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Impact of zero tillage on wheat production in north-western indo-gangetic plains of India

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Abstract
The paper has compared the economics of wheat production in North-Western Indo-Gangetic Plains of Haryana under zero tillage and conventional methods and assessed the contribution of technology and inputs to the increased productivity due to zero tillage (ZT). The net income has been found higher in ZT method, mainly due to lower cost of production and incremental gain in yield as compared to that in conventional method. The study has observed that ZT technology has potential to provide additional income to farmers and help in conservation of scarce resources. The PSM technique revealed 5.30 quintal incremental gain in productivity due to ZT. Despite several economic and environmental advantages, adoption of ZT technology has been limited and one major constraint identified as the lack of lack of technical knowledge followed by more weed infestation. The study has suggested that ZT technology should be disseminated on a wider scale with the help of better technical support to the farmers.

Keywords: Zero tillage, wheat production, economics, PSM, Haryana

Introduction
India is the second largest producer of wheat in the world with an average annual production of 95.90 Mt (million tonnes) in recent years which accounts for approximately 13.16 per cent of world's wheat production (FAO, 2016). Haryana is an important wheat-growing state in the country and produces 11.35 Mt of wheat with yield level of 4.41 tonnes per hectare (DES, 2016). The major challenge to wheat production in the state is the enhancing of its productivity and profitability. In Haryana, many farmers grow late-maturing, fine-grained basmati varieties of rice, causing late sowing of wheat. The delay of every successive day in planting beyond November third week decreases the grain yield progressively (Ali *et al*., 2010; Irfaq *et al.*, 2005; Sharma, 1992) [1, 11]. Therefore, to avoid delay in planting and reduce the cost of production, farmers have started adopting resource conserving technologies such as zero tillage and surface seeding in wheat production (Gupta and Seth, 2007) [9, 13]. Savings in input cost, fuel consumption and irrigation water-use have been reported due to adoption of zero tillage in wheat cultivation (Malik *et al.*, 2003; Bhushan *et al.*, 2007) [4]. Farmers prefer this technology due to farm labour shortage and rising fuel prices. Hence, the present study was undertaken with the objectives of comparing the economics of wheat production with zero tillage and conventional methods and quantifying the incremental gain in output with adoption of technology by comparing adopter with his counterfactual.

Methodology
Zero-tillage (ZT) has been interpreted here as the process of planting wheat seed after the harvest of rice directly on untilled soil which retains the rice crop residues. The conventional tillage (CT) refers to the intensive tillage with multiple passes of a tractor to accomplish land preparation for wheat sowing. Farmers in Haryana are adopting zero tillage technology for wheat cultivation. For this study, Karnal district was selected due to widespread adoption of zero tillage. From the Karnal district, four climate smart villages (CSV) and four non-climate smart villages (Non-CSV) were selected having larger area under ZT in wheat. A total of 30 farmers from CSV who adopted zero tillage technology for wheat production were selected randomly. From the Non-CSV villages, 40 numbers of farmers practising conventional tillage method were selected. The characteristics and socio-economic conditions of both types of the households were found to be dissimilar. The primary data were collected during the years 2016-17 from 70 farmers.

The modern cost concept, i.e., costs A_1, A_2, B_1, B_2, C_1 and C_2, was considered for the estimation of cost of wheat production. The cost C_1 was taken into account in this study to calculate net income and benefit-cost ratio. The cost C_1 included all direct expenses paid in cash and kind for crop production such as hired human labour, machine labour, seeds, fertilizers, irrigation, plant protection measures, overhead charges and imputed value of family labour. The overhead charges included land revenue paid to the state government, interest on working capital and fixed capital and charges paid for repairs, maintenance and depreciation of fixed assets.

In the present study, Propensity Score Matching Technique was used to quantify the impact of ZT technology on yield. In social science studies aiming at estimation of impact of technology, obtaining a suitable counterfactual is a challenge. Often, the units in treatment are different from the units in control, in variable other than treatment. Measuring impact without accounting for such dissimilarity can lead to sample selection bias. One way of circumventing the problem of bias is to match the farmers in treatment and control groups based on the variables, which can determine the program participation and then measure impact as average difference in the matched pair. This is the principle behind Propensity Score Matching (PSM) technique (Wu *et al.* 2010) [14]. The first step in the application of PSM is to estimate the propensity score, also known as the conditional probability which allows identifying similar farmers.

The propensity score can be estimated as follows:

$$P(Z_i) = Prob(C_i=1|Z_i) \quad (1)$$

Where, the propensity score, p (Zi) is estimated by a probit model. Next step is to check the common support or overlap condition it rules out perfect predictability of *Ci* given *Zi*, given as

$$0<P(C_i=1|Z_i)<1 \quad (2)$$

The common support assumption improves the matching quality by excluding farmers at the tails of the propensity score distribution. It ensures that characteristics observed in the ZT technology adopter group can also be observed among the non-adopter group (Bryson *et al*, 2002).

The second step in the implementation of the PSM method is to choose a best matching estimator. Several alternative indicators of matching quality are suggested in the literature. A good matching estimator does not eliminate too many of the original observations from the final analysis while it should at the same time yield statistically equal covariate means for households in the treatment and control groups (Caliendo and Kopeinig, 2008). It is a common practice to experiment with different matching estimators to check for the robustness of estimates. In the present study, nearest neighbourhood method (with 1:1, 1:3 and 1:5 matching) and caliper matching (with caliper of 0.1) was used. However, conventional standard error is not valid due to matching process. Hence, in nearest neighbourhood matching, analytical standard error is used for testing the statistical significance, as bootstrapping is not valid with nearest neighbourhood matching. In case of calliper matching, bootstrapped standard errors are used.

The average treatment effect on the treated (ATT) was estimated as follows (Becker and Ichino, 2002) [3]:

$$ATT = E\{Y^k_{1i} - Y^k_{0i} | C_i = 1\} = E[E\{Y^k_{1i} - Y^k_{0i} | C_i = 1, p(Z_i)\}]$$
$$= E[E\{Y^k_{0i} | C_i = 1, p(Z_i)\} - E\{Y^k_{0i} | C_i = 0, p(Z_i)\} | C_i = 1] \quad (3)$$

Where, Y1 and Y0 are values of the outcome variables of interest for CSA technology adopter farmers and non-adopter farmers respectively,

i refers to households; k refers to the outcome variable being analyzed (yield).

Results and Discussion

An understanding of the socio-economic pattern of the farmers will provide valuable insights on the decision for and mechanism of adapting to climate change. Details regarding the socio-economic status of selected Climate smart Villages and Non - Climate Smart Village respondents have been tabulated in Table 4.1. Age of CSV farmers was lower than that of Non-CSV farmer. It is observed that younger people are more receptive to new technology. The family size of CSV farmers is smaller, are better educated and higher proportion had farming as a main occupation than those of Non-CSV farmers in study area. More number of CSV farmers were members of various organisations likes Farmers Club, Self-Help Groups, Grampanchayat, Co-operative societies etc. as compared to Non-CSV farmers, which could play a role in to get more exposure to the availability of various adaptation strategies to climate change. The CSV farmers have on an average more access to credit and access to training as compared to Non-CSV farmers. The average farm size was also observed to be more in case of CSV farms (4.53 ha) as compared to Non-CSV farms (4.28 ha). At overall level, the cropping intensity on CSV sample farms is 15 per cent more than Non-CSV sampled farms.

Table 1: Table 4.1 Socio-economic characteristics of sample farm households

S. No.	Particulars	Karnal farmers		Overall
		CSV	NCSV	
1	Sample size (No.)	80	40	120
2	Average age (years)	45.84	47.3	46.57
3	Average family size (No.)	6.3	6.9	6.6
4	Literacy (%)	77.5	72.5	75
5	Farming main occupation (%)	92.5	87.5	90
6	Farm size (ha)	4.53	4.28	4.45
7	Training access (Yes=1; otherwise=0)	67	17	42
8	Membership of organization (Yes=1; otherwise=0)	36	11	23.5
9	Credit access (Yes=1; otherwise=0)	66	28	47
10	Cropping intensity	198	183	190.5

Resource-use and Cost and Return Structure in Wheat Production

The major farm inputs used for the production of wheat in CT and ZT methods are mentioned in Table 2.

It is revealed from table that farmers saved 9.09 per cent human labour, 79.36 per cent machine labour, 7.27 per cent seed, 6.10 per cent fertilizer and 11.40 per cent duration of irrigation in ZT compared to CT method of wheat production. Several studies have also shown that ZT method of wheat production provides several benefits such as saving of irrigation water, reduction in production cost, less requirement of labour and timely establishment of crops, resulting in improved crop yield and higher net income (Laxmi *et al*., 2007; Farooq *et al*., 2006; Erenstein *et al*., 2007) [13]. This suggests that by adopting zero tillage method, farmers can save a substantial quantity of resources which helps to overcome the problems of human and machine (tractor) labour shortage at the time of land preparation and sowing operations.

Table 2: Major farm inputs used in wheat production in North-Eastern IGP

Particulars	Zero Tillage	Conventional Tillage	Change (%)
Human labour (human days/ha)	51.18	56.3	-9.09
Machine labour (hours/ha)	1.8	8.72	-79.36
Seeds (kg/ha)	102	110	-7.27
Fertilizer (kg/ha)	462	492	-6.10
PPC (g/ha)	541	507	6.71
Duration of Irrigation (hr/ha)	39.96	45.1	-11.40

The production costs and returns of wheat production using ZT and CT methods are presented in Table 3. Gross returns were Rs. 88110 per ha in ZT and 84315 per ha in CT. The return over operational cost amounted to Rs. 60128 per ha in ZT and Rs. 49579 per ha in CT method of wheat production. The net income was higher in ZT method due to higher yield and lower cost of cultivation as compared to CT method of wheat cultivation. The cost of cultivation amounted to Rs. 27982 per ha in ZT method and Rs.34736 per ha in CT method. The lower cost of cultivation was due to lower expenses on human labour (9.09 per cent), machine labour (79.36 per cent), seed (7.27 per cent), fertilizer (5.57 per cent) and irrigation (11.39 per cent) in ZT than in CT method. The benefit-cost ratio of 1.98 was observed in ZT as against 1.66 in CT method of wheat production.

Table 3: Cost and return in wheat production using Zero Tillage method in Haryana

Particulars	Zero Tillage	Conventional Tillage	Change (%)
Cost on human Labour	14075	15483	-9.09
Cost on machine Labour	1080	5232	-79.36
Cost on seeds	2040	2200	-7.27
Cost on fertilizer	4067	4307	-5.57
Cost on PPC	2232	2160	3.33
Irrigation charges	1944	2194	-11.39
Overhead Cost	2544	3160	-19.49
Total Operational cost	27982	34736	-19.44
Gross income	88110	84315	4.50
Return over operational cost	60128	49579	21.28
Benefit-cost ratio over cost C_1	1.98	1.66	19.28

There was significant difference in wheat yield with and without ZT method of cultivation (Table 4).

Table 4: Yield, cost and return in CT and ZT methods of wheat production in NE IGP

Particulars	Zero Tillage	Conventional tillage	Change (%)
Yield (t/ha)	53.4	51.1	4.50
Operational cost (Rs/ha)	27982	34736	-19.44
Gross income (Rs/ha)	88110	84315	4.50
Net income (Rs/ha)	60128	49579	21.28
Cost of grain production (Rs/kg)	5.24	6.8	-22.94

It was about 4 per cent more with the application of ZT than with CT method. It was also observed that among the integrated conservation and resource management technologies, ZT for wheat was most successful in terms of crop establishment (Ladha *et al*., 2009) and gain in yield ranging from 1 per cent to 12 per cent (Erenstein and Laxmi, 2008) [7]. The gross and net returns in ZT of wheat production were higher by 4.50 per cent and 21.28 per cent, respectively, as compared to in CT method. The higher net return obtained in ZT was mainly due to reduction in the total cost of cultivation by 19.44 per cent. Similar results have been reported by many other studies conducted on this aspect and explained the fact that the net revenue in wheat production was significantly higher under ZT than under CT method (Erenstein *et al*., 2007; Iqbal *et al*., 2002) [13, 10]. The cost incurred to produce a kilogram of wheat was Rs. 6.8 in CT and Rs.5.24 in ZT methods. Thus, the cost of wheat grain production was lower by 22.94 per cent in ZT as compared to in CT method. This analysis suggests that ZT technology offers more scope to generate additional income and helps in conservation of scarce resources.

Estimated Impact of ZT on Yield with PSM technique

Propensity Score Matching (PSM) technique was used to determine the impact of ZT on productivity of sample farmers. PSM method is used to determine the impact of ZT on farmer's crop productivity.

Estimation of propensity scores in Haryana

The propensity scores are estimated by using probit model (Table 5) and it is used to identify the farms with characteristics similar to that of adopters from among non-adopters which are cultivating wheat in study domain.

Table 5: Results of Probit estimations of propensity scores for Zero tillage in Haryana

Variable	Coefficient	Z-value
Age	-0.010	-0.32
Education	0.707	1
Main occupation	-0.422	-0.38
Farm size	0.109	1.47
Membership	-1.013	-1.51
Training access	3.16***	4.22
Credit access	0.608	0.58
Constant	-2.381	-0.98
Balancing	Yes	
Observation	70	
Pseudo R^2	0.539	

Note: ***, ** and * indicate significance at 1, 5 and 10 per cent level, respectively.

Based on conditional independence assumption, the explanatory variables that are influencing the improvement of productivity are selected. The explanatory variables include age of household head, education, main occupation, farm size, membership in organization, training access and credit access. The pseudo-R^2 of the estimates is 0.539 and satisfies the balance requirement of the variables. The result shows the impact of socio-economic characteristics on productivity of farmers. The training access has positive influence on productivity of crop.

Testing for common support in Haryana

Once propensity scores are calculated and balancing property is satisfied, common support is graphically tested. It was found that there was sufficient overlapping of propensity scores across ZT and CT groups. The density plot of propensity score is presented in figure 1 which depicts that the two groups are comparable through matching.

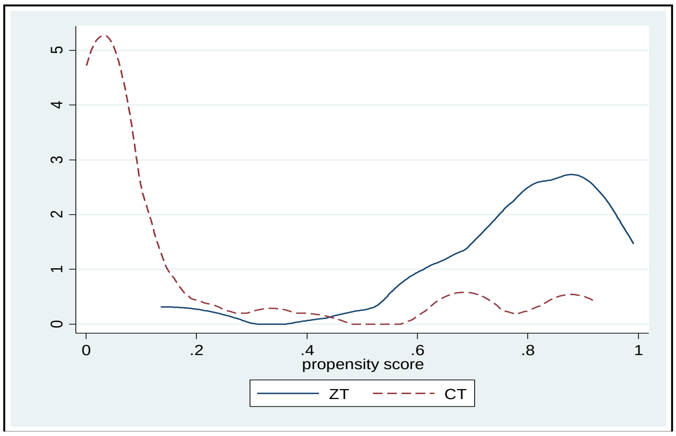

Fig 1: Density of the propensity score for ZT technology impact, Haryana

Average Treatment Effect on the Treated (ATT) in Haryana

The Propensity Score Matching (PSM) method is used to determine the impact of ZT on productivity of sample farms of study area. ATT is considered as measure of impact of technology. Based on theoretical expectation, impact of ZT was measured on productivity.

The impact is assessed using different estimators to assure robustness (Table 6). All the matching estimators have shown different results and it shows maximum impact under calliper matching estimator. ZT has positive impact and statistically significant effect on productivity of farmers. More specifically, the productivity of wheat crop under ZT as compared to CT was increased by 5.30 quintals/ha. In all, the estimated impact on yield by PSM technique was found 3qtl/ha more than that of the observed impact estimated by taking simple mean productivities of adopter and non-adopter farm.

Table 6: Impact of Zero Tillage on yield of wheat, Haryana: ATT

Matching estimator type	ATT	Standard Error	Z- Value
Yield (qtl/ha)			
Nearest Neighbourhood matching (1)	6.03	2.55	2.36
Nearest Neighbourhood matching (3)	5.29	2.78	1.9
Nearest Neighbourhood matching (5)	3.67	2.52	1.46
Calliper Matching (Cal of 0.1)	6.21	2.79	2.23
Average Estimated Impact on Yield	5.30		
Observed Impact on Yield	2.30		

Note: Nearest neighbour matching has bias-adjusted standard errors and calliper matching estimators has bootstrapped standard errors.

Conclusions

The study has revealed that it is possible to save human labour, machine labour, seed, fertilizer and irrigation water under zero tillage than under conventional method. Due to resource saving, net return has been significantly higher in zero tillage technology. Hence, this technology is an important alternative to save scarce resources and enhance the net farm income. The PSM technique has shown that per hectare production of wheat was 5.30 quintal more in zero tillage than in conventional tillage method. Therefore with the adoption of this technology, farmers could save scarce resources and reduce the cultivation cost. In view, in order to enhance the adoption of ZT technology in Haryana it is important to address the constraints namely lack of technical knowledge and control of weeds at the time of drilling.

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