Rs.500.00 per hour, cost of seed was Rs.32 per kg and market price of main and by-product was Rs.1442.50 and Rs.348.50 per quintal. Per hectare economic benefits due to adoption of zero-tillage was estimated to be Rs.18662.96 (Table 3).

Table 3. Economic benefit of RCTs (Rs./Ha).

Sl. No.	Particulars	Amount (Rs.)
1.	Due to reduction in cost of labour	1378.94
2.	Due to reduction in cost of machine labour	3408.12
3	Due to reduction in cost of seed	674.07
4	Due to reduction in cost of fertilizer	411.61
5	Due to reduction in cost of pesticide	27.50
6	Due to save in irrigation cost	1615.37
7	Due to reduction in cost of harvesting	29.26
8	Due to yield benefits (main and by-product)	11118.09
	Total	**18662.96**

Environmental benefit of zero-tillage

The one litre burning of diesel fuel generates 2.6 kg of CO_2 (Jat et al., 2006) and one kg CO_2 is equal to 0.27 kg of carbon (Paustian et al., 2006). Per hectare total diesel used for land preparation and sowing of wheat crop was estimated to be 25.07 and 59.15 litres for zero-tillage adopter and non-adopter respectively. Per hectare CO_2 emission from zero-tillage and conventional method of wheat cultivation was estimated to be 65.17 and 153.78 kg respectively and carbon emission was 17.60 and 41.52 kg respectively. After adoption of zero-tillage, per hectare carbon emission was reduced by 23.93 kg.

Sample farmers of the study area were using groundwater to irrigate their wheat crop. Total water used for irrigating wheat crop by zero-tillage adopters and non-adopters were estimated to be 2235.44 and 3582.95 m^3 per hectare respectively. After adoption of zero-tillage, sample farmers were using less groundwater for irrigating their wheat crop. Reduction in irrigation water was estimated to be 1347.50 m^3 per hectare. Due to reduction in pumping of groundwater, there was saving in energy also i.e. electricity or diesel.

Factors influencing adoption of zero-tillage

Factors influencing adoption of zero-tillage in Ghaziabad district was estimated using binary logit model and results is displayed in Table 4. In case of dependent variable zero-tillage adopters and non-adopters, the binary value was used i.e. one for adopters and zero for non-adopters. Independent variables were family size in number, farming experience in year, land holding size (both own land and leased-in land minus leased-out land) in hectare and age of respondents. Results showed that "B" coefficients for farming experience, land holding size, age of respondents and education level of the respondents were statistically significant. It is clear from the results that farming experience and land holding size has positive impact on adoption of RCTs in the study area. It means if farming experience and land holding size of the farmers' increases, than there is better chance of RCTs adoption. The age of respondents and education level has negative impact on the adoption of RCTs in the study area. Beside above mentioned factors, natural factors viz., soil types and water availability are playing an important role in adoption of zero-tillage. In case of Ghaziabad district is characterised as water scarce district and major soil types of the district are black and clay soil. Both factors were playing an important role in adoption of zero-tillage.

Constraints associated with adoption of zero-tillage

The most important factor that influenced farmers for non-adoption of zero-tillage in the study area was weed problem in the agricultural field and farmers were not sure of profit after adoption of zero-tillage and its rank was estimated to be first and second (Table 5). Other important reasons that inhibiting the adoption of zero-tillage in the study area were non-availability of skilled labour, high cost of the zero-till-drill machine and farmer doesn't own zero-tillage machine and its rank was third, fourth and fifth respectively. The six, seventh and eight ranks are given by the farmers for not sure about the zero-till technology, non-availability of zero-tillage machine on time and on hiring basis respectively. Other reasons for non-adoption of zero-tillage in the study area were custom hiring of zero-tillage is high, uncertainty of irrigation, less yield under zero-tillage, poor soil quality, upland field, lack of financial support and credit unavailability.

Table 4. Factors influencing adoption of RCTs.

Variables	B	S.E.	Wald	df	Sig.	Exp (B)
a. Constant "a"	10.177*	4.976	4.183	1	0.041	26285.040
b. Family size (No)	-0.074**	0.229	0.105	1	0.746	0.928
c. Farming experience (Year)	0.149**	0.089	2.827	1	0.093	1.161
d. Land holding size (Ha)	0.532*	0.175	9.256	1	0.002	1.702
e. Age of respondents (Year)	-0.233*	0.117	3.955	1	0.047	0.792
f. Education level (Years)	-0.301*	0.172	3.054	1	0.081	0.740
Model Summery						
-2 Log likelihood	39.221					
Cox and Snell R Square	0.334					
Nagelkerke R Square	0.445					

*: Significant at 5.0 per cent level of significance; **: Significant at 10.0 per cent level of significance.

Table 5. Constraints for non-adoption of RCTs.

Sl. No.	Reasons for Non-adoption of RCTs	Garrett Score	Rank
1.	Weed problem	73.25	I
2.	Not sure of profit	67.20	II
3.	Labour issues	62.45	III
4.	High cost of zero-tillage machine	62.00	IV
5.	Does not own zero-tillage machine	58.95	V
6.	Not sure about technology	56.55	VI
7.	Non-availability of zero-tillage on time	54.35	VII
8.	Non-availability of zero-tillage on hire basis	50.55	VIII
9.	Custom hiring of zero-tillage is high	48.55	IX
10.	Uncertainty of irrigation	46.75	X
11.	Less yield under zero-tillage	44.00	XI
12.	Poor soil quality	43.80	XII
13.	Upland field	36.90	XIII
14.	Lack of financial support	29.10	XIV
15.	Credit unavailability	20.50	XV

Conditions for adoption of zero-tillage

The most important condition for adoption of zero-tillage in the study area was if zero-tillage machine is available on subsidised rate (Table 6). The sample farmers told that if they convinced of yield benefit then they adopt it on their own farm and its rank was second. The third and fourth condition for adoption of zero-tillage in the study area was if custom hiring rate of the zero-tillage machine is reduced and more observation on there's farmers' field. The least important condition for adoption of zero-tillage was availability of better repair service and availability of skilled labour for operating RCTs machine.

Table 6. Condition for adoption of zero-tillage.

Sl. No.	Condition for adoption of RCTs	Garrett Score	Rank
1.	If zero-tillage machine is available on subsidy	66.70	I
2.	If convinced of yield benefit	62.80	II
3.	If custom hiring rate is low	56.40	III
4.	More observation on other field	52.40	IV
5.	If better repair service is available	31.70	V
6.	Availability of skilled labour	30.00	VI

Summary and policy implications

Zero-tillage playing important role in reduction on cost of land preparation and sowing, saving time and reduction in overall cost of cultivation of wheat crop. It helps farmers to enhance crop production with less inputs use (Laxmi et al., 2007; Kumar et al., 2005; Singh et al., 2011; Pal et al., 2010; Singh and Meena, 2013). It also helps to reduce the carbon emission from land preparation and sowing of wheat crop. Per hectare cost of cultivation of wheat crop under zero-tillage was lower by Rs.5954.78 as compared to conventional method of wheat cultivation. The benefit cost ratio for zero-tillage adopters was 1.74. The economic benefit of zero-tillage adoption was Rs.18662.96 per hectare. The environmental benefits include reduction in carbon emission (23.93 kg per hectare) and irrigation water saving (1347.50 m^3 per hectare). The major factors responsible for the adoption of zero-tillage in the study area was land holding size, age of respondents, education level of farmers, farming experience and family size. Beside this, soil types also playing an important role in adoption of zero-tillage in study area. Among the different constraints, the high cost of zero-tillage machine, non-availability of zero-tillage machine on hiring basis and on time. The conditions for adoption of zero-tillage in the study area were subsidy available on purchase of zero-tillage machine, farmer convinced for yield benefit and reduction in cost of hiring zero-tillage machine. Therefore, government should provide subsidy on purchase of zero-tillage machine and provide training to farmers related to the use and benefits of machine. Increase in number of zero-tillage machine in study area will help farmers in adoption of technology and it will also augment the available machine on hiring basis on time and lower price.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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