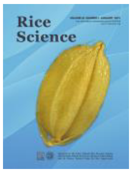
HOSTED BY
ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Rice Science, 2015, 22(1): 35−43



Factors Affecting Adoption of Improved Rice Varieties among Rural Farm Households in Central Nepal

Raju GHIMIRE[1], HUANG Wen-chi[2], Rudra Bahadur SHRESTHA[1]

(*[1]Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, Neipu, Pingtung 91201, Taiwan, China; [2]Department of Agribusiness Management, National Pingtung University of Science and Technology, Neipu, Pingtung 91201, Taiwan, China*)

Abstract: The use of improved high yielding crop varieties is an important avenue for reducing hunger and food insecurity in developing countries. Using cross-sectional data obtained from a survey conducted during 2013 crop season, we performed a probit model (plot-level analysis) to determine the probability of adopting new improved rice varieties (NIRVs) by smallholder farmers particularly from two main agro-ecological regions (hills and tropical plain terai regions) of Central Nepal. The results revealed that education, extension services and seed access play significant roles in adoption decisions. Additionally, farm and field characteristic variables such as farm size, endowment of favorable land type (e.g. lowlands), and animal power (e.g. oxen) are the key factors influencing the probability of adopting NIRVs. The results showed that technology specific variables (e.g. yield potential and acceptability) are significant for explaining adoption behavior, implying that it is important to take farmers' preferences to varietal characteristics into consideration in the design of a research and development program. Given the significant role played by extension and access related variables, increased emphasis on information dissemination, field demonstration, and farmers' participatory research and training programs to popularize new rice varieties and enhance their adoption rate are required. This also suggests that policy intervention should be made on improving the educational status of farming households, and developing programs on varietal package of rice seed which offer farmers a variety of choices among the appropriate pools of germplasm. Such programs ultimately help farmers develop more profit-oriented behavior which are necessary to enhance adoption rate, production and food security in the long run.

Key words: adoption; improved rice variety; probit model; tropical terai region; technology specific characteristic

Productivity improving crop technology can be an option for rural farmers to get rid of hunger and food insecurity by increasing production, reducing food price and making food more accessible to the poor. The use of high yielding crop varieties facilitates the growth of agro-processing enterprise and non-farm sectors, and stimulates the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy (Just and Zilberman, 1988).

Further, developing and promoting the adoption of yield increasing crop varieties in a sustainable manner helps improve livelihood of rural farmers (Asfaw et al, 2012). Rice, the largest crop industry in South Asia including Nepal, has special significance and economic importance in agricultural development and poverty reduction (Gumma et al, 2011). Therefore, increasing rice productivity and production is essential to ensure national food security, reduce poverty, and safeguard against volatility of the rice market. However, adoption of new yield increasing rice varieties in Nepal is fairly low (40%) and its share in national contribution has been declining over the years (Pandey et al, 2012).

In terms of area and production, rice is the largest

Received: 23 January 2014; **Accepted:** 20 July 2014
Corresponding author: HUANG Wen-chi (wenchi@mail.npust.edu.tw)

Peer review under responsibility of China National Rice Research Institute
http://dx.doi.org/10.1016/j.rsci.2015.05.006

crop followed by maize and wheat, and a main staple crop in Nepal. Rice accounts for 46% of the cereal cultivated area and 55% of the production share (CBS, 2011). However, Nepal has the lowest productivity in cereal crops including rice in the South Asian region where population growth rate surpasses the growth rate of cereals, and thus becomes one of the most food-insecure countries in the region (Joshi et al, 2012). Various reports related to agriculture and food security assessments in Nepal have noted that low agricultural productivity is an important constraint on the achievement of national food security in Nepal (Bohle and Adhikari, 1998; Gittelsohn et al, 1998; Seddon and Adhikari, 2003; FAO, 2010; Pyakuryal et al, 2010; Sanogo and Maliki, 2010). Additionally, we lack adequate understanding and accurate information about recent changes in rice area over the years to design appropriate production plans and technology targeting schemes in the country (Gauchan et al, 2012). In this context, it has been a challenge for Nepal to increase production and productivity of rice in order to feed ever increasing population and achieve national food security. With the realization of this milieu, government had hammered out more pro-farmer strategies to promote the adoption of improved crop varieties and new technology with the support from donors and international support organizations, but very little has been achieved so far.

Rice production in Nepal largely depends on climatic variability, as most of rice is produced in rain-fed environment. For example, rice production and yield have noticeable fluctuation, which increase during the favorable monsoon seasons, but drop sharply during unfavorable years (Gauchan et al, 2012; Poudel et al, 2013). Also, rice is grown extensively under a wide range of agro-ecological regions (hills and terai), covering hill terraces, intermountain basins, river valleys, and flat lowland plains bordering to India. Terai exists mostly the low land type and the majority of plots are under irrigated (e.g. Chitwan and Rautahat districts in this study), whereas hill region (Kavre and Nuwakot), the main source of irrigation remains local streams, ponds, rain flood. About three-fourths (74%) of the paddy is produced in the flat lowland of the terai and the rest (26%) in the hills and mountains (Pandey et al, 2012).

Nepal's agriculture is characterized by marginal and small landholdings where land endowments are scattered in different plots or parcels. This is because ever increasing population has put pressure on land to be fragmented, averaging 3.3 parcels per household (Gauchan et al, 2012). Since the size of parcels is small, commercializing and adopting new agricultural technologies has been a difficult task and almost impossible. This hinders smallholders to increase production, generate income and improve livelihood. Farmers own and cultivate rice on different lands or field types based on topographical sequence, soil quality and irrigation source. Farmers also subdivide parcels into plots and subplots to fit the varieties of their own choice (Gauchan et al, 2012). Therefore, farmers' perceptions of new varieties are particularly important in determining which variety they will adopt (Sall et al, 2000). Further, farmers' perceptions of the technology-specific attributes of crop varieties are the major factors in determining adoption and use intensity (Adesina and Zinnah, 1993). As stated by Joshi and Pandey (2006), analyzing farm level data from rain-fed environment in Nepal, farmers' perceptions of varietal characteristics play key roles in determining technology choices. Therefore, there is a need for adoption studies to consider farmers' perceptions of technology specific attributes in the assessment of rice variety adoption decisions. Thus, this study aims to determine the factors among not only farm and farmers' characteristics but also farmers' perceptions of technology specific characteristics in technology adoption decisions relating to improved rice varieties based on the plot level data in Central Nepal.

The adoption of high yielding crop varieties by farmers in developing countries has been viewed as the solution to lower incomes in agriculture over the years (Besley and Case, 1993). As a result, many donor agencies have invested substantial resources in agricultural technologies in developing countries. However, most of the new agricultural technologies have not fully achieved the desired goals (Faltermeier and Abdulai, 2009). This observation has, therefore, spawned numerous studies about agricultural technology adoption and their impact on smallholders' welfare in developing countries in the recent years (Besley and Case, 1993; Doss and Morris, 2000; Mendola, 2007; Becerril and Abdulai, 2010). These studies focused on the adoption of single agricultural technology rather than a bundle of innovations that might enhance agricultural productivity in an integrated approach. For example, if a farmer adopts only one technique rather than a series of packages that includes implying new types of fertilizer, improved planting and weeding methods, new pesticides and irrigation techniques, the productivity improving effect of the new single technology may not be realized (Karanja et al, 2003). Therefore, in order to realize the increased agricultural productivity by rural farmers, adoption should occur in an integrated approach. However, the results of the previous studies (Just and Zilberman, 1988; Uaiene et al, 2009; Becerril and Abdulai, 2010) on technology adoption and poverty related issues suggest that the adoption decisions are based on risk, uncertainty, input rationing, information imperfection, human capital and social networks.

In light of this scenario, Nepal needs to address these issues in designing agricultural programs for rural farmers, particularly for improved rice varieties in order to increase production and productivity. Despite numerous empirical research has been devoted to improved rice technology adoption under diverse production, economic, and environmental conditions, little is known about the attitudes and perceptions of farmers to new improved rice varieties adoption at farm or plot level. In order to fill this research gap, this study attempts to determine the key factors associated with improved high yielding rice varieties adoption on the plot levels of Nepalese smallholders. This study is relevant to food policy decisions because if improved rice seeds had a pro-poor impact, then policies and programs to support rice seed technology can be justified on equity grounds.

Nepal Agricultural Research Council (NARC) is the lead agency for agricultural research in Nepal and mainly works with open-pollinated and inbred varieties of all the food crops. It has been developing and delivering new generations of modern rice varieties to suit the needs of diverse ecosystems and populations. It has released 140 varieties of rice, maize, and wheat since the 1960s. Only 60% of currently released varieties are in demand for rice, covering with 87.56% of the rice area, and only one-third for maize and wheat (Gauchan et al, 2012; Joshi et al, 2012). However, there is a lack of adequate information regarding newly released improved varieties and their patterns of adoption in farmers' fields (Launio et al, 2008). For example, farmers are overwhelmingly growing old and obsolete varieties of these crops: 85% of all the foundation seeds demanded for rice in 2010 were varieties released before 1995 (Joshi et al, 2012). Therefore, in this study, rice varieties were categorized into two groups: old and new improved varieties based on released year. For example, varieties that were released in or before 1990 were considered as old varieties and varieties that were developed and released by research institution and recommended for growing in specific environments after 1990 were considered as new improved rice varieties (NIRVs) (Gauchan et al, 2012).

Farmers allocate their lands (plots) based on the varietal characteristic of rice varieties, land type and agro-climatic variability. Among NIRVs, farmers grew Radha-4, Meghdoot, Rambilas, Radha-9, Hardinath, Radha-12, Ramdhan, Loktantra and Rampurmasuli, which were considered to be popular varieties in the study area. Similarly, among old varieties, Masuli, Sonamasuli, Janaki, Kanchhimasuli, Sabitri, Sarju-52 and Makwanpur-1 were found to be grown extensively. In some instances, farmers in the study area also cultivated hybrid rice imported from India and China particularly in terai and inner terai regions. There were also some local varieties being cultivated that farmers hesitate to shift into a new one because of their specific traits. Choosing improved varieties also depends on consumers' preferences for specific traits such as high yield, insect/pest resistance, drought/stress tolerance, palatability (eating quality), including straw yield and quality. Obtaining specific name and cultivated area by types of particular varieties, their yields, and varietal characteristics is beyond the scope of this study.

MATERIALS AND METHODS

Selection of study site

This study was conducted in four districts of Central Nepal namely Kavre, Nuwakot, Chitwan and Rautahat (Fig. 1). Among these four districts, Kavre and Nuwakot represent mid-hill districts with sub-tropical climate, whereas Chitwan and Rautahat represent terai

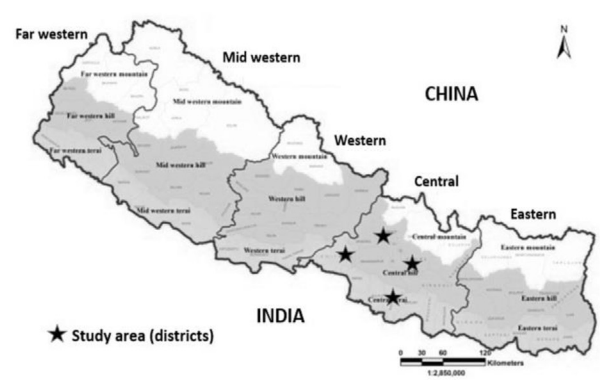


Fig. 1. Map of Nepal showing study area (MOAD, 2012).

districts (Terai is the southern part of the country bordering with India, which has flat fertile landscape and tropical hot climate. This region stretches parallel from east to west in the country, covering more than 1 000 km in length). Study sites from two terai districts are accessible by motorable road and close to market centers whereas the selected villages from hill districts were less accessible from road and market in comparison to the terai districts. The two hill districts Kavre and Nuwakot are located in 30 km east and 40 km northwest of the capital city Kathmandu respectively, whereas terai districts Chitwan and Rautahat are situated in 150 km south and 300 km southeast, respectively. Table 1 shows the agro-ecological profiles of study districts within hill and terai regions.

NARC is also located in the area and is a big asset to the central region in terms of research and development, production, information on quality seed, agronomic practices, marketing, storage, introducing new crop varieties and other relevant information. Further, selected districts represent major rice producing area, highly productive, suitable agro-ecology for rice production, which has the highest contribution to the regional and national production (MOAD, 2012). Similarly, these districts consist of many commercial farmers, using high yielding and hybrid varieties of rice, maize, wheat and vegetables. Farmers in the areas have also adopted various improved agriculture technologies, access to extension services, productive and fertile lands, infrastructures such as roads, markets, irrigation, rural credit institutions and cooperatives compared to other regions.

Theoretical and empirical framework

Coherent adoption analysis needs to view technology adoption within a conceptual framework that treats potential adopters as agents who make decisions in their own best interest. Adoption of agricultural technology and input use are the outcomes of optimization by heterogeneous agents (Foster and Rosenzweig, 2010; Janvry et al, 2010). This optimization takes place in the presence of constraint budget, information, credit access, and the availability of both the technology and other inputs. Thus, households are assumed to maximize their utility function subject to these constraints (Asfaw et al, 2012). The difference between the utility from adopting improved varieties (U_{iA}) and the utility from not adopting the technology (U_{iN}) may be denoted as U_i^*, such that a utility maximizing farm household, i, will choose to adopt new technology if the utility gained from adopting is greater than the utility from not adopting ($U_i^* = U_{iA} - U_{iN} > 0$). Since these utilities are unobservable, they can be expressed as a function of observable elements in the latent variable model as shown in Equation 1. By following Feleke and Zegeye (2006), Janvry et al (2010), Asfaw et al (2012), and Kohansal and Firoozzare (2013), the adoption decision can be modeled in a random utility framework as follows:

$$U_i^* = X_i'\gamma + u_i$$
$$\text{with } U_i = \begin{cases} 1 & \text{if } U_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where, U_i^* is the latent variable which represents the probability of the household's decision to adopt NIRVs, and takes the value '1' if the farmer adopt NIRVs, '0' otherwise. The term X_i' represents explanatory variables explaining the adoption decision, γ is a vector of parameters to be estimated, and u_i is the error term assumed to be independent and normally distributes as $u_i \sim N(0, 1)$.

We employed a probit model (STATA 12.0) to determine the probability of adopting NIRVs using plot-level data. The probit model is the most suitable tool to determine the probability of whether or not to choose NIRVs, particularly at the plot-level data analysis (Gauchan et al, 2012). We, further, are

Table 1. Agro-ecology and production environment of study sites.

Characteristic	Hill region		Terai region	
	Kavre	Nuwakot	Chitwan	Rautahat
Altitude (m)	318–3018	457–5 144	100–2 000	122–244
Climate	Sub-tropical	Sub-tropical	Tropical	Tropical
Annual rainfall (mm)	1 581	1 200	2 150	2 125
Temperature (ºC)	10–32	8–30	10–41	12–43
Cropping system	rice-vegetable-maize rice-fallow rice-maize	rice-vegetable-maize rice-fallow rice-maize	rice-wheat-rice rice-wheat-maize rice-vegetable-maize	rice-wheat-rice rice-wheat-maize rice-vegetable-maize
Major agricultural crop	rice, maize, subtropical fruits and vegetables	rice, maize, subtropical fruits and vegetables	rice, maize, wheat, tropical fruits and vegetables	rice, maize, wheat, tropical fruits and vegetables
Access to road	Some parts of selected sites	Some parts of selected sites	Yes	Yes

interested in assessing the influence of each of the independent variables on the decision of the farm household to adopt NIRVs. For that, we estimated the marginal effect of independent variables in the probit model which can be obtained by differentiating the first and second order conditions as follows (Greene, 2012):

$$\partial E[U_i^*|X_i] / \partial X_i = \Phi(X_i'\gamma)\,\gamma \quad (2)$$

Based on the above mentioned theoretical model and previous study experiences (Gao et al, 1995; Yen and Jones, 1997; Newman et al, 2003; Feleke and Zegeye, 2006; Langyintuo and Mungoma, 2008; Janvry et al, 2010; Asfaw et al, 2012; Gauchan et al, 2012; Noltze et al, 2012; Kohansal and Firoozzare, 2013), we selected our explanatory variables and specified a probit model as follows:

$$U_i = \gamma_0 + \gamma_1X_1 + \gamma_2X_2 + \gamma_3X_3 + \gamma_4X_4 + \gamma_5X_5 + \gamma_6X_6 + \gamma_7X_7 + \gamma_8X_8 + \gamma_9X_9 + \gamma_{10}X_{10} + \gamma_{11}X_{11} + \gamma_{12}X_{12} + \gamma_{13}X_{13} + \gamma_{14}X_{14} + \gamma_{15}X_{15} + \gamma_{16}X_{16} + \gamma_{17}X_{17} + u_i \quad (3)$$

where, U_i is the adoption of NIRVs (binary dependent variable), X_1 represents the age of household head in years, X_2 represents gender (dummy), X_3 represents the formal years of schooling (years), X_4 represents family labor, X_5 represents farm size (hm^2), X_6 represents land type (lowland dummy), X_7 represents oxen (dummy), X_8 represents extension service (number of visits), X_9 represents seed access (dummy), X_{10} represents seed cost (dummy), X_{11} represents the distance to market (km), X_{12} represents off-farm work (dummy), X_{13} represents yield potential (dummy), X_{14} represents pest resistance (dummy), X_{15} represents palatability (dummy), X_{16} represents acceptability (dummy), X_{17} represents region dummy, γ_0 to γ_{17} represent coefficients to be estimated, and u_i is error term.

Data collection and sampling method

The data used in this study were obtained from a survey conducted in four districts of Central Nepal during May to August, 2013, which is the main rice planting season in Nepal. A multistage, random sampling procedure was employed to select districts, villages and farm households. At the first stage, four districts (Kavre, Nuwakot, Chitwan and Rautahat) were purposively selected based on the intensity of rice production, agro-ecology and accessibility. This was followed by a random sampling of eight village development committees (VDC, VDC is the lowest administrative unit of the local government at village level consisting of nine small clusters or villages called Ward) at the second stage (two VDCs from each district). At the third stage, 16 village clusters (two village clusters from each VDC) were randomly selected. A random sample of 416 households from selected villages (26 households from each village cluster) was surveyed using the standardized survey questionnaires at the final stage. The respondents interviewed are the household head or household principal male or female members who directly make the decision and manage the farm. The information about survey sites/districts and villages within the hills and terai regions are presented in Table 2.

As mentioned earlier, NIRVs represent varieties that were developed and released by research institutions and recommended for growing in specific environment after 1990. Similarly, adopters were classified as farmers who planted any of the NIRVs released after 1990 irrespective of the area planted, and non-adopters are those who did not cultivate any of those varieties. Many adopters did not fully allocate their lands to improved varieties as they also grow traditional varieties. Based on the adoption literatures (Feder et al, 1985; Adesina and Zinnah, 1993; Sall et al, 2000; Doss, 2006; Langyintuo and Mungoma, 2008), following explanatory variables are expected to influence the probability and rate of adoption, which are broadly categorized into: (1) household characteristics, (2) farm and field characteristics, (3) institutional and access related, and (4) technology specific attributes.

RESULTS AND DISCUSSION

Descriptive statistics

Summary statistics, explanation of the variables, and the hypothesized effects of the independent variables on the dependent variables are presented in Table 3. As observed, 68% of the sample households adopted

Table 2. Selected survey sites, Village Development Committees and adoption status by region and districts surveyed in 2013.

Region	District	Village Development Committee / Village	Number of households sampled		Total
			Adopter	Non-adopter	
Hill	Kavre	Kusadevi, Nala	71	33	104
	Nuwakot	Okharpuwa, Kakani	66	38	104
Terai	Chitwan	Khairahani, Gunjanagar	82	22	104
	Rautahat	Chapur, Judibela	66	38	104
Grand total			285 (68.51%)	131 (31.49%)	416 (100%)

NIRVs, and 29% of the households were headed by female. The average age of the household head was almost 45 years and economically active family members were 3 persons per household. Farmers, on average, had 8 years of formal schooling which is consistent with the national average in Nepal (CBS, 2011). The mean farm size of 0.51 hm^2 is also comparable to the national average of 0.60 hm^2 (MOAD, 2012). Farmers, on average, had 7 contacts with the extension agents during the previous year. Furthermore, 76% of the households reported to have income from off-farm employment.

Table 4 presents the results of differences between means of characteristics describing NIRVs adopters and non-adopters. There appeared to be a significant difference in age and education of the household head between adopters and non-adopters. Farm size was significantly higher for adopters compared with non-adopter counterparts, whereas the number of active family members was comparable between two groups. The adopting households also differed in owning oxen and land type (low land dummy) which were expected to have significant effect on NIRVs adoption.

Moreover, majority of NIRVs adopters had access to improved seeds and extension services compared with non-adopters. Interestingly, there was no significant difference in gender, distance to market and off-farm work participation among the adoption groups. It

Table 3. Descriptive statistics of variables and hypothesized effects for new improved rice varieties (NIRVs) adoption surveyed in 2013.

Variable	Description	Mean	*SD*	Hypothesized sign
Dependent variable				
NIRV adoption	=1 if the respondent plants NIRVs, 0 otherwise	0.68	0.46	
Independent variable				
Household characteristic				
Age	Age of the household head in years	44.54	10.81	+ , -
Gender	=1 if the household head is male, 0 otherwise	0.71	0.45	+
Education	Years of formal education of the head	7.86	3.38	+
Family labor	Active family members (between 15– 65 years)	3.12	0.98	+
Farm and field characteristic				
Farm size	Cultivated land area in the current year (hm^2)	0.51	0.43	+
Land type	=1 if household own low land, 0 otherwise	0.46	0.49	+
Oxen	=1 if household own oxen, 0 otherwise	0.55	0.49	+
Institutional and access related variable				
Extension service	Number of extension visits received in the previous years	6.80	6.09	+
Seed access	=1 if seed is available at local store, 0 otherwise	0.59	0.49	+
Seed cost	=1 if NIRVs are expensive than the old one, 0 otherwise	0.87	0.33	-
Distance to market	Distance to input/output markets (km)	12.74	6.10	-
Off-farm work	=1 if participate in off-farm work, 0 otherwise	0.76	0.42	+
Technology specific variable				
Yield potential	=1 if the NIRVs to yield more than the old one	0.81	0.38	+
Pest resistance	=1 if the NIRVs to be more resistant to field pests than the old one	0.51	0.50	+
Palatability	=1 if the NIRVs perceived to be more palatable than the old one	0.45	0.49	+
Acceptability	=1 if it is easier to sell grain from NIRVs compared with the old one	0.51	0.50	+
Region dummy	=1 if household live in terai region, 0 otherwise	0.50	0.50	+ , -

'+' indicates the expected positive influence, and '-' indicates the negative influence of independent variables on the dependent variable.

Table 4. Characteristics of adopters and non-adopters of new improved rice varieties.

Variable	Adopter	Non-adopter	Difference	*t*-value
Age of household head (years)	42.81	48.31	5.49	4.95**
Gender of household head male (%)	71.93	68.70	-0.03	-0.67
Years of schooling of household head (years)	9.22	4.92	-4.30	-14.91**
Active family members (number)	3.17	3.01	0.16	-1.59
Farm size (hm^2)	0.65	0.22	-0.42	-12.91**
Land type (dummy)	0.62	0.11	0.51	-11.11**
Access to seed (dummy)	0.76	0.23	-0.54	-11.97**
Oxen (dummy)	0.72	0.17	-0.55	-12.31**
Off-farm work participation (dummy)	0.75	0.79	0.04	0.88
Distance to nearest input/output market (km)	12.79	12.61	-0.19	-0.29
Access to extension services	9.33	1.31	-8.02	-15.76**

**, Significant at 1%.

should, however, be noted that mean difference comparisons may not take into consideration other characteristics of the farmers which may compound the impact of adoption on the farmers' welfare with the influence of other characteristics.

Factors influencing probability of adopting NIRVs

The results of estimated probit models are presented in Table 5, which represents the propensity to adopt NIRVs by rural farm households. Some of the variables had significant effects on the probability of adopting agricultural technology and were in agreement with some of the findings in previous studies. For instance, education appeared to be an important factor in adoption decisions of NIRVs. Our result showed that the propensity to adopt NIRVs by farm households increased with the level of education of household head. The result suggested that the more educated the farmer is, the more likely he/she will adopt NIRVs, possibly because he can process information more rapidly than others. This result is consistent with earlier literatures (Langyintuo and Mungoma, 2008; Kassie et al, 2011; Asfaw et al, 2012). To assess the effect of farm size on the probability of adopting NIRVs, cultivated land owned by household was included in the model. The positive and significant sign on farm size indicated that as farm size increased, the likelihood of adopting NIRVs increased. This result is consistent with Mendola (2007), Kassie et al (2011), and Mariano et al (2012).

Table 5. Parameter estimates of adoption of new improved rice varieties.

Variable	Parameter estimate	*z*-value	Average marginal effect
Age	0.010 (0.014)	0.70	0.001
Gender	0.104 (0.289)	0.36	0.009
Education	0.252 (0.054)	4.65***	0.023
Family labor	0.177 (0.135)	1.32	0.016
Farm size	1.412 (0.865)	1.63*	0.131
Land type	1.215 (0.348)	3.49***	0.113
Oxen	0.547 (0.274)	1.99**	0.051
Extension service	0.079 (0.030)	2.62***	0.007
Seed access	0.532 (0.271)	1.97**	0.049
Seed cost	-0.232 (0.421)	-0.55	-0.021
Distance to market	-0.038 (0.025)	-1.52	-0.004
Off-farm work	-0.142 (0.313)	-0.45	-0.013
Yield potential	1.547 (0.410)	3.77***	0.143
Pest resistance	0.049 (0.295)	0.17	0.004
Palatability	0.286 (0.283)	1.01	0.026
Acceptability	0.447 (0.269)	1.66*	0.041
Region dummy	-0.272 (0.351)	-0.77	-0.025
Constant	-5.303 (1.239)	-4.28***	
Log-likelihood	-70.438		
LR chi^2 (17)	377.430		
Prob > chi^2	0.000		
Pseudo R^2	0.728		
Correctly predicted percent	92.790		

***, Significant at 1%; **, Significant at 5%; *, Significant at 10% confidence level. The numbers in parentheses are standard errors.

In this study, land type (dummy for low land) was included in the model, and results showed the positive and significant effect on NIRVs adoption at the plot level. The significance of the land type variable indicated that endowment of lowland fields is important in increasing NIRVs adoption (Gauchan et al, 2012). Similarly, owning oxen by farm households appeared to significantly and positively impact on the probability of adopting NIRVs by farm households. This result is consistent with Cunguara and Darnhofer (2011), and suggested that animal power for plowing is important where the size of the cropped area is smaller and tractor mechanization is not profitable.

The availability extension services significantly increases the adoption of NIRVs among farm households, underlining the importance of extension in promoting adoption. This result is consistent with Feleke and Zegeye (2006), Mignouna et al (2011), Asfaw et al (2012) and Mariano et al (2012). Adoption of NIRVs is positively influenced by the availability of seeds in the local stores. Our possible explanation is that availability of seeds in the local stores eases the households to purchase and cultivate new improved varieties in their fields.

Whether producing rice is mainly for home consumption or for the market, yield potential plays a fundamental role in planting a given variety (Langyintuo and Mungoma, 2008). It is, therefore, not surprising that the probability of adopting NIRVs will increase once a farmer perceives that the yield potential of the given variety is higher than that of the existing local ones. Acceptability is another variable added in the model in order to capture the consumers' preference or acceptability of grain in the market which has positive and significant impact on the adoption of NIRVs. The market oriented households are willing to trade-off palatability for consumer acceptability, which was incidentally statistically significant in the model. If the variety is perceived by farmers to meet the preferences of consumers, its adoption will increase to produce more and sell in the market rather than home consumption (Langyintuo and Mungoma, 2008).

The household characteristic related variables such as family labor, age and gender of the household head have no statistically significant effect on the adoption of NIRVs. This finding is consistent with earlier studies in Nepal (Gauchan et al, 2012). For the gender variable not being significant here is possibly because, in general, most of the household decisions in farming operation including seed selection are made in consultation with female members, so men are not the sole decision maker for the choice of crop varieties in Nepal context. The estimated marginal effects in order to examine the individual effect of each independent variable towards the decision of adopting NIRVs by households are presented in Table 5.

CONCLUSION AND POLICY IMPLICATIONS

Improved seed technology allows farmers to save labor and managerial time, thereby improving efficiency of farming operation. Using the cross-sectional data and the probit model (plot-level analysis), we examined the factors affecting the adoption of NIRVs by smallholder farmers particularly from two main agro-ecological regions (hills and tropical plain terai regions) of Central Nepal. There seemed to be no significant gender differential and family labor between adopters and non-adopters of improved rice varieties. However, there were significant differences in age, the number of years of schooling, farm size, land type, access to seed and the number of extension visits between the adopters and non-adopters. The study revealed that the factors influencing the probability of adoption are education, farm size, seed access, extension service, yield potential and consumers' acceptability of rice varieties. Further, the econometric analysis revealed that endowment of favorable land type (e.g. lowlands), and animal power (e.g. oxen) are the key factors influencing the probability of the adoption of NIRVs.

The results showed that technology specific variables (e.g. yield potential and acceptability) are significant for explaining adoption behavior, implying that it is important to take farmers' preferences to varietal characteristics into consideration in the design of a research and development program. Given the significant role played by extension and access related variables, increased emphasis on information dissemination, extension demonstration, and farmers' participatory research and training programs to popularize new rice varieties and enhance their adoption rate are required. Therefore, planners and decision makers need to consider farmers' preferences on varieties, land-types to be cultivated, and demonstrations at farmers' field to enhance and promote the adoption of NIRVs.

ACKNOWLEDGEMENTS

The authors thank to the staffs of District Agriculture Development Offices and Agriculture Service Center in the study areas for their advice, help and support to collect data. Similarly, our profound acknowledgement and thanks are due to the members of farmers' association in the study districts for their direct and indirect contribution in cooperating and arranging time to conduct interviews.

REFERENCES

Adesina A A, Zinnah M M. 1993. Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agric Econ*, **9**(4): 297–311.

Asfaw S, Shiferaw B, Simtowe F, Lipper L. 2012. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, **37**(3): 283–295.

Becerril J, Abdulai A. 2010. The impact of improved maize varieties on poverty in mexico: A propensity score-matching approach. *World Dev*, **38**(7): 1024–1035.

Besley T, Case A. 1993. Modeling technology adoption in developing countries. *Am Econ Rev*, **83**(2): 396–402.

Bohle H G, Adhikari J. 1998. Rural livelihoods at risk: How Nepalese farmers cope with food insecurity. *Mountain Res Dev*, **18**(4): 321–332.

CBS (Central Bureau of Statistics). 2011. Nepal Living Standard Survey. National Planning Commission Secretariat, Government of Nepal, Kathmandu, Nepal.

Cunguara B, Darnhofer I. 2011. Assessing the impact of improved agricultural technologies on household income in rural Mozambique. *Food Policy*, **36**(3): 378–390.

Doss C R. 2006. Analyzing technology adoption using microstudies: Limitations, challenges, and opportunities for improvement. *Agric Econ*, **34**(3): 207–219.

Doss C R, Morris. M L. 2000. How does gender affect the adoption of agricultural innovations? *Agric Econ*, **25**(1): 27–39.

Faltermeier L, Abdulai A. 2009. The impact of water conservation and intensification technologies: Empirical evidence for rice farmers in Ghana. *Agric Econ*, **40**(3): 365–379.

FAO (Food and Agriculture Organization). 2010. Assessment of Food Security and Nutrition Situation in Nepal. A Report Prepared for National Medium: Term Priority Framework (NMTPF), Kathmandu, Nepal.

Feder G, Just R E, Zilberman D. 1985. Adoption of agricultural innovations in developing countries: A survey. *Econ Dev Cul Change*, **33**(2): 255–298.

Feleke S, Zegeye T. 2006. Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. *Food Policy*, **31**(5): 442–457.

Foster A D, Rosenzweig M R. 2010. Microeconomics of technology adoption. *Ann Rev Econ*, **2**(1): 395–424.

Gao X, Wailes E J, Cramer G L. 1995. Double-hurdle model with bivariate normal errors: An application to US rice demand. *J Agric Appl Econ*, **27**(2): 363–376.

Gauchan D, Panta H K, Gautam S, Nepali M B. 2012. Patterns of adoption of improved rice varieties and farm-level impacts in stress-prone rainfed areas of Nepal. *In*: Patterns of Adoption of Improved Rice Varieties and Farm-Level Impacts in Stress-Prone Rainfed Areas in South Asia. Los Baños, Laguna, Philippines: International Rice Research Institute: 37–103.

Gittelsohn J, Mookherji S, Pelto G. 1998. Operationalizing household food security in rural Nepal. *Food Nutri Bull*, **19**(3): 210–222.

Greene W H. 2012. Econometric Analysis. 7th edn. Princeton Hall: New York University.

Gumma M K, Gauchan D, Nelson A, Pandey S, Rala A. 2011. Temporal changes in rice-growing area and their impact on livelihood over a decade: A case study of Nepal. *Agric Ecosyst Environ*, **142**(3/4): 382–392.

Janvry D A, Dustan A, Sadoulet E. 2010. Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: Options for the CGIAR. *In*: Proceeding of University of California at Berkeley. http://impact cgiar org/meetings-and-events.

Joshi G R, Pandey S. 2006. Farmers' perceptions and adoption of modern rice varieties in Nepal. *Quart J Int Agric*, **45**(2): 171.

Joshi K D, Conroy C, Witcombe J R. 2012. Agriculture, seed, and innovation in Nepal: Industry and policy issues for the future. *In*: International food Policy Research Institure Project Paper: 60.

Just R E, Zilberman D. 1988. The effects of agricultural development policies on income distribution and technological change in agriculture. *J Dev Econ*, **28**(2): 193–216.

Karanja D D, Renkow M, Crawford E W. 2003. Welfare effects of maize technologies in marginal and high potential regions of Kenya. *Agric Econ*, **29**(3): 331–341.

Kassie M, Shiferaw B, Muricho G. 2011. Agricultural technology, crop income, and poverty alleviation in Uganda. *World Dev*, **39**(10): 1784–1795.

Kohansal M R, Firoozzare A. 2013. Applying multinomial logit model for determining socio-economic factors affecting major choice of consumers in food purchasing: The case of Mashhad. *J Agric Sci Technol*, **15**: 1307–1317.

Langyintuo A S, Mungoma C. 2008. The effect of household wealth on the adoption of improved maize varieties in Zambia. *Food Policy*, **33**(6): 550–559.

Launio C, Redondo G, Beltran J, Morooka Y. 2008. Adoption and spatial diversity of later generation modern rice varieties in the Philippines. *Agron J*, **100**(5): 1380–1389.

Mariano M J, Villano R, Fleming E. 2012. Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agric Syst*, **110**: 41–53.

Mendola M. 2007. Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh. *Food Policy*, **32**(3): 372–393.

Mignouna D B, Manyong V M, Rusike J, Mutabazi K D S, Senkondo E M. 2011. Determinants of adopting imazapyr-resistant maize technologies and its impact on household income in Western Kenya. *AgBioForum*, **14**(3): 158–163.

MOAD (Ministry of Agriculture Development). 2012. Statistical Information on Nepalese Agriculture, Government of Nepal, Kathmandu, Nepal.

Newman C, Henchion M, Matthews A. 2003. A double-hurdle model of Irish household expenditure on prepared meals. *Appl Econ*, **35**(9): 1053–1061.

Noltze M, Schwarze S, Qaim M. 2012. Understanding the adoption of system technologies in smallholder agriculture: The system of rice intensification (SRI) in Timor Leste. *Agric Syst*, **108**: 64–73.

Pandey S, Gauchan D, Malabayabas M, Bool-Emerick M, Hardy B. 2012. Patterns of adoption of improved rice varieties and farm-level impacts in stress-prone rainfed areas of Nepal. *In*: Patterns of Adoption of Improved Rice Varieties and Farm-Level Impacts in Stress-Prone Rainfed Areas in South Asia. Los Baños, Laguna, Philippines: International Rice Research Institute.

Poudel M P, Chen S E, Ghimire R. 2013. Rice yield distribution and risk assessment in South Asian countries: A statistical investigation. *Int J Agric Manag Dev*, **3**(1): 53–63.

Pyakuryal B, Roy D, Thapa Y. 2010. Trade liberalization and food security in Nepal. *Food Policy*, **35**(1): 20–31.

Sall S, Norman D, Featherstone A M. 2000. Quantitative assessment of improved rice variety adoption: The farmer's perspective. *Agric Syst*, **66**(2): 129–144.

Sanogo I, Maliki A M. 2010. Rice market integration and food security in Nepal: The role of cross-border trade with India. *Food Policy*, **35**(4): 312–322.

Seddon D, Adhikari J. 2003. Conflict and food security in Nepal: A preliminary analysis. A report to Rural Reconstruction Nepal, Kathmandu.

Uaiene R N, Arndt C, Masters W A. 2009. Determinants of Agricultural Technology Adoption in Mozambique. Discussion papers (67E). National Directorate of Studies and Policy Analysis, Ministry of Planning and Development, Republic of Mozambique: 1–31.

Yen S T, Jones A M. 1997. Household consumption of cheese: An inverse hyperbolic sine double-hurdle model with dependent errors. *Am J Agric Econ*, **79**(1): 246–251.