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Determinants Influencing the Acceptance of Resource Conservation Technology: Case of Zero-Tillage in Rice-Wheat Farming Systems in Uttar Pradesh, Bihar and Haryana States

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I

INTRODUCTION

Rice-wheat farming systems have identified the economic benefits of zero tillage farming and it covers about 80 per cent of the food requirement and about 60 per cent of the nutritional requirement of the Indian population (Timsina and Connor, 2001). Out of the total rice and wheat production in India, 45 per cent comes from the Indo-Gangetic Plains. The productivity data indicates an increasing trend for the period of 1960-2000, but a decreasing or stagnating trend afterwards (Ladha *et al.,* 2003).

The increase in rice-wheat production during 1960-2000 can be attributed to many factors, which include mainly the intensification of land use, investments in irrigation facilities and adoption of modern seed-fertiliser technologies. Some of the important policies adopted by the Indian Government, such as input price subsidies, output price support, subsidised power supply and low interest farm credit etc., have also contributed in bringing about this big lead in rice-wheat production. However, the stagnation in productivity can be attributed to intensive agricultural farming practices which lead to environmental problems and in turn make the whole system unsustainable (Fujisaka *et al.,* 1994; Hobbs and Morrs, 1996; Kumar *et al.,* 1998, 1999, 2003). The prevailing policy environment has further encouraged unsuitable practices (Pingali and Shah, 2001). Thus, while the intensive rice-wheat farming caters to food requirements of the growing population, it has also led to resource depletion and lower land productivity. Hence, there is a need for the adoption of improved resource conservation technologies. These technologies seem to offer opportunities which would increase production and income substantially (Sharma and Kumar, 2000). The zero tillage technology is one such technology, which can increase food production to meet the future demand while conserving the resources.

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II

ISSUES RELATED TO RICE-WHEAT FARMING SYSTEMS

The conventional tillage practices consisting of 8-10 tillage operations in the rice-wheat farming systems, aims to destroy weeds and loosen the top soil to facilitate water infiltration and crop establishment. It delays the sowing of wheat, and the recurring disturbance of the top soil, buries soil cover and destabilises the soil structure. An additional problem of conventional tillage is that it results in compacted soils, which negatively affect productivity (Murgai, 1999; Mehta *et al.*, 2000). This negative impact of soil tillage on farm productivity and sustainability as well as on environmental processes has been increasingly recognised. Timely sowing under zero tillage improves crop yields and thus provides resilience against drought and other hazards (Mehta *et al.*, 2000).

Zero Tillage Technology

Zero tillage is defined as planting crops in previously unprepared soil by opening narrow slots or trenches of the smallest width and depth needed for proper coverage of the seed. At least 32 per cent of the soil surface remains covered with crop residue. Zero tillage is, in a way, a complete farm management system that should include many agricultural practices including planting, plant residue management, weed and pest control, harvesting and crop rotations (Ekboir, 2003). The maximum benefits of zero tillage can be obtained if the package follows the three principles, viz., (a) soil is disturbed as little as possible, (b) soil is covered by plants or plant residues, and (c) crops are rotated. In India in the Indo-Gangetic Plains (IGP), both reduced tillage (where farmer only reduces the number of tillage operations using the zero tillage drill machine) and zero tillage are being currently practiced.

Work on the diffusion and benefits of zero tillage in India started as early as 1970s, by several State Agricultural Universities but it was not successful due to technical difficulties such as the lack of adequate planting equipment and difficulty in chemically controlling the weeds. It restarted in 1990 with the introduction of inverted T openers by the CIMMYT. In 1991, a prototype was developed at the G.B. Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh. After many refinements and the adaptation of the zero tillage machine in 1997, about 150 zero tillage drill machines were supplied to state agricultural universities and ICAR institutions. This was done to understand the problems in machine operations. The combined efforts of National Agricultural Research Stations, State Agricultural Universities, private manufacturers, the rice-wheat consortium for Indo-Gangetic plains and CIMMYT resulted in widespread adoption of zero tillage after the turn of the century. It is estimated that approximately 1-7 million hectares area is lender zero tillage and reduced tillage in India covers the states of Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal. The benefits of the adoption of zero tillage in India are generally reported on the basis of experiments on-farms and on-station trial data. Several studies (Chahal *et al.,* 2002; Nagarajan, 1998; Dhiman *et al.,* 2003; Malik *et al.,* 2004) have reported gain in yield from their field trial data due to timely sowing and increased efficiency in fertiliser use, besides significant saving on diesel use has also been reported (Sharma *et al.,* 2002; Malik *et al.,* 2004). The studies conducted by Nagarajan *et al.,* 2002, Pandey *et al.,* 2003; and Thakur, 2002 have also reported saving in the cost of production. Other than the economic benefits, there are very large environmental benefits associated with the adoption of zero tillage. The main environmental benefits are conservation of soil due to higher organic carbon contents (Chauhan *et al.,* 2002); and ground water conservation as it reduces irrigation water requirement (Malik *et al.,* 2004). It also helps in reducing green house gas emissions due to reduction in diesel use (Sharma *et al.,* 2002).

Keeping in mind the benefits of zero tillage and the present phase of its diffusion, the objectives of this study are to examine the benefits of adoption of zero tillage at farmer's field level and to identify the factors influencing its adoption in wheat crop for rice-wheat system of Indo-Gangetic plains. The factors affecting adoption differ across countries or regions due to diverse socio-economic, cultural and agro-ecological environment (Feoler *et al.,* 1985). Therefore, in this study we have focused on three different regions of IGP, i.e., one in Haryana from the trans-gangetic plains and one in Bihar from the middle gangetic plains and one in control Gangetic Plains in Uttar Pradesh. These states also represent three different levels of agricultural development.

III

ANALYTICAL APPROACH AND DATA COLLECTION

Analytical Approach

Zero tillage is new in the Indian context and we hardly find any study discussing the factors influencing the adoption of this technology. However, several studies pertaining to the new technology adoption have been reported. This literature can be grouped into two. One deals with the process of adoption and is dynamic in nature. The other group of studies focuses on identifying the factors influencing technology adoption using the characteristics of adopters and non-adopters (Harper *et al.,* 1990), which is static in nature. In this study, we focus on the static nature of adoption theory to identify the possible factors influencing zero tillage technology adoption in India.

An econometric modelling has been attempted for this purpose. Such modelling has been earlier done by Shiyani *et al.,* (2000), and Harper *et al.,* (1990) etc. in different contexts. The zero tillage farming has gained a lot of acceptance in Brazil (Ekboir, 2003), by some of the African countries (Araya and Adjaye, 2001) and in the North American plains we find many case studies related to the adoption of zero tillage practices in these areas. But these studies focus mainly on the soil conservation effects of adoption. Special and relevant mention are given to studies by Rahm and Huffman (1984); Belkanp and Saupe (1988); Soule *et al.,* (2000); and Arya and Adjaye (2001) in which they have tried to identify the human capital characteristics, farm characteristics, economic and institutional factors that influence the adoption of farm-level conservation efforts through zero-tillage.

The dependent variable in the present study is taken as a discrete variable indicating whether or not the zero tillage technology was adopted. Although the presence of partial adoption of zero tillage makes the dependent variable continuous, we have considered a partial adopter farmer as a full adopter even if the proportionate area under zero tillage was low.

The reason for such an assumption is that zero tillage is a relatively new technology (on farm trial started in 1997-98 in Haryana, in 2000-2001 in Bihar and 2002-03 in Uttar Pradesh) and it is still at a stage where mass adoption is yet to take place. Therefore, there were very few farmers having zero tillage on the whole farm. The data set can be analysed by using binary choice models, which are appropriate when the choice between the two alternatives depends on the characteristics of the problems (Gujarati, 2003) The Logit model was selected for this study and the maximum likelihood technique was used for estimation. The dependent binary variable for the Logit model is

Y_j =1, if farmer j has adopted ZT.
0, otherwise

The probability of adoption, P, for a given set of values of variables is given by the Logit model.

$$\text{In } (P/1\text{-}P) = \beta_0 + \sum_{i=1}^{n} \beta_u X_1 + \sum$$

where β_1S are Logit coefficients for the variables X/S_1 and $\sum$ is the error term. The set of regressors, comprising personal and socio-economic variables influencing technology adoption used in the model are listed in Table 1. The Logit model was estimated without the constant term using state 7.0 for Windows. Tests for the flatness of the tails of the distributions of error terms also suggest the Logit Model. The Probit Model was also tried but there was hardly any difference in the results, as for large samples both the Probit and Logit models give almost similar results. During the analysis, care has been taken for the presence of outlines and errors in the data. In order to examine the multi-collinearity among the explanatory variables, a zero order co-relation matrix was computed.

TABLE 1. STUDY VARIABLES IN THE LOGIT MODEL

Variable (1)	Description (2)	Expected Sign (3)
Farm Size	No. of family members	-
Age	Age of respondent	-
Farming experience	Farming experience	+
Total Land	Total Farm land	+
E	Education of respondent	+
Education index	Education Index of family	+
CROUM i	Availability of institutional credit	+
CROUM z	Availability of credit from private sources	+
VCM	Participation is village community meeting	+
MMEDA	Exposure to mass media	+
DFAIRATT	Participation in farmers fairs	+
DEXTOFF	Visit of extension officers	+

Variables in The Model

The factors affecting an individual's decision to adopt new technology can be divided into two categories, one that deals with sociological factors such as the awareness about the technology, knowledge of the costs and benefits involved, information regarding the other place where the new technology has been successfully implemented; and the other set of factors comprising mainly the economic variables such as the availability of credit and affordability of labour etc. In this study we have tried to capture both these types of factors by developing a model of technology adoption.

The individual characteristics of the respondent (who is in most of the cases, the decision maker in the family) included age, education, farming experience and the also the data on the available land. Age is hypothesised to have a negative impact on the decision of adopting new technology, since the younger farmers are usually more willing to take risk and are likely to perceive increased profits from adoption (Ekboir, 2003; Soule *et al.*, 2000; Khanna *et al.*, 1999; Kiresur *et al.*, 1999), and have greater willingness to adopt the new technology. The older farmers, on the other hand, are more dogmatic in farming practices and it is difficult to induce them to change their mindset from the existing agricultural practices.

The level of education of the respondents had a positive impact on the new technology adoption decision. But the education levels of the rest of the family members could also affect the decision making process. Hence an education index was calculated to reflect the education of the entire family. It is hypothesised to have a positive relationship with the adoption of zero tillage. Adesioa and Baidu-farson (1995) found a positive relationship between education and the adoption of new technology in Guinea. Similarly, Kebede *et al.,* (1990), Putler and Zilberman (1988), and Shiyani *et al.,* (2000) have shown positive impact of education on the adoption of new technology.

The farming experience as a measure of human capital invested in farming makes its effect on adoption uncertain, as this variable also acts as proxy for farmer's age. While a positive effect might be expected from the experience, the advanced age would be associated with a reduced probability of adoption (Belknap and Savpe, 1988; Rahm and Huffman, 1984). Family labour also work as unpaid labourers on their own farm which reduces the labour requirement. Hence for larger families where labour is sufficiently available, adoption may not bring much benefit especially in resource poor areas. So we expect a larger family size to have a negative impact on technology adoption. This is contrary to what Kiresur *et al.,* 1999 observed with respect to the number of on-farm workers in the family.

There are two schools of thought with respect to farm size and the adoption of improved technologies. One argues that the variable has a positive influence on adoption, as large farm size farmers generate more income which enhance their risk bearing capacity (Sarap and Vashist, 1994). Another argument advocates that the small holding farmers utilise their limited resources more efficiently and adopt new technologies faster (Barker and Herdt, 1980; Shiyani *et al.,* 2000). In this study, we go with the last argument.

A farmer with large farm size is expected to have already invested in terms of capital (such as tractors, tubewells and farming machinery) for the prevailing agricultural practices. Therefore, it may not be unconditional for him to switch to this system. Also the large farmers have more risk bearing capability as compared to small farmers. Therefore, the farm size is hypothesised to have a positive impact on the adoption of Zero Tillage. The availability of credit is an important factor. Bhalla (1979) has reported lack of credit as a major constraint in the adoption of high-yielding varieties by the small farmers. Therefore, in this study two dummy variables are included taking into account the institutional and non-institutional credit availability.

The level of social awareness among farmers has been captured by incorporating dummy variables that control the exposure of farmers to mass media (Radio and Television), awareness about the visit of extension officers, incidence of and participation in farmer fairs and village community meets. These factors are being hypothesized to have a positive impact on the adoption of Zero Tillage based on the study by Belknap and Saupe (1988).

DATA COLLECTION

Primary survey was conducted in three states, Uttar Pradesh, Haryana and Bihar, and the data were collected purposively. Uttar Pradesh from the Central Gangetic Plains, Haryana from the trans-gangetic plains are at an advanced stage of agricultural mechanisation and intensification and has a higher rank in the Human Development Index, Bihar from middle gangetic Plains, Uttar Pradesh from central Gangetic Plains, is at a lower level of agricultural development and has lower rank in human development index. The data was collected under the "Roles of Agriculture" project funded by the FAO.

One representative district from each of three states was selected, viz., Kanpur from Uttar Pradesh, Kaithal from Haryana and Begusarai from Bihar. In each of the selected districts, the sample size consisted of 250 farmers with an equal number of adopters and non-adopters and the inverse sampling technique was employed to select the households.

The data was collected in collaboration with the rice-wheat consortium from the Indo-Gangetic Plains. The questionnaire was tested and modified after the pilot of surveying of the field. Data collected from the farmers included information on different input uses and on various farming operations practiced. The individual perceptions about zero tillage, of both these adopters and non- adopters, were also recorded.

IV

RESULTS AND DISCUSSION

Characteristics of Sample Farmers

The area under zero tillage in Uttar Pradesh was 275 hectares, in Haryana 350 hectares where as in Bihar it was 18 thousand hectares in 2004-05 (RWC, 2004). The important factors of the sample farmers are given in the Table 2 (A) and (B). The data show the average area is more for the adopters of zero tillage in Haryana, where as the difference is not significant in Bihar and Uttar Pradesh. The adoptions are relatively young in three states. The sample data has shown that the percentage of illiterates is higher in Haryana than in Uttar Pradesh and Bihar. The participation in village community meetings was also reported to be higher in Bihar.

TABLE 2(A). SAMPLE DESCRIPTION FOR UTTAR PRADESH HARYANA AND BIHAR

	Uttar Pradesh		Haryana		Bihar	
Variable (1)	Adopters (2)	Non-Adopters (3)	Adopters (4)	Non-Adopters (5)	Adopters (6)	Non-adopters (7)
Family size (No.)	5	4	7	6	7	6
Age (years)	35	41	36	42	42	47
Respondent's farm area (ha)	4.3	3.2	4.2	3.1	1.11	1.37
Farming experience (years)	19	27	18	28	21	25
Per cent of non-farm income in total income	27.6	40.5	28.7	40.5	38.6	50.5
Number of tillage	1	3	1	3	1	5

TABLE 2 (B). SAMPLE CHARACTERISTICS

Variable (1)	Criteria (2)	Uttar Pradesh (3)	Haryana (4)	Bihar (5)
Education	Illiterate	56.30	61.58	17.93
	Primary	17.16	1.69	21.20
	Secondary	21.36	20.34	18.84
	Higher Secondary	13.95	12.43	21.20
	College	14.92	3.95	21.20
Village community meetings	Do not attended	64.12	75.86	32.80
	Attend	56.18	24.14	67.20
Mass media	No Exposure	27.10	30.10	25.00
	Exposure	58.21	69.90	75.00
Farmers fairs	Do not Attend	62.17	66.84	56.12
	Attended	36.19	33.16	43.88
Village extension officer	Unaware	45.67	54.08	67.86
	Aware	39.61	45.92	32.14

Benefits of Adoption of Zero Tillage

As stated earlier most of the studies have reported benefits from on-station trial data. In this study, we have tried to capture the benefits of zero tillage technology adoption at the farmer's field level. The on- farm economic benefits of the adoption of zero tillage are presented in Table 3, which show that there is a significant saving in diesel used for preparation of the land and also tractor used for tillage. Increase in yield was deserved, though statistically significant yield gain was observed in Bihar only. It needs to be mentioned here that the average productivity in Haryana and Uttar Pradesh is very high as compared to that of Bihar.

TABLE 3. NET SAVINGS AND YIELD GAIN DUE TO ADOPTION OF ZERO-TILLAGE

Net savings (1)	Uttar Pradesh (2)	Haryana (3)	Bihar (4)
Diesel in land preparation (Rest./ha.)	732.2*	995.8*	635.5*
Saving in tractor used for tillage	395.71*	430.16*	1328*
Cost of seeds	39.6	41.3	28.6
Sowing charges (including drill)	- 32	- 35	- 71.2
Yield gain (per cent)	6.12	6.15	8.7*

Note: 1. *Significant at 5 per cent level. Adopted from Vijay Lakshmi *et al.*, (2003).
2. Saving in diesel and tractor use reported only for user.

The farmer's perceptions on the benefits of zero tillage and reasons for not adopting were also recorded during the survey. Most of the farmers were of the opinion that the adoption of zero tillage leads to increased yield, saving in cost of cultivation, irrigation water saving and reduction in weed in three states. In Bihar, an additional advantage was reported for timely sowing of the wheat crop. The main reason for not adopting the zero tillage was the unavailability of the zero-tillage machine in time. In Bihar the scarcity of the zero-tillage machine and the absence of market for hiring services were reported.

Factors Affecting Adoption

The maximum likelihood estimates of the Logit Model are presented in Table 4. These values indicate the effects of the changes in each independent variable on the likelihood of adoption of zero tillage, assuming that the changes in other variables are constant. The analysis shows that the age of the farmers/respondents, as expected have a negative and significant impact on the probability of technology adoption in these states. The older the farmers, the lesser the chances of him adopting zero-tillage technology. This effect can be explained by the fact that young farmers are more aware of the latest technology and have a larger risk taking ability.

TABLE 4. ESTIMATION OF RESULTS

	Uttar Pradesh		Haryana		Bihar	
Variables (1)	Coefficient (2)	P-value (3)	Coefficient (4)	P-value (5)	Coefficient (6)	P-value (7)
FAMSIZE	0.016	0.462	0.012	0.837	- 0123	0.367
AGE	-0.124**	0.003	-0.120**	0.004	- 0124**	0.005
FEXP	0.127**	0.116	0.125**	0.016	-0.130**	0.015
TOTAL LAND	0.019	0.167	0.017	0.616	0.081	0.421
EINDEX	0.004	0.872	0.003	0.938	- 0.659	0.034
CRDUMI	1.521**	0.006	1.481**	0.033	4.334**	0.011
CRDUMZ	0.986*	0.046	0.971**	0.094	5.011**	0.005
VCM	1.624**	0.002	1.681**	0.024	- 0.142**	0.837
MMEDIA	0.272	0.716	0.256	0.711	1.176**	0.076
DFAIRATT	1.032**	0.360	1.345**	0.033	- 0.048	0.682
DEXTOFF	0.046	0.942	0.043	0.936	- 0.018	0.979
LOG-Likelihood	- 43.76	-	- 52.48	-	- 35.38	

Note: * and ** Significant at 5 and 10 per cent level, respectively.

The effect of the education index, as a factor influencing the probability of technology adoption was positive but not significant in Haryana.

However, it turns out to be negative and significant in the case of Uttar Pradesh and Bihar, the result from Uttar Pradesh and Bihar is in line with the study by Harper *et al.* (1990), where they found that education has a significant but negative influence on technology adoption, But this finding contrasts with the positive relationship reported by Rahm and Huffman (1984) and Putler and Zilberman (1988). If we look at the comparative statistics in percentage terms, we find that the education levels are much more evenly distributed in Bihar's dataset. This negative influence could be due to the unobserved socio-economic variables such as the least involvement of educated persons in farming. This variable needs to be investigated in more detail separately.

The farming experience is found to have positive and significant impact on the probability of adoption in three states hence we may conclude that the more experienced the farmer the higher the probability of him adopting new technology. A farmer who is involved in the cultivation for a longer time must be more aware of the way his soil is losing fertility and how the annual yield is decreasing. Hence, an experienced farmer is more conscious of the benefits of soil conservation and he is likely to adopt the zero-tillage technology [Rahm and Huffman (1984) and Shiyani *et al.* (2000)]. The availability of credit is found to be a significant factor offsetting the probability of adoption of zero tillage in three states, as hypothesised. The availability of credit for buying different capital assets is always a major bottleneck for the Indian farmers. The availability of institutional and/or non-institutional credit acts as a major decision factor for farmers adopting the new technology, size of the farm, and family size were found to have a significant impact on the adoption of zero tillage.

The variables capturing the social interaction and implementation of government programmes show varying results in the three states. Participation in village community meetings and farmer fairs have a significant impact towards the zero-tillage technology in Haryana but the impact is insignificant in Uttar Pradesh and Bihar. Similarly, the exposure to mass media had more significant impact on the people in Uttar Pradesh and Bihar, as compared to that in Haryana. In the case of village community meetings (Vem_s) and farmer fairs, there could be a lot of differences in the implementation across the three districts. The survey shows that Vems in Uttar Pradesh and Bihar are not regular and they are not as well focused towards promoting technology adoption as in Haryana. Certain limitations of the study need to be recognised and one of the major limitations is the assumption that dependent variables are discrete. A few more independent variables should have been introduced to better explain the adoption behaviour especially like the ownership of land, off-farm employment, debt and the availability of the labour.

V

CONCLUSIONS

The study has identified the economic benefits of zero-tillage farming, and the different factors affecting its adoption using primary data from Uttar Pradesh, Haryana and Bihar. The results show that zero-tillage saves diesel and reduces the cost of cultivation resulting in yield increase of wheat in three states, although the yield increase is statistically significant in Bihar only. Further, the adoption of zero-tillage may be successfully implemented through the timely availability of zero-tillage machines, developing markets for hired services and proper administration. The results also indicate that the probability of adoption is higher for the experienced but relatively young farmers. The government policies to improve human capital in the form of training and awareness are beneficial for the adoption of zero-tillage. Thus there is a need for resource allocation to improve the human capital through extension programme, village community meetings, farmer fairs, etc., for enhancing the efficiency of adoption. The availability of credit plays a very important role in this decision making process. Therefore, for promoting new technology, the availability and accessibility of credit should be ensured. This result has a particular relevance with respect to the area of less intensive agriculture where adoption can give higher benefits. Some of the factors influencing the adoption differ in the two settings and hence the adoptions programme should be more focused and targeted in accordance with the requirement of the specific area.

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