# Adoption and Impact of Zero Tillage Technology for wheat in Rice-Wheat System– water and cost saving technology. A case study from Pakistan (Punjab).

Muhammad Naeem Sarwar[1] and Muhammad Arif Goheer[2]

**Abstract**

*One of the major cropping systems of South Asia is rice-wheat, grown on 13.5 million hectares on the Indo-Gangetic Plains (IGP). It has a pivotal role in the food security and livelihoods of millions of farmers and workers. Continuously, need is being felt to explore the possibilities of saving critical inputs by adopting alternative resource conservative technologies as zero tillage. Main aim of this paper was to see factors affecting the adoption and impact of zero tillage technology in rice wheat system. Economic analysis of the data presented in this paper shows that zero tillage method for wheat cultivation is the most economical and attractive option for farming community. The high yield grain and less cost of production per hectare were noted on zero tillage farms as compared with conventional farms. In this paper, analytical technique was employed for the adoption of zero tillage technology in Pakistan (Punjab). A binary Logit model was also estimated based on the available data set, with the probability of adoption of zero tillage technology as a dependent variable and set of other variables as the explanatory variables. It was found that with the increase in farm size, the probability of adoption of zero tillage technology increases. While with the high NPK nutrients cost per hectare and with more tubewell irrigation time required to irrigate one hectare of land the probability of adoption of zero tillage technology reduces. Finally, the adoption of zero tillage technology improves farmer's profit and eventually contributes towards reducing poverty and keeping environment clean. However, the long-term impacts of this technology on food production, natural resources (land and water) and linkages with poverty alleviation should be further explored.*

**Key words**: Adoption, Zero tillage, Binary Logit model, Economics

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The authors are currently working as Research Officer and Sr. Research Fellow with the Centre for Research on Poverty Reduction and Income Distribution and Global Change Impact Studies Centre respectively. The author's would like to acknowledge the valuable comments and suggestions by Dr.Intizar Hussain on earlier draft of this paper.

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## Introduction

The Indo-Gangetic Plains of Pakistan, India, Nepal and Bangladesh are endowed with plentiful natural resources, deep productive soil, sufficient good quality water, climatic conditions that permit multiple-cropping, high population density and relatively good infrastructure. The Green Revolution technologies, beginning 1970s, have remained the cornerstone of South Asian strategy for food security, nutrition, rural development, and poverty alleviation. Slowed growth of productivity in agriculture, and negative impacts of intensive agriculture on environmental quality, suggest infusion of a complimentary set of new agricultural technologies to boost productivity growth.

The rice-wheat cropping system occupies 21 million hectares of cultivated land in the Asian subtropics (Dawe et al., 2003). In South Asia, the rice-wheat cropping system is practiced on 13.5 million hectares and is one of the most important cropping patterns for food security in the region as it provides staple grain for more than 400 million people. The area of rice-wheat systems in India, Pakistan, Bangladesh and Nepal is 10.0, 2.2, 0.8, and 0.5 million hectares respectively. Rice-Wheat systems represent 32 percent of total rice area and 42 percent on the wheat area in these countries. (Ladha et al., 2000).

In Pakistan, under rice-wheat cropping system, farmers grow rice in Kharif season followed by Wheat in Rabi season. The total area under rice in Pakistan is about 2.2 million ha, out of which 62 percent of rice area is in Punjab alone. Out of total rice area in the country, 50 percent is under fine rice varieties (Basmati). Punjab, the largest rice-growing province in the country, occupies 78 percent of area under fine varieties. Farmers prefer to grow fine rice in spite of low productivity and longer time period due to its high gross margins. Punjab province contributes about 96 percent to the total rice production of Pakistan (Khan 2002).

Farmers in the Indo-Gangetic Plains are rapidly adopting zero-tillage for sowing wheat after rice. Because of the benefits from zero tillage i.e. more yield, cost effectiveness, significant saving in water, soil quality and inputs, the zero tillage area surpassed 200000 ha in the year 2001 in the Indo-Gangetic Plains and its adoption is expected to exceed one million in the next few years because local manufacturers are trying hard to fulfill the equipment demand. In India and Pakistan on an average, there is a net benefit of US$150 per ha, through higher yields and less land preparation cost (Gupta 2002).

The technique of zero tillage was demonstrated during 1995-96 in an area of 50 acres, which has now registered a phenomenal growth raising it to 0.5 million acres in Pakistan. It ensures timely sowing of wheat minimizes cost of production through land preparation, seed rate, labor and irrigation water, fertilizer use efficiency as well as increases uniform seed germination.

The speedy development of agriculture is vital for the progress of country and to secure maximum crop production, the best use of the available land has to be made and the latest method of crop husbandry put into practice. There is an increase in the yield with zero-tillage technology over the conventional tillage and the savings made through less fuel consumption and machinery use (Grey et al. 1996). Economically zero tillage is superior over conventional method of sowing because more net returns were recorded on zero tillage farms than that of conventional wheat farms in addition to its edge of eco-friendly practice (Nagarajan et al. 2002). For a technology to be adopted and effective really, it is pre-requisite that it has been evaluated with respect to its economic feasibility and viability which is a major determinant of its adoption. The specific objective of current paper is to see which factors are mostly affecting the adoption of zero tillage technology in rice-wheat system of Pakistan's Punjab and also to compare and evaluate the cost and crop yield per ha of wheat crop by using conventional and zero tillage technologies.

## Materials and Methods

The study was conducted in the Rice-Wheat area of Sheikhupura and Hafizabad districts of Punjab, Pakistan. The study sites fall in the Punjab Rice-Wheat Zone and are located $32^0$ N latitude and $74^0$ E longitudes. The climate is characterized as sub-tropical semi-arid and typically represents low-lying interior of the Indo-Pakistan sub-continent. Three distributaries were selected namely Ghour Dour, Gujjiana and Kakar Gill Sub-Minor. Gujjiana and Ghour Dhour distributaries off-take from Upper Gugera Canal of Lower Chenab Canal system (LCC) and come under the Chuharkana irrigation sub-division in district Sheikhupura whereas Kakar Gill sub-minor falls in the Gujranwala irrigation sub-division in district Hafizabad. One watercourse from each of Gajiana distributary (WC#74634-R) and Kakar Gill sub-minor (21900-TF) and two watercourses (WC#28915-L and WC# 32326-L) from Ghour Dour distributary were selected.

## Sample size

Total sample size was consisted of fifty-six farmers falling in two categories namely, those who adopted Zero tillage technology, and those who never used it. The farmers of different tenancy status including, owner, owner cum tenant and tenant were interviewed in order to know the rate of adoption among different farmers' categories.

## Data collection

A comprehensive questionnaire was developed for the collection of data regarding the production technology of wheat crop in the study area. The questionnaire was pre-tested before actually conducting the interviews of the sample respondents. The data was collected for the season i.e. Rabi (2002-03). A field team of five well-trained data collectors was deployed in the field for survey and field observations.

## Data analysis

The main focus of the current paper was to see the adoption of zero tillage technology and also to evaluate the impact of Zero tillage as against the conventional methods of wheat sowing. So the data analysis proceeded in the same way with the application of binary Logit model to see the factors affecting the adoption of zero tillage. Total costs, gross margins, crop yield and Benefit-cost analysis were calculated both for zero tillage and conventional methods of sowing. Water use efficiency and fertilizer use efficiency for both zero tillage technology and conventional method of sowing was also calculated.

**Model Specification**

Several previous studies have used the Logit model in relation to adoption of different technologies (Zegeye et al 2001, Kalyebare, R. 1999, Zegeye et al 2001, Caswell et al 2001, Lee et al 1983, Ouma et al 2002).
Logit modeling technique is used when dependent variable is binary with values 1 or 0. The coefficients of independent variables tell about the probability of happening or not happing of the one of the two possibilities of dependent variable.
From the estimated coefficients of the model, marginal effect of each independent variable was calculated. The marginal probability is defined by the partial derivative of the probability that dependent variable assumes a value of 1 with respect to that independent variable. The marginal probability is defined by

$$\partial \mathbf{P} / \partial \mathbf{B} = \boldsymbol{f}(\mathbf{BX})\mathbf{B}$$

B is the slope of the coefficient. X is the independent variable while *f* () is the density function of the cumulative probability distribution function [F (BX)], which ranges from 0 to 1). The marginal effect could be interpreted as the change in the probability of household being poor with a one-unit increase in the explanatory variable. The marginal probability values were estimated at the mean values of the explanatory variables. A farmer's decision to adopt or reject new technologies is influenced by the combined effect of a number of factors such as: farming experience, inputs and farm size. (CIMMYT, 1993)

Dependent variable: Adoption of zero tillage ( If adopted then 1, otherwise 0 )

Adoption $=\beta_0 + \beta_1$(FARMS) + $\beta_{2.}$ (TWIRRIT) $+\beta_3$(CSTNPK) $+\beta_4$(CSTCHEM) $+\beta_5$(QFYM) $+\beta_6$(ABIANAC) $+\beta_7$ (EXPERF)$+\beta_8$(DTS1) $+\beta_9$(DTS2) $+\beta_{10}$Ln(DDKAKGL) $+\beta_{11}$(DDGUJNA)

Where

| | |
|---|---|
| $\beta_0$ | = denotes intercept term |
| $\beta_I$ - $\beta_{12}$ | = were unknown parameters to be estimated |
| Dependent variable | = Adoption of zero tillage ( If adopted then 1, otherwise 0) |
| FARMS | = Farm size (ha) |
| TWIRRIT | = Tube well irrigations time required to irrigate one ha |
| CSTNPK | = Cost of NPK nutrients (Rs/ha) |
| CSTCHEM | = Cost of chemicals (Rs/ha) |
| QFYM | = Quantity of FYM per ha |
| ABIANAC | = Abiana charges Rs/ha |
| EXPERF | = Experience of farmer in years |
| DTSI | = Dummy for tenancy status (1 for owner-cum-tenant otherwise 0) |
| DTS2 | = Dummy for tenancy status (1 for tenant otherwise 0) |
| DDKAKGL | = Dummy for kakargill distributary (1 for kakargill otherwise 0) |

DDGUJANA = Dummy for Gujiana distributary (1 for Gujiana otherwise 0)

## Results and discussions

### Economics

For a technology to be adopted and effective, it is pre-requisite that it has been evaluated with respect to its economic feasibility and variability which is major determinant of its adoption and further sustenance so as to achieve the goals set forth before it. To assess the economic feasibility of the zero tillage technology a survey was conducted in a Sheikupura district, a rice-wheat system. The data was collected through personal interview method so as to draw information regarding socio-economic background, input usage, practice adopted, prices etc. to arrive at the figures of net returns and cost of production through zero tillage technology and conventional sowing of wheat. The results as depicted in Table 1a and Table 1b, are quite convincing as far as economic superiority of zero tillage is concerned over conventional method.

The yield recorded was significantly higher than conventional method (3409.98 kg/ha as compared to 3122.64 kg/ha). Total cost were Rs.10217/ha in the zero tillage, significantly lover than that of Rs. 12321/ha in traditional /conventional planting system. Gross margins were Rs. 17146/ha in the zero tillage technology, significantly higher than that of Rs. 13794/ha in conventional method of sowing. Benefit-cost analysis calculated shows that zero tillage method was economically the most feasible (B/C= 1.68) and attractive option as compared to conventional (B/C=1.12) for farming community. Of the bread-up of total cost of production in rupees per hectare, farmers were investing significantly less on land preparation and on irrigation cost per hectare, which is major source of reduced working cost in zero tillage as compared to conventional sowing of wheat.

Table 1(a) Benefit cost analysis of wheat with various techniques

| | Techniques | |
|---|---|---|
| | Traditional Mean | Zero Tillage Mean |
| Yield in kg per hectare | 3122.64 | 3409.98 |
| Total cost of production in Rs. Per hectare | 12321.17 | 10216.6 |
| Gross Margins in Rs. per hectare | 13794.02 | 17145.65 |
| Benefit cost ratio | 1.12 | 1.68 |

Table 1(b) Break-up of Total cost of production (Rs/ha)

| | Techniques | |
|---|---|---|
| | Traditional Mean | Zero Tillage Mean |
| Seed Cost (Rs/ha) | 948.64 | 986.25 |
| Cost of Ploughings (Rs/ha) | 2093.25 | 756.74 |
| Cost of Irrigation water (Rs/ha) | 1057.37 | 753.7 |
| Fertilizer Cost (Rs/ha) | 3685.78 | 4471.09 |
| Chemical cost (Rs/ha) | 389.03 | 516.44 |
| Harvesting cost (Rs/ha) | 2413.59 | 2315.04 |
| Threshing cost (Rs/ha) | 1733.51 | 1174.1 |

Most importantly water use efficiency kg/$m^3$ for both methods was also recorded. Table 2 shows that water use efficiency obtained on zero tillage farms was much higher as compared to conventional farms. Volume of water for zero tillage was 1828.8 $m^3$/ha significantly lower than that of 2256.9 $m^3$/ha in conventional method. Water use efficiency kg/$m^3$ was noted high 1.86 kg/m3 in zero tillage, which was significantly higher than that of 1.38 kg/m3 in case of traditional/conventional method of sowing.

Table 2 Effect of sowing techniques on water-use efficiency for wheat production

| | Techniques | |
|---|---|---|
| | **Traditional Mean** | **Zero Tillage Mean** |
| Yield in kg per hectare | 3122.64 | 3409.98 |
| Volume of Water ($m^3$/ha) | 2256.97 | 1828.8 |
| Water productivity (kg/$m^3$) | 1.38 | 1.86 |

NPK levels on zero tillage farms and conventional farms are shown in table 3. The efficiency of fertilizer at zero tillage farms was noted lower as compared to conventional method. The reason of this is that farmer's of Rice-Wheat cropping area use more fertilizer to get more production.

Table 3 Effect of sowing techniques on fertilizer-use efficiency for wheat production

| | Techniques | |
|---|---|---|
| | **Traditional Mean** | **Zero Tillage Mean** |
| Yield in kg per hectare | 3122.64 | 3409.98 |
| NPK kg/ha | 171.20 | 209.40 |
| Fertilizer use efficiency | 18.24 | 16.28 |

The results of the logit model are shown in Table 4. All the coefficients of explanatory variables except experience of farmers in years were found significant at 99, 95 and 90 percent of significant level. The results showed that with an increase in land holding of one hectare the probability of adoption of zero tillage technology increases by 0.001. The results are according to the priory expectation because with the increase in landholding, farmers have better choices to experiment with new technologies as compared to resource poor farmers. Similarly according to the perceived benefits of this new technology it should have decreased water consumption in order to be adopted on wider scale. The results support this perception and show that the probability of zero tillage adoption decreases (-0.009) with the increase in irrigation timing (hours/ha) especially tube well irrigation because tube well irrigation has maximum contribution for fulfilling the crop water requirements in the study area. Farmers adopt those technologies, which they perceive as cost effective. Such relationship is depicted by the results of the logit model with respect to cost of fertilizers i.e. the marginal probability (-0.004) of adoption of zero tillage technology decreases with the increase in the cost of fertilizer per hectare. The relationship between cost of chemicals and adoption of zero tillage although is significant but its marginal effect is negligible. The coefficient of marginal probability (.000) of zero tillage adoption with respect to abiana charges (canal water charges) indicates that although the relationship is positive and significant but its effect is nominal i.e. very less probability near to negligible. Marginal probability of zero tillage adoption with respect to Farm Yard Manure is –0.027 indicating that additional use of FYM would lead to increased cost of production which would lead towards less advantageous situation. More over, FYM is not available in greater and continuous supply that is why sign of FYM is according to the priory expectations. Similarly, with increase in number of years of agricultural experience marginal probability of adoption for zero tillage decreases by the coefficient –0.001. The major reason behind this result is that old people are still of the view that indigenous ways of cultivation are superior to new ones and are following the famous proverb "more you till the soil more would be the crop production".

Table 4. Regression Results of Logit model

| Variables | Coeff. | Std.Err. | P-value | Marginal Probability |
|---|---|---|---|---|
| Constant | 8.882 | 10.476 | 0.397 | 0.031 |
| Farm size in ha | 0.268 | 0.109 | 0.014*** | 0.001 |
| Tubewell irrigation time of one ha (hours/ha) | -2.532 | 1.239 | 0.041** | -0.009 |
| Cost of NPK nutrients in Rs/ha | -1.152 | 0.555 | 0.038** | -0.004 |
| Cost of chemicals in Rs/ha | 0.013 | 0.006 | 0.042** | 0.000 |
| Quantity of FYM (trolleys/ha) | -7.703 | 4.865 | 0.113 | -0.027 |
| Abiana charges in Rs/ha | 0.071 | 0.042 | 0.086* | 0.000 |
| Experience of farmer in years | -0.146 | 0.100 | 0.147 | -0.001 |
| Dummy for owner-cum-tenant | 14.567 | 7.343 | 0.047** | 0.051 |
| Dummy for tenant | 7.136 | 4.054 | 0.078** | 0.025 |
| Dummy for Kakargill distributary | 13.052 | 6.881 | 0.058** | 0.045 |
| Dummy for Gujiana distributary | 15.023 | 7.254 | 0.038** | 0.052 |

Chi square = 55.227
-2 Log likelihood = 16.876
Cox and snell R square = .634
Negelkerke R square = .867
Df = 11

* Significant at 90 percent confidence level
** Significant at 95 percent confidence level
*** Significant at 99 percent confidence level

Dummies for owner-cum-tenant and tenant were included. Marginal probabilities of adoption for zero tillage technologies for owner-cum-tenant and tenant farmer were found to be 0.051 and 0.025 respectively. Similarly if a farm household is located in the command area of Kakargill and Gujiana distributaries instead of being located in the command area of Ghourdour distributary, the marginal probability of adoption for zero tillage technology is 0.045 and 0.052 respectively. Increased marginal probabilities can be attributed for favorable environment regarding the awareness about the new technology and flexibility and easiness of availability of zero tillage drill in the command areas of the first two distributaries.

## Environment

Despite of a plenty of resources the Indo Gigantic Plains are burdened with overpopulation resulting in increased pressures on agriculture sector for food security. The intensive agriculture has resulted in the dismal agricultural productivity, excessive depletion of resources and rapid environmental degradation (Hobbs 2001). With the challenges of sustainability, any intervention in technology is acceptable only when it is easily applicable, economically viable as well as environmentally beneficial. Zero tillage technology provides an opportunity of improving water use efficiency and conservation. Other benefits which zero tillage technology provides are in reducing the need for applying herbicides, controlling erosion, reducing the amount of N that "leaks" into the environment, providing environmentally friendly options for managing crop residues, reducing soil compaction and bettering soil physical structure over time.

## Conclusions and recommendations

Zero tillage technology contributes in increasing wheat yield and also helps in reducing cost of production. The results show a convincing as far as economic superiority of zero tillage over conventional method of sowing. Zero tillage technology is very conducive in increasing the crop production and net income, its popularity would increase day by day among the farming community and area under such technologies is expected to enhance widely in Pakistan. The suitable policies are needed in order to further facilitate promotion of zero tillage technology by encouraging private sector-public sector cooperation and educating farmers about the use of this technology. The long-term impacts of this technology on food production, natural resources (land and water) and linkages with poverty alleviation should be further explored. The participatory research at farmers' field could play pivotal role in technology improvements and dissemination.

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