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Factors Affecting the Adoption of Resource Conservation Technology: Case of Zero Tillage in Rice-Wheat Farming Systems

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I

INTRODUCTION

Rice-wheat farming systems (RWS) cover about 80 per cent of the food requirement and about 60 per cent of the nutritional requirement of the Indian population (Timsina and Cornor, 2001). Out of the total rice and wheat production in India, 42 per cent comes from Indo-Gangetic Plains (IGP). The productivity data indicate an increasing trend for the period of 1958-98, but a decreasing or stagnating trend afterwards (Ladha *et al.*, 2003).

The increase in rice-wheat production during 1958-98 can be attributed to many factors, mainly the intensification of land use, investments in irrigation facilities and adoption of modern seed-fertiliser technologies. Some of the crucial 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 leads to environmental problems and in turn make the whole system unsustainable (Fujisaka *et al*., 1994; Hobbs and Morris, 1996; Kumar *et al*., 1999; Ladha *et al.*, 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 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 (ZT) technology is one such technology, which can increase food production to meet future demand while conserving the resources.

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II

ISSUES RELATED TO RICE-WHEAT FARMING SYSTEMS

The conventional tillage practice, of 6-10 tillage operations in RWS, aims to destroy weeds and loosen the topsoil to facilitate water infiltration and crop establishment. It delays the sowing of wheat, and the recurring disturbance of the topsoil buries soil cover and may destabilise the soil structure. An additional problem of conventional tillage is that it often results in compacted soils, which negatively affect productivity (Murgai, 1999; Mehla *et al*., 2000). This negative impact of soil tillage on farm productivity and sustainability, as well as on environmental processes, has been increasingly recognised. ZT facilitates timely sowing and improves crop yields and thus resilience against drought and other hazards (Mehla *et al*., 2000).

ZT 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 30 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 ZT 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 Indian IGP, both reduced tillage (where farmer only reduces the number of tillage operation using ZT drill machine) and ZT are being currently practiced.

Diffusion and Benefits of ZT in India

Work on ZT in India started as early as in the 1970s by several state agricultural universities, but it was not successful due to technical difficulties, such as lack of adequate planting equipment and difficulty in chemically controlling the weeds. It restarted in 1990 with introduction of inverted T openers by the CIMMYT. In 1991 a prototype was developed at G B Pant University of Agriculture and Technology, Pantnagar. After many refinements and adaptation of ZT machine in 1997, about 150 ZT drill machines were supplied to state agricultural universities (SAUs), and ICAR institutions. This was done to better understand the problems in machine operations. The combined efforts of National Agricultural Research Stations (NARS), SAUs, private manufacturers, Rice-Wheat Consortium for Indo-Gangetic Plains, and CIMMYT resulted in wide spread adoption of ZT after the turn of the century. It is estimated that approximately 1.6 million hectare area is under ZT and reduced tillage in Indian IGP (RWC 2004; www.rwc-cgiar.org), covering states of Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal.

The benefits of adoption of ZT in India are generally reported on the basis of experimental on-farm 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 fertiliser use efficiency. Further, 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 cost of production. Other than the economic benefits, there are very large environmental benefits associated with adoption of ZT. 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 emission due to reduction in diesel use (Sharma *et al*., 2002).

Keeping in mind the benefits of ZT and the present phase of its diffusion, the objectives of this study are to examine the benefits of adoption of ZT at farmers' field level and to identify factors influencing its adoption in wheat crop for RWS of Indo-Gangetic Plains (IGP). The factors affecting adoption differ across countries or regions due to diverse socio-economic, cultural, and agro-ecological environment (Feder *et al.*, 1985). Therefore, in this study we have focused on two different regions of IGP, i.e., one in Haryana from Trans-Gangetic Plains and one in Bihar from Middle Gangetic Plains. These states also represent two 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 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 modeling has been attempted for this purpose. Such modeling has been earlier done by Shiyani *et al.* (2000), Sharma and Kumar (2000), and Harper *et al.* (1990), etc. in different contexts. The zero tillage farming has gained a lot of acceptance in Brazil (Ekboir, 2003), some of the African countries (Araya and Adjaye, 2001) and in the North American plains. We find many case studies related to adoption of zero tillage practices in these areas. But these studies focus mainly on soil conservation effect of adoption. Special and relevant mention would be studies by Rahm and Huffman (1984); Belknap and Saupe (1988); Soule *et al.* (2000); and Araya 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 ZT.

The dependent variable in the present study is taken as a discrete variable, indicating whether or not the ZT technology was adopted. Although the presence of partial adoption of ZT makes the dependent variable continuous, we have considered a partial adopter farmer as full adopter even if the proportionate area under ZT was low. The reason for such an assumption is that ZT is a relatively new technology (on-farm trial started in 1997-98 in Haryana and 2000-01 in Bihar) and it is still at a stage where mass adoption has to take place. Therefore, there were very few farmers having ZT on whole of the farm.

The dataset can be analysed by using binary choice models, which are appropriate when the choice between the two alternatives depends on the characteristics of the problem (Gujarati, 2003). The logit model was selected for this study and 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 ….(1)

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

$$\ln (P/1\text{-}P) = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon \qquad \text{….(2)}$$

where $ß_i$'s are logit coefficients for the n variables X_i's, and ε 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 Stata 7.0 for Windows. Tests for the flatness of the tails of the distribution of error terms also suggest the logit model. Probit model was also tried but there was hardly any difference in the results, as for large samples both probit and logit models give almost similar results. During the analysis, care has been taken for the presence of outliers and errors in the data. In order to examine the multi-collinearity among the explanatory variables, a zero order correlation matrix was computed.

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 the sociological factors such as the awareness about the technology, knowledge of the costs and benefits involved, information regarding the other places where the new technology has been successfully implemented; and the other set of factors comprising mainly the economic variables such as availability of credit, availability 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 also the data on the available land. Age is hypothesised to have 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 existing agricultural practices.

The level of education of the respondent should have 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 (EINDEX) was calculated (average education level of all adult members of the family), to reflect the education of the entire family. It is hypothesised to have positive relationship with adoption of ZT. Adesina and Baidu-Forson (1995) found 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.

Farming experience is a measure of human capital invested in farming. Its effect on adoption is uncertain, as this variable is also a proxy for farmer's age. While a positive effect might be expected from experience, advanced age would be associated with reduced probability of adoption (Belknap and Saupe, 1988; Rahm and Huffman, 1984).

The family members also work as unpaid labourers on their own farm. The ZT 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 larger family size to have negative impact on the 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 adoption of improved technologies. One argues that the variable has a positive influence on adoption, as large farm size farmers generate more income, which enhances their risk bearing capacity (Sarap and Vashist, 1994). Another argument advocates that small holding farmers utilise their limited resources more efficiently and adopt new technology faster (Barker and Herdt, 1980; Shiyani *et al*., 2000). In this study, we go with the first argument. A person with large farm size is expected to have already invested in terms of capital (such as tractors, tubewell, farming machinery) for the prevailing agricultural practice. Therefore, it may not be uneconomical for him to switch to this system. Also the large farmers have more risk bearing capability as compared to small farmers. Therefore, farm size is hypothesised to have positive impact on the adoption of ZT.

ZT technology has lumpiness of investment in the form of ZT drill machine. Feder *et al*. (1985) have reported in their review paper that lumpiness of investment can be taken care of by the availability of credit or developing market for hired services. The availability of credit is an important factor. Bhalla (1979) has reported lack of credit as a major constraint in adoption of high-yielding varieties by the small farmers. Therefore, in this study, two dummy variables are included to take into account the institutional and non-institutional credit availability. The variable is defined in the form, 'if such a source (institutional/ non-institutional) is available to farmer when needed'.

The level of social awareness among farmers has been captured by incorporating dummy variables that control for the exposure of farmers to mass media (i.e., radio and television), awareness about visit of extension officer, incidence of and participation in farmer fairs and village community meets. These factors are being hypothesised to have positive impact on the adoption of ZT based on the study by Belknap and Saupe (1988).

TABLE 1. STUDY VARIABLES IN THE LOGIT MODEL

Variable (1)	Description (2)	Expected Sign (3)
FAMSIZE	No. of family members	-
AGE	Age of respondent	-
FEXP	Farming experience (years)	+
TOTLAND	Total farm land	+
EDUC	Education of respondent	+
EINDEX	Education index of family	+
CRDUM1	Availability of institutional credit: 1, if institutional credit available; 0, otherwise	+
CRDUM2	Availability of credit from private sources: 1, if private credit is available; 0, otherwise	+
VCM	Participation in village community meetings: 1, if attends village community meetings; 0, otherwise	+
MMEDIA	Exposure to mass media: 1, if he has mass-media exposure; 0, otherwise	+
DFAIRATT	Participation in farmer fairs: 1, if attends farmer fairs; 0, otherwise	+
DEXTOFF	Visit of extension officer: 1, if aware of village extension officers visits; 0, otherwise	+

Data Collection

Primary survey was conducted in two states, Haryana and Bihar, selected purposively for collection of data. Haryana from trans Gangetic Plains is at an advanced stage of agricultural mechanisation and intensification and has a higher rank in Human Development Index (5th rank as per NHDR, 2001). Bihar from Middle Gangetic Plains, is at a lower level of agricultural development and has lower rank in Human Development Index (15th rank as per NHDR, 2001). The data were collected under, "Roles of Agriculture" project funded by FAO.[1]

One representative district, from each of the two states was selected, viz., Kaithal from Haryana and Begusarai from Bihar. In each of the selected districts, the sample size consisted of 200 farmers, with equal number of adopters and non-adopters. Inverse sampling technique was employed to select the households.

The data were collected in collaboration with Rice-Wheat Consortium for the Indo-Gangatic Plains. The questionnaire was tested and modified after the pilot survey in the field. Data, collected from the farmers, included information on different input uses and the various farming operations practiced. Individual perceptions about zero tillage, of both adopters and non-adopters, were also recorded.

IV

RESULTS AND DISCUSSION

Characteristics of the Sample Farmers

The area under ZT in Haryana was 350 thousand hectares, whereas in Bihar it was 18 thousand hectares in 2003-04 (RWC, 2004). The important features of the sample farmers are given in Tables 2 and 3. The data show the average area is more for the adopters of the ZT in Haryana, whereas the difference is not significant in Bihar. The adopters are relatively young in both the states. The sample data have shown that the percentage of illiterates is higher in Haryana than in Bihar. The participation in village community meetings was also reported to be higher in Bihar (Table 3).

TABLE 2. SAMPLE DESCRIPTION FOR HARYANA AND BIHAR

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

TABLE 3. SAMPLE CHARACTERISTICS

Variable (1)	Criteria (2)	Haryana (3)	Bihar (4)
Education	Illiterate	61.58	17.93
	Primary	1.69	21.20
	Secondary	20.34	18.84
	Higher Secondary	12.43	21.20
	College	3.95	21.20
Village community meetings	Do not Attend	75.86	32.80
	Attend	24.14	67.20
Mass media	No Exposure	30.10	25.00
	Exposure	69.90	75.00
Farmer fairs	Do not Attend	66.84	56.12
	Attend	33.16	43.88
Village extn. officers	Unaware	54.08	67.86
	Aware	45.92	32.14

Benefits of Adoption of ZT

As stated earlier, most of the studies have reported benefits from on-farm field and on-station trial data. In this study, we have tried to capture the benefits of ZT technology adoption at the farmer's field level. The on-farm economic benefits of adoption of ZT technology are presented in Table 4, which shows that there is a significant saving in diesel used for preparation of land and also tractor used for tillage. Increase in yield was observed, though statistically significant yield gain was observed in Bihar only. It needs to be mentioned here that the average productivity in Haryana is very high as compared to that for Bihar.

TABLE 4. NET SAVINGS AND YIELD GAIN DUE TO ADOPTION OF ZT

Net savings (1)	Haryana (2)	Bihar (3)
Diesel in land preparation (Rs./ha)	995.8*	635.5*
Saving in tractor used for tillage	430.6*	1328*
Cost of seeds	41.3	28.6
Sowing charges (including drill)	-35	-71.2
Yield gain (per cent)	6.15	8.7*

Notes: 1. * Significant at 5 per cent; adopted from Vijay Laxmi *et al.* (2003).
2. Saving in diesel and tractor use reported only for users.

The farmers' perceptions on the benefits of ZT and reasons for not adopting it were also recorded during the survey. Most of the farmers were of the view that adoption of ZT leads to increased yield, saving in cost of cultivation, irrigation water saving, and reduction in weed (especially *Phalaris minor*) in both the states. In Bihar, additional advantage was reported for timely sowing of wheat crop. The main reason for not adopting the ZT was unavailability of ZT machine in time. In Bihar, scarcity of ZT machine and absence of market for hiring services were reported.

Factors Affecting Adoption

The maximum likelihood estimates of the logit model are presented in Table 5. These values indicate the effects of the changes in each independent variable on the likelihood of adoption of ZT, assuming that changes in other variables are constant. The analysis shows that the age of the farmer/respondent, as expected has negative and significant impact on the probability of technology adoption in both the states. The older the farmer the lesser are the chances of him adopting zero tillage technology. This effect can be explained by the fact that the young farmers are more aware of the latest technology and have a larger risk taking ability.

TABLE 5. ESTIMATION OF RESULTS

	Haryana		Bihar	
Variables (1)	Coefficient (2)	P –value (3)	Coefficient (4)	P –value (5)
FAMSIZE	0.012	0.837	-0.123	0.367
AGE	-0.120**	0.004	-0.124**	0.005
FEXP	0.125**	0.016	0.130**	0.015
TOTLAND	0.017	0.616	0.081	0.421
EINDEX	0.003	0.938	-0.659**	0.034
CRDUM1	1.481**	0.033	4.334**	0.011
CRDUM2	0.971*	0.094	5.011**	0.005
VCM	1.681**	0.024	-0.142	0.837
MMEDIA	0.256	0.711	1.176**	0.076
DFAIRATT	1.345**	0.033	-0.354	0.682
DEXTOFF	0.043	0.936	-0.018	0.979
Log-likelihood	-52.48		-35.38	

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

The effect of 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 Bihar. The result from 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 (given in Table 3), 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 least involvement of educated persons in farming. This variable needs to be investigated in more detail separately.

The farming experience (in number of years) is found to have a positive and significant impact on probability of adoption for both the states. Hence we may conclude that the more experienced farmer will have higher probability of adopting new technology. A farmer who is involved in 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 would go for adopting the zero tillage technology. This result is in line with the results reported by Rahm and Huffman (1984) and Shiyani *et al*. (2000).

The availability of credit is found to be a significant factor affecting the probability of adoption of ZT in both the 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 (provided by Grameen Banks, NGOs, self-help groups) and/or non-institutional (provided by local money lenders) credit acts as a major decision factor for farmers adopting the new technology. Size of the farm and the family size were found to have an insignificant impact on the adoption of zero tillage.

The variables capturing social interaction and implementation of government programmes show varying results in both the states. Participation in village community meetings and farmer fairs has significant impacts towards the ZT technology adoption in Haryana but the impact is insignificant in Bihar. Similarly, the exposure to mass media has more significant impact on the people in Bihar, as compared to that in Haryana. In the case of village community meetings (VCMs) and farmer fairs, there could be a lot of differences in implementation across the two districts. The survey shows that VCMs in Bihar are not regular and they are not as well focused towards promoting the technology adoption as in Haryana.

Certain limitations of the study need to be recognised. One of the major limitations is the assumption that dependent variable is discrete. A few more independent variables should have been introduced to better explain the adoption behaviour, especially the ownership of land, off-farm employment, debt, and the availability of 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 Haryana and Bihar. The results show that ZT saves diesel and reduces cost of cultivation. It increases yield of wheat in both the states, although the increase in yield is statistically significant in Bihar only. Further, the adoption of zero-tillage may be successfully implemented through timely availability of ZT machines, developing market 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 ZT. Thus there is a need to have resource allocation to improve the human capital through extension programmes, 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, availability and accessibility of credit should be ensured. This result has a particular relevance with respect to 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 adoption programmes should be more focused and targeted in accordance with the requirement of the specific area.

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NOTE

1. Details of the project "Environmental Impact of Improved Technology- Farm Level Survey and Farmers' Perception on ZT" are available on website. http://www.fao.org/es/ESA/Roa/pub_studies_country_en.asp#country

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