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Economic impact of zero tillage on wheat cultivation in Ambala (Haryana), India

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Abstract: The present study was conducted with the specific objective i.e. to analyze the economic impact of re-course conservation technology (zero tillage) as compare to conventional tillage practices on wheat cultivation in Ambala district of Haryana. The study revealed that there was significant impact of conservation practices, 22% human labour, 37% machine labour, 25% seed cost and 33% irrigation water was saved under zero tillage compared to conventional tillage (CT) method of wheat production. B: C ratio under zero tillage was 2.86 while under conventional method it was reduced to 2.56. Therefore, zero tillage was economically feasible. It was observed that through the zero tillage farmers can get 3% more yield. The net returns in ZT of wheat production were higher by 4% as compared to CT method. In case of zero tillage, economic efficiency measure was 0.61 as compared to 0.34 in conventional system of wheat cultivation. The research work conducted was holistic in nature combining various elements of technology, resource conservation and economics.

Keywords: Analysis, Conventional, Economic, Zero tillage

INTRODUCTION

World wheat market increasing every year due to increase in wheat demand resulting in more wheat production. Production of wheat in 2012/13 was 655.1 million tonnes which was increased to 734.1 million tonnes in 2015- 16. India is the second largest producer of wheat in the world with an average annual production of 88.93 million tonnes in 2015/16 (Directorate of Economics and Statistics, Ministry of Agriculture). It accounts for approximately 11.98 percent of world's wheat production (FAO, 2016). Haryana is one of the major wheat-growing state in the country and produces 10.3 million tonnes wheat with yield level of 4.72 tonnes per hectare (Anonymous, 2015). The major challenge to wheat production in the state is the enhancing 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 (Sharma, 1992, Irfaq *et al.*, 2005 and Ali *et al.*, 2010). Therefore, to avoid delay in planting and reducing 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) 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). Keeping these facts in view a holistic study was conducted to assess the resource conservation and economics of wheat production in Ambala district of Haryana using zero tillage.

MATERIALS AND METHODS

Data collection: Both secondary and primary data were collected for the study. The primary data refers to direct input from farmers using a pre developed questionnaire covering socio-economic strata of the growers, wheat production practices being followed in the region, production input costs , input and income ratio's etc. Secondary data on similar aspects such as, area , production and productivity covering various cultivation methods pertaining to some villages in Ambala Duistrict were collected from government statistical agencies.

Selection of district: Ambala district of Haryana was selected purposively on account of a large area of wheat under zero tillage.

Selection of blocks and villages: Three blocks were

selected randomly. In Ambala district, Barara, Ambala -1 and Saha blocks were selected. Further, from each block, two villages were selected randomly i. e. Nahra and TalheriRangran selected from Barara block and Amipur and Bullana selected from Ambala-1 block and Akbarpur and Harda selected from Saha block.

Selection of farmers: Twenty farmers from each village were selected randomly i.e. half of them adopted conservation agricultural practices and half adopted conventional agricultural practices. Thus 120 farmers were selected. The primary data were collected on various aspects of conservation and conventional practices in wheat cultivation.

The appropriate statistical models (both tabular and functional analysis) were applied for the analysis of related data.

Cost concepts: Wheat production using zero tillage and conventional tillage methods involve method specific costs on various inputs. These included variable and fixed costs. The variable cost included input costs on fertilizers, seeds, labour costs including sowing ,interculture, harvesting irrigation, agrochemicals for plant protection etc. The fixed costs mainly include the cost of land, machinery etc.

Returns measures: For computing economic impact of zero tillage technology for wheat production various kinds of return measures were calculated. These included

Gross returns: Gross returns were obtained by multiplying the total product with the price realized.

Net returns over operational cost: Net returns were obtained by deducting the total costs incurred from the gross returns obtained.

Benefit: cost ratio over operational cost : Returns per rupee of cost were obtained by dividing the gross returns with cost of cultivation.

Resource productivity in crop production: The specific Cobb-Douglas type of production function used for the study was :

$$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} U \quad \ldots\ldots\ldots \quad (1)$$

Where,

Y = Gross returns (Rs./ha)
α = Intercept, a scale parameter
X_1 = Human labour (Rs./ha)
X_2 = Machine labour (Rs./ha)
X_3 = Seed (Rs./ha)
X_4 = Chemical fertilizers (Rs./ha)
X_5 = Plant protection chemicals (Rs./ha)
U = Error term
b_i = Output elasticity of respective inputs. The summation of these give returns to scale.

The equation (1), upon logarithmic transformation took the linear form; the parameters were estimated using the Ordinary Least Square (OLS) method.

$$\ln y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + U \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Economic efficiency of conventional and conservational practices in wheat systems

Frontier production function analysis: To capture the ability of farmers to achieve the maximum realizable crop outputs with minimum level of inputs under the existing situation and given technologies, a careful examination of farm specific technical efficiency of the farmers was necessary.

$$\sum_{i=1}^{n} \beta i \; In \; xi + U$$

The function in log form will be:

$$\text{In } Y = A + U \leq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The above model was estimated using Corrected Ordinary Least Squares (COLS) regression. As a first step, Ordinary Least Squares (OLS) was applied to the regression equation to yield best linear unbiased estimates of βi coefficient. The function estimated was in the form below:

$$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} U \quad \ldots\ldots\ldots\ldots (4)$$

Where,

Y = Gross returns (Rs./ha)
α = Intercept, a scale parameter
X_1 = Human labour (Rs./ha)
X_3 = Seed (Rs./ha)
X_4 = Chemical fertilizers (Rs./ha)
X_5 = Plant protection chemicals (Rs./ha)
X_6 = Irrigation (Rs./ha)
U = Error term
b_i = Output elasticities of respective inputs. The summation of these gave returns to scale.

Equation (4) was estimated in log form using Ordinary Least Square test. The above equation was chosen in place of equation (2) and (3) to nullify the scale effect in assessing the technical efficiency. The frontier production function was derived from the Cobb-Douglas type production function fitted to the gross returns from crop cultivation. The technical efficiency was worked out using potential output that can be realized from a set of inputs. The potential gross returns are given by the following method :

$$Y^* = Y + e_m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

Y* = Potential gross returns that could be derived from crop cultivation
Y = Estimated gross returns from crop cultivation
e_m = Highest positive error term

The intercept estimate 'α' was then corrected by shifting the function until no residual was positive and one became zero. This was done by adding the largest error term of the fitted model to the intercept. The new production function with shift in the intercept in the frontier production function and it gave the maximum gross returns obtainable for given level of input and it would be of the form.

$$\sum_{i=1}^{n} \beta i \; In \; Xi + U$$

$\ln Y^* = A + U \leq 0$ …….. (6)

If the value of β_i was negative, then the geometric mean of i^{th} input X_i was taken instead of $\beta_i \ln X_i$. The frontier production functions were estimated separately for canal irrigated and well irrigated farms.

Timmer's measure of technical efficiency: It was the ratio of actual gross returns to the potential gross returns on the production function given the level of input use on the i^{th} farm.

Technical efficiency of i^{th} farm = Y_i / Y_i^*

Where,

Y_i = Actual gross returns from crop cultivation on i^{th} farm

Y_i^* = The potential gross returns attainable from crop cultivation on i^{th} farm

Allocative efficiency:

$$\text{Allocative efficiency} = \frac{VMP_{Xi}}{MFC_{Xi}}$$

$$VMP_{Xi} = \frac{\beta_i Y_i}{X_i} \quad \ldots\ldots (7)$$

Where,

VMP_{Xi} = Value marginal product of i^{th} input

β_i = Input coefficient of i^{th} input

$\overline{Y}_i$ =Geometric mean of gross returns of i^{th} input

$\overline{X}_I$ =Geometric mean of input of i^{th} input

Economic efficiency: Economic efficiency (EE) is the product of technical efficiency (TE) and allocative efficiency (AE)

$$EE = TE \times AE \quad \ldots\ldots (8)$$

RESULTS AND DISCUSSION

Cost of cultivation of wheat in Ambala district of Haryana among different practices: It can be observed from Table 1 that on adoption of zero tillage and conventional mode of practices of wheat cultivation, farmers incurred a total cost of Rs. 29000 and Rs. 33200/ha, respectively. The cost of cultivation on the zero seed drill farms was lower than the cost incurred by the conventional farms due to higher cost incurred towards human labour, machine labour, seed and irrigation. This result coincides with that obtained by Tripathi *et al.* (2013) i.e. Gross returns were ` Rs. 60181/ha in ZT and Rs. 59070/ha in CT. The net return amounted to Rs. 34057/ ha in ZT and Rs. 29135/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. 26124/ha in ZT method and` Rs. 29935/ha in CT method. The lower cost of cultivation was due to lower expenses on human labour (5.74%), machine labour (46.30%) and irrigation (17.65%) in ZT than in CT method. The benefit-cost ratio of 2.30 was observed in ZT as against 1.98 in CT method of wheat production.

. The cost incurred on PPC was higher in case of zero seed drill farms. This was because of high infestation of weed in zero tillage. The seed cost was high in conventional farms as the seed rate used was higher compared to zero tillage. Expenditure on human labour was relatively higher in conventional farms due to more family labour worked under conventional farms. The rental charge of machine labour was higher so the expenditure on machine labour was high in conventional farms. The expenditure on irrigation was high in case of conventional farms because farmers used more number of irrigations compared to zero tillage.

The total fixed cost was higher in conventional farms than that of zero tillage farms because of high depreciation of machine in the conventional farms and also farmers in conventional system of farming possessed more machinery and farming implements and hence got getting high depreciation cost, which led to high total fixed cost. Net returns in case of zero tillage farms were higher compared to conventional farms. The benefit: cost ratio was found to be 2.86 for zero tillage and 2.56 for the conventional tillage. The benefit: cost ratio in the zero tillage was much higher than the conventional tillage. The zero-till-seed-cum-fertiliser drill sowing of wheat gave a weighted average increase in yield of 6.4 percent in Haryana and 2.6 percent in Punjab over conventional method of sowing. It reduces the phalaris minor (a menacing weed of

Table 1. Cost and return in wheat production using zero and conventional tillage methods in Haryana (Rs./ha).

Particular	Zero tillage	Per cent share	Conventional	% share
Cost on human labour	5150	17.75	6250	18.82
Cost on machine labour	9850	33.96	13500	40.66
Cost on seed	3000	10.34	3750	11.29
Cost on fertilizer	5250	18.10	4250	12.80
Cost on PPC	3500	12.06	2450	7.37
Irrigation charges	2250	7.75	3000	9.03
Operational cost	29000	100	33200	100
Gross returns	83025	-	85200	
Net returns	54025	-	52000	
Benefit : cost ratio over operational cost	2.86	-	2.56	

Table 2. Benefits of zero tillage over conventional agriculture in input use (Rs./ha).

Particular	Conventional tillage	Zero tillage	Gain over conventional tillage (%)	Loss over conventional tillage (%)
Cost on human labour	5150	6250	22	
Cost on machine labour	9850	13500	37	-
Cost on seed	3000	3750	25	-
Cost on fertilizer	5250	4250	-	19
Cost on PPC	3500	2450	-	30
Irrigation charges	2250	3000	33	-

Table 3. Gain and loss of zero tillage over conventional agriculture in yield, cost and return.

Particular	Zero tillage	Conventional tillage	Gain (%)	Loss (%)
Yield (t/ha)	5.20	5.25	-	3
Operational cost (Rs./ha)	29000	33200	15	-
Gross returns (Rs./ha)	83025	85200	-	3
Net returns over variable cost (Rs./ha)	54025	52000	4	-
Cost of production (Rs./kg)	5.86	6.51	11	-
B : C ratio	2.86	2.56	10	

Table 4. Regression coefficient under zero tillage.

S. No.	Particular	Coefficient	Std. error	t- value
1.	Intercept	5.256	0.832	6.317
2.	Labour	0.256	0.143	1.790
3.	Machine	0.133	0.151	0.880
4.	Seed	0.204	0.244	0.836
5.	Fertilizer	-0.250***	0.094	2.659
6.	PPC	-0.230	0.140	0.1.64
7.	Irrigation	0.278**	0.136	2.044
	Adjusted R^2		0.810	

***, **Indicate significance at 1 and 5 per cent levels, respectively.

Table 5. Regression coefficient under conventional tillage.

S. No.	Particular	Coefficient	Std. error	t- value
1.	Intercept	9.660	0.822	11.758
2.	Labour	0.687**	0.337	2.038
3.	Machine	-0.007	0.125	0.052
4.	Seed	-0.882**	0.377	2.340
5.	Fertilizer	0.251***	0.095	2.537
6.	PPC	-0.013	0.187	0.070
7.	Irrigation	0.096	0.097	0.991
	Adusted R^2		0.71	

*** and ** Indicate significance at 1 and 5 per cent levels, respectively.

wheat) population by 30 percent and cost of tillage operations from Rs. 2,000 to 500/ha (Mehta and Singh, 2005). The net income was found higher in ZT method, mainly due to lower cost of production compared to that in conventional method in wheat crop (Tripathi *et al.*, 2013).

Benefits of zero tillage over conventional agriculture in case of input use, yield, cost and return: The major farm inputs used for the production of wheat in conventional tillage (CT) and zero tillage (ZT) methods are mentioned in Table 2.

It was observed that through the zero tillage farmers could save 22% human labour, 37% machine labour, 25% seed cost and 33% irrigation water in ZT compared to CT method of wheat production. Several studies have also shown that ZT method of wheat produc-

Table 7. Distribution of sample farmers in wheat cultivation according to technical efficiency levels.

S. No.	Inputs	Zero seed drill			Conventional		
		MVP	MFC	Allocative efficiency (MVP/MFC)	MVP	MFC	Allocative efficiency (MVP/MFC)
1.	Labour (Rs.)	0.71	1	0.71	0.44	1	0.44
2.	Machine (Rs.)	0.18	1	0.18	-0.03	1	-0.03
3.	Seed (Rs.)	0.27	1	0.27	-0.21	1	-0.21
4.	Fertilizer (Rs.)	-0.37	1	-0.37	0.56	1	0.56
5.	PPC (Rs.)	-0.07	1	-0.07	-0.04	1	-0.04
7.	Irrigation (Rs.)	0.73	1	0.73	0.47	1	0.47
Allocative efficiency of this model				0.71			0.38

Table 8. Different efficiency measures of different practices.

Practices	Technical efficiency	Allocative efficiency	Economic efficiency
Zeroseed drill	0.96	0.64	0.61
Conventional	0.94	0.36	0.34

tion provides several benefits such as saving of irrigation water, reduction in production cost, less requirement of labour and timely establishment of wheat crops, resulting in improved crop yield and higher net income (Farooq*et et al.*, 2006; Laxmi*et et al.*, 2007). 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 labour shortage at the time of land preparation and sowing operations.

Table 3 shows that through zero tillage farmers can get 3% more yield. The net returns in ZT of wheat production were higher by 4% as compared to CT method. The higher net returns obtained in ZT were mainly due to reduction in the total cost of cultivation by 15%. Similar results were 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 (Iqbal *et et al.*, 2002; Erenstein *et al*., 2007). The cost of wheat grain production was lower by 11% in ZT as compared to in CT method.

Resource productivity in wheat cropping system under zero seed drill cultivation system: The regression estimates of Cobb Douglas are presented in Table 4. The intercept, which represents the contribution of the factors that are not included in the model, was found to be 5.256. The adjusted coefficient of multiple determinations was 0.810, indicating adequacy of fit for the model, about 81% variability in gross returns was explained by the variables considered in the model.

The regression coefficient which shows change in dependent variable due to unit change in input was worked out. The results showed that the regression coefficients for labour (0.256) and irrigation (0.278) were significant at 10 and 5% levels of significance, respectively. The regression coefficients for machine (0.133) and seed (0.204) were positive but not significant. The coefficient pertaining to fertilizer (-0.250) was negative and significant at 1% level of significance. Whereas PPC (-0.230) was negative and significant at 1% level.

Resource productivity of wheat cropping system under conventional cultivation system: Data presented in Table 5 shows that the intercept was found to be 9.660. The adjusted coefficient of multiple determination was 0.71, indicating adequacy of fit for the model. The regression coefficients of labour (0.687) and fertilizer (0.251) were significant at 5 and 1% levels of significance, respectively. The regression coefficient of seed (-0.882)was negative but significant at 5% level of significance. The coefficient pertaining to irrigation (0.096) was positive but not significant, whereas machine (-0.007) and PPC (-0.013) regression coefficients were negative but non-significant.

Allocative efficiency in wheat cultivation under zero seed drill cultivation system: The allocative efficiency of wheat cultivation under zero tillage with zero seed drill is presented in Table 6. The allocative efficiencies (MVP) for labour (0.71) and irrigation (0.73) were less than unity which indicates over use of these resources implying additional investment in these inputs is not economical, since the additional revenue obtained will not be adequate to cover the additional cost incurred. However, the allocative efficiency measure of fertilizer (-0.37) was negative indicating that its use is in the irrational region (III region) of the production function. Other inputs like seed, machine, and PPC did not show significant regression coefficient, hence avoided from interpretation of results.

The allocative efficiency of wheat cultivation in conventional tillage is presented in Table 6. The allocative efficiencies (MVP) for labour (0.44) and fertilizer (0.56) were less than unity indicating over use of these resources, any additional investment in these inputs was not economical. However, the allocative efficiency measure of seed (-0.21) was negative indicating that its use was in the irrational region (III region) of the production curve. Other inputs like seed, machine, PPC and irrigation did not show significant regression coefficient.

Technical efficiency of wheat cultivation under zero

seed drill system and conventional agriculture system: The mean technical efficiency (Table 7) of wheat cultivation under zero seed drill cultivation system was 96%. Majority of the farmers using zero seed drill for cultivation of wheat (48.57%) had higher efficiency (95-100% technical efficiency) and 31.43% farmers had moderate efficiency (90-95% technical efficiency) among the different categories of farmers. Only 14.29% farmers were under medium efficiency (85-90% technical efficiency) and remaining farmers were with the low efficacy which comprised only 5.71% (80 -85% technical efficiency). The stochastic frontier production function was used to determine the technical efficiency of these farmers. Technical efficiency was found different under both the conditions. The estimated mean technical efficiency of wheat farmers under dry condition was found to be 0.84, indicating 84% efficiency in their use of production inputs, and for irrigated condition it was found to be 0.88, that means the average output of wheat could be increased by 12% by adopting technology properly (Kachrooa *et al.*, 2010).

The mean technical efficiency (Table 7) of wheat cultivation under conventional cultivation system was 94%. Among the different categories of efficiency level, majority of farmers (51.43%) practised conventional method of wheat cultivation with moderate efficiency (90-95% technical efficiency), and 24.29% farmers were in high efficiency (95-100% technical efficiency). Only 18.57% farmers were under medium efficiency (85-90% technical efficiency). And remaining farmers were with low efficiency which comprised only 5.71% (80-85% technical efficiency).

Economic efficiency of different cultivation systems of wheat cultivation: The economic efficiency for different practices of wheat cultivation was calculated as product of the technical efficiency of particular cultivation system with their respective allocative efficiency and the results are presented in Table 8. In case of zero seed drill system, economic efficiency measure was 0.61 indicating that there was scope to increase the returns by 38% with optimum allocation of resources. It was 0.34 in conventional system of wheat cultivation. This indicates 66% with optimum allocation of resources in conventional tillage. The results showed that zero seed drill cultivation of wheat cultivation system was economically more efficient compared to rotavator and conventional system of wheat cultivation. Stochastic frontier production and cost functions were used to estimate the economic efficiency of farmers. The results showed that the mean technical efficiencies of wheat were 0.75 and 0.66 in Dongola and Ed-abba, respectively, while for faba bean they were 0.65 and 0.71, the overall mean allocative efficiencies of wheat in the two localities were 0.72 and 0.68, whereas they were 0.86 and 0.84 for faba bean. The predicted overall mean of economic efficiencies that estimated as inverse of their cost efficiencies of wheat was 0.41 and 0.45 in the two localities, while in faba bean production they were 0.57 and 0.62 in Dongola and Ed-abba, respectively (Ali *et al.,* 2012).

Conclusion

The comparative study of cost of cultivation of wheat indicated that zero tillage was more profitable in comparison to other conservation agricultural practices, namely, the conventional. The reason behind this is that the cost of cultivation was lower due to lower cost incurred towards human labour, machine labour, seed and irrigation. In case of zero seed drill, economic efficiency was 61%, whereas the economic efficiency was only 34% under conventional system of wheat cultivation. The result showed that zero seed drill cultivation of wheat was economically more efficient compared to conventional system of wheat cultivation as it accrued 4% higher net returns over conventional tillage system that corresponded to gain of Rupees 2025 per hectare

The research work conducted was holistic in nature combining various elements of technology, resource conservation and economic impact of zero tillage technology on net returns to the farmers in terms of sustainability.

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