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FARMERS' ADOPTION OF IMPROVED RICE VARIETIES IN CAMBODIA

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ABSTRACT

Determinants of adoption of wet- and dry-season improved rice varieties in Cambodia were analyzed. Selection pattern and intensity of information sources, and barriers to adopt agricultural technologies by rice farmers were examined. Probit model was used to analyze household survey data, covering 24 provinces, 48 districts, 95 communes and 192 villages. The results show that farmers use a combination of information sources to meet their needs indicating that any single source does not satisfy all the farmers' information needs. The most used information sources were farm radio and television, followed by farm extension meetings/workshops. Frequent service providers for both male and female farmers were NGOs, local commune/village office and local extension service centers. The frequently-mentioned barriers to adopting new farm technologies are lack of technical knowledge/skills and technological incompatibility -- farmers stated that technologies were not suitable to their farms. This may mean either that the technology is not climatically fit or it is labor-intensive, costly or not suitable to smallholder farmers. Other frequently mentioned barriers were unavailability of credit to invest in new technology and access to market information. Adopters and non-adopters were significantly different in educational levels, access to improved seeds, and contact with extension agents. The study highlights how the farmer's age, educational level, family size, and extension-related variables influenced the farmer's behavior in selecting wet- and dry-season rice varieties. Use of seed from their own harvest showed a negative effect on adoption, suggesting that access to seed from reliable sources will benefit the farmers by increasing production and income. Incorporating researchers' and extension officials' message in television and radio programs, and implementing educational learning programs may be the policy alternatives to enhance adoption and rice productivity in Cambodia.

Key words: Cambodia, extension services, wet-and dry-season rice, technology adoption

INTRODUCTION

In Cambodia, the agriculture sector accounts for 28% of the gross domestic product, and it employs 67% of the total workforce (FAO 2014, World Bank 2015). Two-thirds of the total agricultural land is used for wet-season cultivation (2.2 million hectares). This is approximately six times higher than the amount used for dry-season cultivation. In the wet season, 32% of total agricultural land is irrigated; only 10% of agricultural land is irrigated during dry-season cultivation (CSES 2015). Rice is the main staple food crop in Cambodia. It covers more than 90% of the total cultivated area and accounts for 70% of the total calorie supply (Wang et al. 2012a). Rice is mostly grown in the northwestern and southeastern parts of the country. Banteay Meachey, Battambang, and Pursat are the three major northwestern provinces that account for 22% of the total rice area in the country (Pandey and Bhandari 2010). In the southeastern areas bordering Viet Nam, the major rice-

growing provinces are Kompong Cham, Kandal, Prey Veng, and Takeo. The production area of dry-season rice is mainly located in the southeast, with these four provinces accounting for over 70% of the total dry-season rice area.

Intensifying inputs and planting improved rice varieties is generally low in rain-fed areas (Wang et al. 2012b). This prevents smallholders from increasing production, generating income and improving their livelihoods. Farmers generally consider varietal characteristics of rice such as good eating quality, grain quality, and yield before choosing a specific variety to grow (Pandey and Bhandari 2010). Farmers grow modern varieties such as IR66 mainly because of their high yield; the preference for improved traditional varieties such as Riang Chey and Phka Rumduol is driven by their good agronomic characteristics, resistance to pests and diseases, and good market value (Pandey and Bhandari 2010). The limited use of technological innovations and policy constraints has resulted in low adoption of improved rice production technologies (Kleinhenz et al. 2013). Therefore, adoption of high-yielding varieties and intensification of inputs is the long-term solution through which Cambodians will be able to respond to high rice prices and reduce poverty (Yu and Fan 2009).

Farmers cultivate rice on the basis of topographical sequence, soil quality, and irrigation sources. A study in Nepal by Gauchan et al. (2012) indicated that the farmers subdivide parcels into plots and subplots to fit the varieties of their choice. Geographic location, the hydrological ecosystem and field/plot characteristics may be the important factors for farmers' adoption of improved rice varieties. In Cambodia, some of the previous studies (e.g., Wang et al. 2012a, Wang et al. 2012b) focused on agronomical and varietal characteristics of paddy rice, but data on how agricultural extension and information sources play a role in adopting wet- and dry-season rice varieties is lacking. Extension advisory services are fundamental to support farmers in adoption of improved technologies and agricultural production. Moreover, the role of extension is crucial in various stages of the adoption and diffusion process and the lack of extension service constrains the transmission of modern agricultural technologies (Rogers 2003). Our paper explores this opportunity to investigate factors affecting adoption of wet- and dry-season rice varieties in Cambodia.

Agricultural extension in Cambodia

Agricultural extension activities in Cambodia began in 1957, when the Agriculture Ministry set up an extension unit that used television, radio and publications to disseminate information to farmers. The civil war in the 1970s devastated the country's economy, and almost all agricultural extension infrastructures were destroyed. The provision of agricultural extension services to farmers returned in 1986 with an extension office under the Ministry of Agriculture and then, in 1995, the Department of Agricultural Extension (DAE) was established (MAFF 2015). The Ministry of Agriculture, Forestry and Fisheries (MAFF) and DAE provides agricultural extension services. The provincial department of agriculture (PDA), with support of the DAE, creates a forum at the district agriculture office (DAO) level in which diverse stakeholders in agriculture are represented. The DAO facilitates the agricultural development work and mainstreams these into the commune development plan. These plans are then discussed in district integration workshops before implementation. Most extension services are planned and managed by the PDA. Further, agricultural extension services in Cambodia are delivered through various NGOs, collaborating suppliers of inputs such as seed, fertilizer, pesticides, and credit, and focus on technology transfer. More recently, NGOs are working under the new rubric of public-private partnership and/or NGO-private partnership.

Smallholders need adequate agricultural information that is accessible, relevant, and well-communicated. An innovation is more likely to be adopted when it has a high relative advantage -- perceived superiority to the idea or practice that it supersedes -- and when it is easy to test and learn about before adoption (Pannell et al. 2006). The role of extension is crucial in this stage of the

adoption and diffusion process. It has been recognized that a lack of extension service constrains the transmission of modern agricultural technologies, thereby weakening the research-extension-farmer's linkage that extends such technologies and skills to the grass-roots level (Vuthy 2014).

MATERIALS AND METHODS

Data and sampling procedure

The population of this study included rice farmers from all provinces of Cambodia. A systematic random sampling method was used to select farmer respondents. First, two districts were selected randomly from each province (i.e., 48 districts from 24 provinces). Second, two communes were selected randomly from each district except in Rathanagiri, where only one commune was selected (i.e., 95 communes). Third, two villages from each commune were selected randomly except in Malek commune of Rathanagiri, where four villages were selected, making the total 192 villages (Fig. 1). Finally, using the household list for each village, and with the help of the Commune Council Chair, households not engaged in farming, fishing, or other agricultural activities were excluded to create the sampling frame for each village. From each sample village, 16 farm households were selected randomly using systematic sampling with a random start. This resulted in a sample of 3,072 households. Of this sample, 2,224 (84%) indicated growing wet-season rice and the remaining 423 (16%) indicated growing dry-season rice. The sample was further disaggregated into subsamples of wet-season lowland rain-fed and dry-season lowland irrigated rice plots. This resulted in 2,171 households growing rice under wet-season lowland rain-fed condition and 162 households under dry-season lowland irrigated environment, respectively. It should be noted that some of the households were found to be planting rice under both wet-season rain-fed and dry-season irrigated plots. Thus, the analysis on adoption of improved rice varieties was run using plot level data.

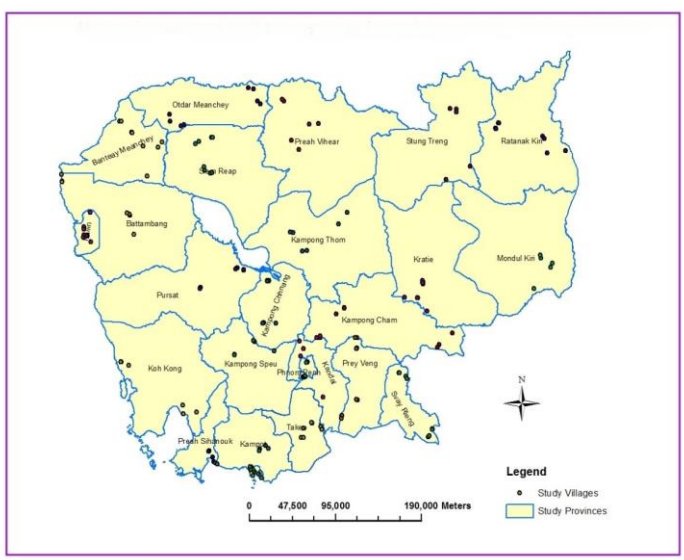

Fig. 1. Map of Cambodia showing sampling villages (source: Suvedi and Sarom 2017).

Survey instrument

A household survey questionnaire was developed to collect data on rice production and the prevalence of extension services in Cambodia. The questionnaire was reviewed by the faculty members of the Royal University of Agriculture (RUA) to ascertain validity, and then translated into the Khmer language (the primary Cambodian language) before field testing. Reliability of Likert-type

scales (i.e., sources of information used and barriers to adoption) were computed using Cronbach's α and was found at 0.70 and 0.75, respectively. Eight RUA faculty members served as data collection team leaders. The RUA faculty members identified and recruited 64 RUA students as field data collectors or enumerators. Special attention were given to selecting at least two RUA students from each province. This allowed for local familiarity with districts and communes during data collection. Each data collection team consisted of both male and female students and was led by a RUA faculty member. All teams received training on field data collection prior to the fieldwork. Data were collected during May-June 2013. Data analysis was performed by using STATA 14 software.

Theoretical and empirical framework

Innovations or new practices are not adopted by all individuals in a social system at the same time. The adoption is a process through which an individual or decision-making unit passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, and to the final confirmation of the adoption decision (Rogers 2003). Adopters can be classified into various categories based upon how long it takes for them to begin using the new idea. Generally, farmers with higher level of education and income tend to adopt an innovation earlier than others. Similarly, farmers with greater exposure to mass media, greater extension agent contact, greater social participation, and contacts with persons outside the community are among early adopters (Suvedi and Kaplowitz 2016).

Viewing adoption through the lens of optimization by rational agents, households should adopt a technology if and only if adoption is actually a choice that can be taken, and if adoption is expected to be profitable or otherwise advantageous. Modeling farmers' decision making about whether to adopt or not to adopt a technology constitutes both a discrete (whether or not to take up the technology) and a continuous (the intensity of use) decision. Following Asfaw et al. (2012) and Becerril and Abdulai (2010), we designed a model of adoption decision in a random utility framework as:

$$U_A^*(\pi) > U_N^*(\pi) \quad (1)$$

where π represents net income. This shows that farmers will adopt technology if it's expected utility (U) is greater than that of non-adoption. As the parameters associated with farmers' decisions are not observable, a latent variable U_i^* can be expressed in terms of socioeconomic variables (X_i):

$$U_i^* = X_i\beta + e_i \; (i = 1,2,3,\ldots,N) \quad (2)$$

where β represents a vector related to adoption parameters and e_i represents a random error term. After getting the choice of farmers' adoption, the dummy variable (Y_i) is denoted as:

$$Y_i = 1 \; if \; U_A^*(\pi) > U_N^*(\pi), \; 0 \; otherwise \quad (3)$$

where Y is a binary adoption decision variable taking a value of 1 if a farmer adopts an improved rice variety and zero if a farmer does not adopt.

The probit model is the most suitable tool to predict the probability of whether a farmer adopts the technology because of our discrete dependent variable with binary outcomes (Wooldridge 2012). The influence of each independent variable on the household's adoption decision is assessed by estimating the marginal effect of independent variables in the probit model (Greene 2012) .

Variable specification

Drawing on the available literature, variables that might affect adoption of new rice varieties and increase agricultural productivity were included. The variables expected to influence farmers' behaviors and stimulate adoption are presented in Table 1 with their descriptions and hypothesized effects on the dependent variables.

Table 1. Variables specification and hypotheses based on the literature.

Variables name	Description of variables	Literature (used in similar studies but different contexts)	Expected sign of regressors to the dependent variables used in probit model
Adoption status	Dependent binary variable: adoption of wet- and dry-season improved rice varieties (1=if adopted, 0=did not adopt)	(Shiferaw et al. 2014, Suvedi et al. 2017)	
Gender	Dummy for male household head (1=male, 0=female)	(Shiferaw et al.,2014)	+, -
Age of the HH head	Age of the household head in years	(Ghimire and Huang 2016)	+, -
Household size	Number of household members	(Ghimire and Huang 2016)	+
Education	Number of years of schooling (HH head)	(Mittal and Mehar 2015)	+
Farm size	Total area cultivated in the previous year (ha)	(Langyintuo and Mungoma 2008)	+
Tropical livestock units (TLU)	Numbers of livestock owned by the household. Weighted value for each type of livestock as: TLU=(cattle +oxen) × 0.5 + pigs × 0.2 + (goats + sheep + chickens) × 0.1	(Arslan et al. 2014)	+, -
Extension services: local ASC	Extension services from local agric. service center (1=yes)	(Budhathoki and Bhatta 2016)	+
Extension services: local commune/village office	Extension services from local commune/village office (1=yes)	(Misiko and Halm 2015)	+
Extension services: local demo farms	Extension service from local demonstration farms (1=yes)	(Mariano et al. 2012)	+
Extension services: NGOs	Extension services received from NGOs (1=yes)	(Simtowe et al. 2016)	+
Seed source	Seed source: 1=own harvest/fellow farmers/relatives, 0=seed dealers/company/NGO/government	(Kleinhenz et al. 2013), (Ghimire and Huang 2015)	-
Information source: fellow farmers/neighbors/relatives	Information source: fellow farmers/neighbors/relatives (1=yes)	(Misiko and Halm 2015, Shiferaw et al. 2014)	+
Information source: extension meeting/workshop	Information source: extension meetings/workshops/courses (1=yes)	(Suvedi et al. 2017)	+
Information source: Television	Information received from TV channel (1=yes)	(Asfaw et al. 2012, Misiko and Halm 2015)	+
Information source: Radio	Information received from radio (1=yes)	(Misiko and Halm 2015)	+
Access to credit	If access to credit (1=yes, 0 otherwise)	(Asfaw et al. 2012, Datta 2015)	+
Access to market information	If access to market information (1=yes, 0 otherwise)	(Suvedi et al. 2017)	+
Access to irrigation	If access to irrigation in rice field (1=yes, 0 otherwise)		+

HH=Household. Source: Compiled by authors from various sources

RESULTS AND DISCUSSION

Production environment of wet- and dry- season rice varieties

Table 2 shows the number of rice plots, average plot area and status of the adoption of improved and local rice varieties in various rice growing conditions for wet- and dry- season rice varieties in Cambodia. During the wet-season, lowland rain-fed rice was planted in 3703 plots with the average plot area of 3.54 ha, covering improved rice varieties in 24% of the plots. Upland rain-fed rice was planted in 157 plots with 1.52 ha plot size and 7% of the plots by improved varieties. About 27% on the pots were covered by improved varieties in the case of deep water/floating condition with an average size of 2.52 ha. Table 2 also presents dry-season rice in various growing conditions. As observed, 142 plots with an average area of 4.97 ha covered by 55% improved rice varieties, and 162 plots with 2.7 ha average plot size was planted with dry season flood recession (with supplementary irrigation) and 70% of plots were covered by improved varieties under these conditions. The largest number of plots in dry-season (192 plots and 2.29 ha plot size) was covered by 76.56% improved varieties in dry-season lowland irrigated condition.

Table 2. Types of rice varieties grown in wet- and dry- season at plot level

Rice growing conditions	Total number of plots under rice	Varieties planted in plots		
		Avg. plot area (ha)	Improved N (%)	Local N (%)
Wet season rice				
Rice: Lowland rain-fed	3703	3.54	885 (23.90)	2818 (76.10)
Rice: Upland rain-fed	157	1.52	11 (7.01)	146 (92.99)
Rice: Deep water/floating	71	2.51	19 (26.76)	52 (73.24)
Dry season rice				
Rice: Lowland rain-fed	142	4.97	79 (55.63)	63 (44.37)
Rice: Dry season flood recession with supplementary irrigation	162	2.70	115 (70.99)	47 (29.01)
Rice: Dry season lowland irrigated	192	2.29	147 (76.56)	45 (23.44)

N= number of plots planted rice varieties, Numbers in parentheses are percentage of plots planted rice varieties

Demographic characteristics and extension-related variables of the surveyed farmers

For plot level analysis, wet-season (lowland rain-fed) and dry-season (lowland irrigated) plots were used because these two categories consist of the most plots and popular rice growing conditions in Cambodia. Table 3 shows descriptive statistics of the demographic and other variables relating to adopters and non-adopters of wet- season (lowland rain-fed) and dry-season (lowland irrigated) improved rice varieties. The adoption of improved varieties is low in wet-season rice but relatively high in the case of dry-season cultivation. Only 32% of the rice growers used improved wet-season rice varieties but this percentage among dry-season rice growers was 77%. However, as discussed earlier, the wet season is the main rice production season in Cambodia and contributes more than two-thirds of the country's production.

Age and gender of the household head appeared to be significantly different at 1% level of significance between the adopters and non-adopters of wet-season improved rice varieties. Adoption of improved rice varieties was higher among male than female farmers. The mean difference of gender of the household head was statistically significant at 1% level. Adopters had a little more than

four years of formal schooling; non-adopters had only three and a half years, and this difference was significant at 1% level among wet-season rice growers. The total number of livestock was higher among adopters of wet-season rice growers as compared to non-adopters.

About 25% and 15% of the adopters among wet- and dry-season rice growers, respectively, received extension services from local agricultural service centers, compared with 23% and 4% of non-adopters. However, this difference was not significant between adopters and non-adopters in wet-and dry-season rice production. Additionally, a local demonstration farm is an important extension tool in disseminating and promoting new technology. The percentage of farmers receiving extension messages from the demonstration plot -- particularly wet-season rice varieties in Cambodia -- was significantly higher in the adopter group (27%) than among non-adopters (21%).

Table 3. Summary statistics for adopters and non-adopters of improved rice varieties by growing season.

Variables [Percentage reported for dummy variables]	Wet-season rice (lowland rain-fed)			Dry-season rice (lowland irrigated)		
	Non-adopters [n=1485 (68%)]	Adopters [n=686 (32%)]	t-test	Non-adopters [n=37 (23 %)]	Adopters [n=125 (77%)]	t-test
Age of the HH head in years	44.42	46.00	2.60**	46.24	46.66	0.16
HH head gender (1=male)	50.10	58.65	3.71**	48.65	57.26	0.92
Household size (# of people)	5.34	5.28	0.58	5.38	6.02	0.79
Number of years of schooling (HH head)	3.68	4.39	4.37**	4.56	5.10	0.94
Total area cultivated (ha)	3.93	3.83	0.30	1.82	1.71	0.26
Tropical livestock unit (TLU)	1.81	2.04	2.02*	2.19	2.39	0.38
Extension services from local agric. service center (1=yes)	22.89	25.29	0.96	3.57	14.61	1.57
Extension services from local commune office (1=yes)	47.75	52.82	1.72	35.71	52.22	1.53
Extension services from local demonstration farms (1=yes)	21.03	26.85	2.29*	35.71	30.77	0.49
Extension services from NGOs (1=yes)	60.34	56.34	1.38	53.57	60.0	0.59
Seed source: 1=own harvest/ fellow farmers/relatives; 0=seed dealers/company/ NGO/government	91.57	70.32	13.34**	78.38	46.40	3.54**
Information source: neighbors/ relatives (1=yes)	50.35	58.04	3.31**	58.33	58.87	0.06
Source of information: extension meetings/ workshops /courses (1=yes)	43.43	49.63	2.70**	64.86	68.00	0.36
Information received from TV channel (1=yes)	41.65	47.22	2.43*	48.65	50.40	0.19
Information received from radio (1=yes)	51.79	50.58	0.52	59.46	62.40	0.32

Variables [Percentage reported for dummy variables]	Wet-season rice (lowland rain-fed)			Dry-season rice (lowland irrigated)		
	Non-adopters [n=1485 (68%)]	Adopters [n=686 (32%)]	t-test	Non-adopters [n=37 (23 %)]	Adopters [n=125 (77%)]	t-test
Access to credit (1=yes)	27.08	32.19	1.99*	22.22	19.57	0.30
Access to market (1=yes)	28.83	24.89	1.55	25.93	17.58	0.96
Access to irrigation (1=yes)	11.46	12.04	0.32	18.52	26.37	0.83

Notes: n= number of observations; t-test: * $p < 0.05$, ** $p < 0.01$.

There is a significant mean difference between adopters and non-adopters in access to improved seed from formal sources (NGOs, seed companies, government) at 1% level of significance for both wet-and dry-season rice production. About 70% and 46% of adopters from wet- and dry-season production, respectively, used seed from own harvest and/or harvest from fellow farmers. This shows that only 30% of the adopters from wet-season category had access to reliable sources of seed -- for example, seed dealers, companies, NGOs and government. The percentage of farmers using seed from their own harvest or from fellow farmers/relatives was significantly higher among non-adopters -- 91% and 78% of wet- and dry-season rice producers, respectively. This is possibly because of the farmers' traditional practice of using seeds from own harvest or this highlights the lack of quality seed availability, high price of the improved seeds and the underdevelopment of seed networks in rural Cambodia.

Information sources such as extension meetings/workshops/courses (50% versus 43%) and information from fellow farmers/relatives (58% versus 50%) also significantly differ at 1 % level between the two groups of adoption in wet-season cultivation. Mariano et al. (2012) also found the similar result that underpins the role of extension services in adoption of improved crop varieties and other technologies. The percentage of farmers receiving agricultural information from TV was significantly higher among adopters than among non-adopters of improved wet-season rice varieties (47% versus 41%). Similar findings were reported by Nazari and Hassan (2011) suggesting that the role of media such as TV is important in disseminating improved technology among farming communities. Access to credit appeared to be significantly different between adopters and non-adopters of wet-season rice varieties (Mariano et al. 2012). This difference was significant at 5% lever with 32% of the adopters having access to credit as compared to only 27% access among non-adopters.

Selection pattern and use intensity of information sources by farmers

Table 4 presents farmers' selection of various sources of information and intensity of use relevant to their farming practices. Not relying on a single source of information, farmers rather use a combination of information sources to meet their needs. As presented in Table 4, Cambodian farmers reported that no single source provides all the information they need -- they rely on different sources for similar and different types of information. For example, the information about inputs and prices is best available from input dealers, newspapers, or magazines; output market price information can be obtained from TV, radio, internet/website, and middlemen in the village. Similarly, extension meetings and workshops might provide information about new technology such as improved seed varieties, adoption methods, and pesticide application. As shown in Table 4, in the percentage of farmers and intensity of use, farm radio and neighbors/relatives were the most used sources, followed by television and extension meetings/workshops. In general, almost half -- or even more – of the farmers did not have access to information sources for their rice farming practices (Table 4).

Radio farm program was the most used information source -- 3.08% to 16.59% of farmers used at various levels from a great deal to a little use, respectively. However, almost half of the farmers (48.32%) did not use farm radio program as an information source. The average mean intensity of the use of radio was 2.07, less than the average mean of 3. Similarly, 3.44% to 18.07% of farmers received information from fellow farmers, neighbor, and relatives. Extension meetings/workshops was useful to 14.89% farmers at various level of extent, with the mean use intensity at 1.89. Almost 14% of farmers had access to farm TV program at various degree of receipt as a source of agricultural information, with the use intensity score 1.89. However, the choice of the source of information by farmers mainly depends on their needs.

Table 4. Proportion of farmers using various sources of information.

Sources of information	Nothing at all	A little	Some	A fair amount	A great deal	Total		
	[Percentage]					N	Mean	SD
General newspapers	93.19	3.4	2.38	0.93	0.09	2,145	1.11	0.46
Farm magazines	89.40	5.46	3.46	1.4	0.28	2,141	1.18	0.58
Extension publications	82.04	7.23	6.67	3.68	0.37	2,144	1.33	0.79
TV farm programs	56.43	13.98	15.85	12.01	1.73	2,139	1.89	1.16
Radio farm programs	48.32	16.59	17.66	14.35	3.08	2,140	2.07	1.23
Local demonstration farms	81.80	7.14	7.05	3.27	0.75	2,143	1.34	0.81
Web/internet/e-mail	97.66	1.03	0.79	0.42	0.09	2,139	1.04	0.31
Extension meetings, workshops, courses	54.58	14.89	19.09	10.18	1.26	2,142	1.89	1.12
Agricultural research stations	93.74	3.17	2.24	0.75	0.09	2,142	1.10	0.44
Demonstration plots at local farmers' field, field days, and tours	87.76	5.89	4.58	1.5	0.28	2,140	1.21	0.62
Personal contact with extension agents	84.21	7.9	5.47	2.01	0.42	2,140	1.27	0.69
Leader farmers	80.24	8.41	6.21	3.97	1.17	2,141	1.37	0.86
Neighbors/fellow farmers/relatives	47.80	18.07	14.72	15.97	3.44	2,092	2.09	1.25
Others[a]	85.07	3.47	4.69	6.08	0.69	576	1.34	0.88

Note: ***** Means were calculated based on Likert-type scale on to what extent the farmers use information sources in the past 12 months: 1=nothing at all, 2= a little, 3= some, 4= a fair amount, 5= a great deal.

[a] Other sources include: NGOs such as ACOSON, CP, Me Koum, school teachers, and so on.

The least used source of information was information communication technology (ICT) sources such as internet, websites, and email, followed by general newspapers or farm magazines. More than 90% farmers did not use this type of information sources for farming. This is possibly because farmers have limited education and/or limited access to internet facilities in the rural villages. This indicates that there is a potential to invest in ICT and modern information sources, and thereby increase farmers' access to information and raise farm productivity and income (Zhang et al. 2016).

Receipt of extension services

Cambodia has a variety of extension service providers. The DAE of MAFF has the overall responsibility for monitoring and evaluating service quality by developing and implementing guidelines and regulations for all extension services providers. Farmers receive extension services from various sources including NGOs, research and educational institutions, input suppliers, private companies, community-based organizations, and expert/leader farmers (demo farms), who are important players in provision of agricultural extension services. As shown in Table 5, the highest proportion of farmers (58% of both male and female) received agricultural extension services from

NGOs, followed by local commune/village offices (52% male versus 43% female), local agricultural service centers (25% male versus 20% female), and local demonstration farms (25% male versus 19% female).

The average number of contact with extension personnel of local agricultural extension service centers between male and female farmers was significantly different at 1% level with the mean of 2.35 and 3.84, respectively. Similarly, the number of contact with NGO-managed project staff was significantly different between male and female farmer with the mean for male as 2.65 and for female as 3.77. In general, the number of contacts with various extension providers was low among male farmers as compared to female farmers (Table 5). Such contact needs to be increased by promoting frequent visits by extension workers to the farmers' home/farm. The least used service provider was research institutions and agriculture colleges/universities, technical or vocational schools, CDRI and local agricultural research stations. These institutions provided services for less than 10% of the both male and female farmers. Least number of contacts for both male and female farmers was from local demonstration farms and local fertilizer/input suppliers, with less than two contacts in the past 12 months. The reason may be either they do not have extension/outreach programs or their presence is very weak. To facilitate diverse and pluralistic extension service system, the DAE needs to promote strong collaboration and networking among service providers from multiple organizations (MAFF 2015). As outlined in agricultural extension policy of Ministry of Agriculture, Forestry, and Fisheries of Cambodia, extension programs should be aligned with the commune development plans and discussed in district integration workshops with various agricultural extension service providers at the local level.

Table 5. Receipt of extension services from various service providers and number of contacts.

Extension service providers/organizations	**N**	**% receiving extension services**			**# of contacts in the past year**		
		Male	**Female**	**t-test (M vs F)**	**Male**	**Female**	**t-test (M vs F)**
Local agricultural service center	1,327	25.04	20.27	2.42*	2.35	3.84	3.24**
Local village/commune office	1,302	52.91	43.88	3.24**	2.10	2.44	1.45
Agriculture colleges/universities	1,242	4.54	3.22	1.57	3.23	1.75	1.17
Technical or vocational school	1,240	7.43	3.24	3.45**	2.16	3.35	1.03
Extension agents from the MAFF	1,264	25.00	19.12	2.59**	2.00	2.04	0.15
Cambodian Agricultural Research and Development Institute (CARDI)	1,243	7.99	5.58	1.57	2.21	3.40	0.83
NGO-managed projects	1,295	58.32	58.56	0.14	2.65	3.77	2.41*
Local demonstration farms	1,248	25.08	19.78	1.93*	1.72	1.94	0.96
Local agricultural research stations	1,240	6.05	3.20	2.57**	2.24	2.27	0.03
Local fertilizer/input supply dealer	1,250	16.08	12.00	2.42*	1.79	1.63	0.39
Other service providers[a]	1,044	9.42	6.62	1.69	2.35	3.84	3.24

Note: N= number of observations (overall); M=male; F=female; numbers in parentheses are standard deviation; t-test: * $p < 0.05$, ** $p < 0.01$; [a]Akip Seed Company, Orn Doung Community, Australia government.

Farmers' perceptions of barriers to adopting improved farming practices

Barriers to adoption of improved farming practices are reported in Table 6. The barriers are mainly related to the use of technologies -- for example, lack of technical knowledge, education or skills; time and technological incompatibility; labor shortage; lack of on-farm trials and demonstrations; and incompatibility with operation size and complexity. Less access to irrigation facilities was the most important barrier to adopt new technology. The extent of importance ranged from little to somewhat important, with a mean score of 3.93 on a 1-5 scale with higher the more important (Table 6). Lack of irrigated land or irrigation capability may prevent farmers from growing newly developed high-yielding crop varieties and using other inputs such as fertilizers and pesticides. The lack of technical knowledge about technology was the second most important barrier (score 3.53), followed by less education or skills (score: 3.41). No access to market information and unavailability of credit to adopt new technology were the major barriers, with mean scores of importance of 3.25 and 3.22, respectively. These barriers could be related to education and knowledge factors because it is generally believed that an educated person can better process and analyze information and make favorable decision.

Technological incompatibility with existing socio-cultural context is a common barrier to adoption. Other reasons may include unsuitable climatically conditions, that it is labor-intensive, requires costly inputs, or it is not suitable to the scale of smallholder farmers. In this study, respondents were neutral, with a mean score of 2.90 with the statement, “the agricultural technology is not suitable to my farm.” This indicates that the unsuitability of technology to the farmers' field was not an important barrier to adoption of improved technologies.

Incompatibility with operation size is another barrier experienced by farmers. Some farmers are smallholders, and adopting technology that requires a large area or intensive use of resources (cost/land/labor) may not be practical or profitable. As some of the respondents said, “My farm is too small and not appropriate to adopt the new technology.” Such beliefs perhaps contribute to the general “won't work on my farm" attitude of farmers. Farmers also indicated that learning and implementing new farming practices require a time investment. In addition to being too time-consuming, trying out and adopting new practices may require extra labor during busy times in the growing season. Both labor and time can be barriers if the farmer is involved in other off-farm sectors such as teaching, business, or migrant employment. The mean score of the importance of this barrier was 2.15 (little importance).

Table 6. Farmers' perceptions of the importance of barriers to adopting improved agricultural technologies.

Statements: Barriers to adopt improved farming practices		Mean	SD
		[Responses in scale 1-5]*	
My farm has no access to irrigation	1,398	3.93	1.11
I do not have sufficient knowledge about the new technology	1,404	3.53	1.06
I do not have the education or skills to adopt the new technology	1,401	3.41	1.09
I do not have access to a market for my products	1,387	3.25	1.26
I cannot get credit needed to adopt the new technology	1,395	3.22	1.32
The agricultural technology is not suitable to my farm	1,400	2.90	1.10
My farm is too small	1,400	2.78	1.25
I do not own the land which I farm	1,398	2.46	1.34

Other reasons (e.g. Lack of time, labor)	379	2.15	1.62

Note: *Responses based on scale: 1=not at all important, 2=a little important, 3=neutral, 4=somewhat important, 5=very important.

Factors influencing adoption of wet- and dry-season improved rice varieties

The estimated coefficients of the parameters in the binary probit model are summarized in Table 7. The marginal effects for both wet- and dry-season rice varieties are reported. The chi-squared test statistic is significant at the 1% and 5% levels, suggesting that the explanatory variables jointly determine the adoption of wet- and dry-season improved rice varieties, respectively.

The farmers' age has a significantly positive effect on the probability of adopting improved rice varieties, but the age squared variable exerted a significantly negative effect on adopting improved rice varieties. This suggests that the life cycle effect on the likelihood of adopting improved rice varieties was quadratic. With younger household heads, the probability of adoption increases with age; with older household heads, the probability of adoption decreases. This result is consistent with Ghimire and Huang (2016) in their study in Nepal, indicating that older farmers are less likely to adopt improved agricultural technologies and particularly they are less interested in changing crop varieties. This is possibly because young farmers are more flexible, more often exposed to new ideas, and more willing to bear risk than their older counterparts. The relationship between household size and adoption is significantly different from zero and negative. This indicates that, for each additional member added in the household, the probability of adopting wet-season rice varieties decreases by 2%, but this relationship between family size and adoption is not significant for dry-season production. These results agree with the studies by Ghimire and Huang (2016) who indicated that an increase in the number of household members tend to divert to other sectors. The results also show that farmers with higher levels of education have a higher probability of adopting improved varieties of wet-season rice. It is assumed that farmers who are better educated have greater ability to process information and search for technologies suitable to their production constraints than those who are less educated. This finding is consistent with Mariano et al. (2012), suggesting that educational programs for farmers should be given the necessary attention by policymakers.

The number of tropical livestock unit has a positive influence on adopting improved wet-season rice varieties. The higher the number of livestock, the greater the likelihood of farmers growing wet-season improved varieties by 4%. This is probably because livestock provide farmyard manure for the rice field, and rice straw can be used as feed for animals in the lean season.

The farmers receiving extension services from NGOs were more likely to adopt improved wet-season rice varieties. For instance, receiving a service from NGOs increases the probability of adopting wet-season improved rice varieties by 9.4%. The result underpins the concept of pluralistic extension and the role of NGOs and private-sector providers in disseminating new technology among farming communities. Variable "seed source" is highly significant and has a negative influence on adopting improved rice varieties. If the farmers use seeds from their own harvest or fellow farmers' harvest, their probability of adopting improved rice varieties in both wet- and dry–season production decreases by 25% and 20 %, respectively. This finding is in line with Ghimire and Huang (2015), in their study about factors affecting improved rice varieties in Nepal. The result shows that sourcing information from extension meetings/workshops/courses is significantly different from zero and positive among wet-season rice farmers. This means farmers who contact extension officials and attend meetings/workshops have a higher probability of adopting wet-season improved rice varieties by 7%. This finding is consistent with Mariano et al. (2012), corroborating the role of the extension in providing information about new practices or new crop varieties and motivating farmers to adopt in their field. Similarly, having contact with extension agents and receiving information from them promote adoption of improved crop varieties and other farm technology (Ghimire et al. 2015).

Table 7. Estimating the probability of adopting of wet- and dry-season improved rice varieties in Cambodia.

Variables [Dependent variables are binary: 1=adoption of wet- and dry-season improved rice varieties, 0 otherwise]	**Wet-season rice (lowland rain-fed)**	**Dry-season rice (lowland irrigated)**
Age of the HH head in years	0.021**	0.035*
	(0.008)	(0.017)
Head's age squared	-0.001*	-0.001*
	(0.000)	(0.000)
HH head's gender (1=male)	0.022	-0.008
	(0.032)	(0.086)
Household size (number of people)	-0.017*	0.003
	(0.008)	(0.021)
HH head's education (number of years of schooling)	0.015**	0.015
	(0.005)	(0.013)
Total area cultivated (ha)	0.009	-0.090
	(0.010)	(0.052)
Tropical livestock units (TLU)	0.042*	-0.010
	(0.019)	(0.054)
Extension services from local agric. service center (1=yes)	-0.015	0.273
	(0.043)	(0.142)
Extension services from local commune/village office (1=yes)	-0.010	0.114
	(0.034)	(0.080)
Extension services from local demonstration farms (1=yes)	0.048	
	(0.039)	
Extension services from NGOs (1=yes)	0.094**	0.028
	(0.032)	(0.078)
Seed source: 1=own harvest/fellow farmers/relatives, 0=seed dealers/company/NGO/government	-0.256**	-0.199*
	(0.041)	(0.085)
Information source: neighbors/relatives (1=yes)	0.055	0.088
	(0.034)	(0.102)
Information source:	0.070*	
1. extension meetings/workshops/courses (1=yes)	(0.034)	
2. TV channel (1=yes)	0.041	0.144
	(0.036)	(0.092)
3. Radio (1=yes)	-0.054	-0.135
	(0.036)	(0.098)
Access to credit (1=yes)	0.070*	0.167
	(0.035)	(0.108)
Access to market information (1=yes)	-0.024	
	(0.037)	
Access to irrigation (1=yes)	-0.002	
	(0.046)	
Observations	806	90
Pseudo R-square	0.093	0.214
Chi^2-statistic	94.412	25.106

Variables [Dependent variables are binary: 1=adoption of wet- and dry-season improved rice varieties, 0 otherwise]	**Wet-season rice (lowland rain-fed)**	**Dry-season rice (lowland irrigated)**
p-value of Chi^2-statistic	0.000	0.049
Log likelihood	-467.485	-39.324

Notes: Marginal effects estimated; robust standard errors in parentheses; t-test $^{***}p < 0.01$, $^{**}p < 0.05$.

Credit access was found to have a positive effect on the adoption of wet-season improved rice varieties. With the availability of credit, farmers' probability of adopting wet-season improved rice variety adoption will increase by 7%. In rural areas, farmers lack sufficient capital to invest on improved technology, hence, the availability of credit to smallholder farmers who often have insufficient capital will encourage the adoption of improved crop varieties.

CONCLUSION AND POLICY RECOMMENDATIONS

This paper has examined the factors influencing adoption of improved rice varieties under lowland conditions in Cambodia. We also analyzed the barriers to adopting technologies and their degree of importance. The results indicate that farmers use a combination of information sources to meet their needs. They may be complementary or substitute for one another, and this implies that any single source does not satisfy all information needs of the farmer. Farmer's age, educational level, and farm size influence the farmers' behavior in selecting sources of information and adopting improved rice varieties. Farm radio and neighbors/relatives were the most used sources, followed by farm television and extension meetings/workshops. These findings imply that extension service should focus on utilizing mass media channels for technology dissemination and hold extension meetings and workshops with local development partners. Furthermore, NGOs, local commune office or the village chief and local extension service centers were the frequent service providers for farmers.

No access to irrigation, lack of technical knowledge, skills, and incompatibility of technology were frequently mentioned barriers to adopting new farm practices. Farmers referring to technology as "not suitable to their farm" may mean that the technology is not climatically fit or it is labor-intensive, costly, or not suitable to farmers. Unavailability of credit to adopt new technology and access to market information were also frequently mentioned barriers. Thus, agriculture development policies should address the need for farm credit services to farmers to enhance adoption.

Adopters and non-adopters were significantly different in their educational level, access to improved seeds, and contact with extension agents (including access to information sources such as TV, extension training/workshops/courses). Along with farmer characteristics variables (age, education, family size, livestock), extension-related variables significantly affected the adoption of wet-season improved rice varieties. Use of seed from their own harvest or from fellow farmers has a negative effect on adopting wet-and dry-season improved rice varieties. This suggests that access to seed from reliable sources such as seed companies/dealers will benefit farmers in adopting improved seeds. Seed companies should extend their network in rural areas, and government should support them through coordination in a public/private partnership model. The findings suggest that agricultural extension policies should create a favorable environment for collaboration and providing extension services to rural people through pluralistic extension approaches to enhance adoption of improved rice varieties. Future research may focus on the intensity of adoption and continued adoption of improved crop varieties.

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