Journal of International Agricultural and Extension Education

Volume 29
Issue 3 *Summer 2022*

Article 3

9-2022

Adoption of improved agricultural practices: Learning from off-season vegetable production in Nepal

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Recommended Citation
Ghimire, R., Suvedi, M., & Kaplowitz, M. (2022). Adoption of improved agricultural practices: Learning from off-season vegetable production in Nepal. *Journal of International Agricultural and Extension Education, 29*(3), 32-47. https://doi.org/10.4148/2831-5960.1027

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Abstract

This study examines factors that appear to contribute to farmers' adoption and discontinuation of poly house technology for off-season vegetable production. We collected cross-sectional survey data from a sample of 151 households in Kaski district, Nepal during October 2018. The data are analyzed using Heckman's two stage sample selection model. The study reveals that the family members report being engaged in nonfarm sector that there is an increased probability of discontinuation of poly house technology. Farmers may be diverting their labor towards nonfarm activities that result in higher returns to labor and different risks. At the same time, the results indicate that farmers who did not receive training on vegetable production were more likely to discontinue poly house technology. It was also found that increasing farmers' engagement with marketing activities increased the likelihood of farmers to continue poly house technology and increase household income. The provision of continued technical support (e.g., training), input supply (e.g., seeds, fertilizers) and market information are essential to sustain the adopted technologies. The study sheds light on the sustainability of technology adoption by underpinning the importance of extension services for longer-term adoption. We believe that the combined effect of various technologies would be associated with sustained adoption of the improved off-season technologies. This provides a new direction to operationalize farmer-oriented policies in agricultural extension and helps in devising programs for sustained adoption of technology.

Keywords

Technology adoption, Off-season vegetables, Poly house, Sustainability, Farm income, Nepal

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Abstract

This study examines factors that appear to contribute to farmers' adoption and discontinuation of poly house technology for off-season vegetable production. We collected cross-sectional survey data from a sample of 151 households in Kaski district, Nepal, during October 2018. The data are analyzed using Heckman's two-stage sample selection model. The study reveals that family members being engaged in nonfarm activities increased the probability of discontinuation of poly house technology. Farmers may have been diverting their labor toward nonfarm activities that resulted in higher returns to labor and different risks. At the same time, the results indicate that farmers who did not receive training on vegetable production were more likely to discontinue poly house technology. It was also found that increasing farmers' engagement with marketing activities increased the likelihood of farmers continuing poly house technology and increasing household income. The provision of continued technical support (e.g., training), input supply (e.g., seeds, fertilizers), and market information is essential to sustain the adopted technologies. The study sheds light on the sustainability of technology adoption by underpinning the importance of extension services for longer term adoption. We believe that the combined effect of various technologies would be associated with sustained adoption of the improved off-season technologies. This provides a new direction to operationalize farmer-oriented policies in agricultural extension and could help in devising programs for sustained adoption of technology.

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Introduction

Farming is the main occupation of 60 percent of the people of Nepal and accounts for 27 percent of Nepal's gross domestic product (NPC, 2019). Most of Nepal's farming is seasonal and subsistence. Adoption of agricultural technologies that are climate- resilient and suitable for smaller land holdings may help increase farm productivity and income. However, not all farmers adopt new technologies quickly and uniformly. Innovation adoption is a complex process, and a number of factors, including risk and uncertainties, are associated with the adoption process (Mottaleb, 2018; Suvedi & Ghimire, 2016). Better understanding of the barriers and supports to farmer adoption and continuation of agricultural technology innovation in developing country contexts can help to increase and sustain farm productivity and income.

Innovation adoption studies have been undertaken in the context of adoption of agricultural technologies in developing countries. These studies often focus on adoption of a single innovation or practice. Most of these studies are limited to assessing the determinants of adoption of technology (Doss, 2006). A few studies have focused on risk of failure, post-adoption behavior of farmers, and discontinuation of adoption (Glover et al., 2016; Ngwira et al., 2014). However, some have called attention to what they see as growing discontinuation of technology after a period of adoption (Arslan et al., 2014). Others posit that the discontinuation of technology adoption is a result of an interruption in participating farmers' free or subsidized inputs and extension services (Pedzisa et al., 2015; Twomlow & Delve, 2016).

Farmers evaluate new technology options using their sociocultural context and profitability criteria and, we believe, do so when deciding to continue technology adoption or discontinue it. That is, a farmer decides to adopt or discontinue a new technology based on personal experiences, perceived attributes, social compatibility, and characteristics of the technology (Chinseu, Dougill, & Stringer, 2019). We know that more 'how-to' knowledge is required for more complex innovation to promote continued adoption (Rogers, 2003). Further, it has been shown, unsurprisingly, that technologies considered ineffective are abandoned or discontinued (Pedzisa et al., 2015; Twomlow & Delve, 2016). At the same time, Sietz and Van Dijk (2015) and Arslan et al. (2014) underscore the importance of both agroecological and socioeconomic motivation for successful scaling up and sustainable adoption of new technologies.

Therefore, we use the experience of Nepali farmers with poly house technology for off-season vegetable production to examine the factors that appear to be impactful on continued adoption. At the same time, we explore why some farmers decided to abandon the poly house technology and return to conventional vegetable production practices. The results shed light on the sustainability of agricultural technology adoption. In particular, this research illustrates the importance of improved agricultural extension services for longer term adoption of improved agricultural technology.

Background of the project and study framework

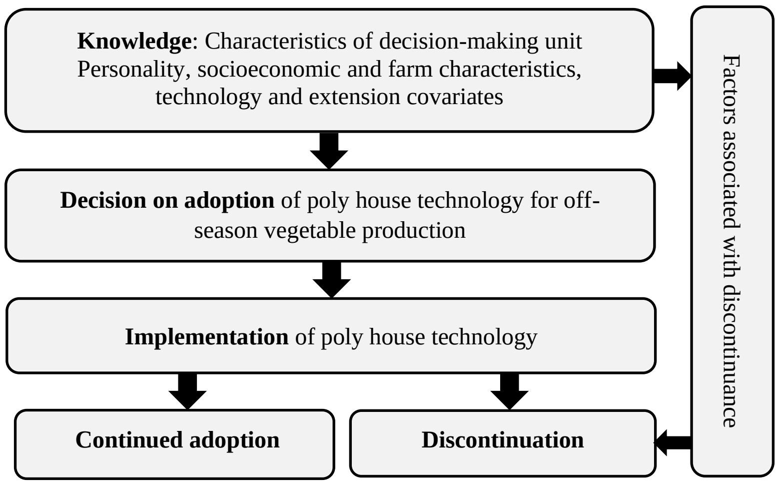
In 2011, Michigan State University (MSU) successfully piloted off-season vegetable production technology using poly houses in the Kaski district of Nepal. The goal of the project was to help increase production, nutrition, and income of subsistence farmers through off-season vegetable production and marketing using high- rise plastic tunnels (locally known as poly houses).

The poly house technology allows farmers to grow vegetables despite bad weather such as heavy rainfall, hailstorms, or drought. Growing tomatoes and other vegetables during the off-season in this region has become a new income source for participating farmers. The initial project provided the farmers with training on off-season tomato production, the material for and construction of the poly houses, and seedlings of the recommended variety. In addition to general training for all growers, the project provided extra training to develop "lead farmers" who are also entrepreneurs. This approach to training of lead farmers resulted in a new role for extension -- building local capacity through co-learning rather than the traditional top-down technology transfer approach. Additionally, a farmer-managed cooperative was established in the area to help market farm products and to coordinate the bulk purchase of needed inputs such as seeds, seedlings, fertilizer, and pesticides. The project worked to promote environment-friendly, climate- resilient approaches to grow off-season vegetables in an integrated manner. This study revisits the original poly house study area to assess and learn from changes in the participants' use of poly house technology and the characteristics of farmers and their groups associated with continued use of the technology.

Study framework

The study adds to Rogers' (2003) diffusion theory by including interrelated technological components and combining improved technologies at the farm level. Figure 1 shows a pathway of the adoption decision process of innovation and its discontinuation. Characteristics of the decision-making unit, including external factors, play a role in deciding whether to adopt or reject any technology at the early stage of adoption. Once adopted, the adopter evaluates the new technology against the sociocultural context and economic profitability criteria and makes decisions about whether to continue adoption or discontinue it. Such decisions seem to depend on personal experiences, perceived attributes of the technology, social compatibility, and characteristics of the technology itself. As a result, we believe that the combined effect of various technologies would be associated with increased and sustained adoption of the improved off-season technologies.

Figure 1
Authors' compilation of adoption and discontinuation framework based on Rogers (2003).



Methods

Study area

The study was conducted in Hamsapur village of the Kaski district in western Nepal, where a Michigan State University-funded off-season vegetable production technology project began in 2011 (Suvedi, Ghimire, & Kaplowitz, 2017). In 2017, additional new technological interventions such as good livestock management practices, rainwater harvest, drip irrigation, and a farmer-managed cooperative were implemented in an effort to promote long-term adoption of off-season vegetable production and, in turn, increase households' income and improve nutrition.

Nepal is a country with inhabitants with a range of social identities and groups. The inhabitants in the study village reflect several distinct castes and ethnic groups including Brahmins, Chhetries, Gurungs, Magars, Kami, and Sarki. Hamsapur is located in the Annapurna mountain range, a unique production environment for vegetables and cereal crops (rice and maize) with good potential for vegetable production. The dominant (traditional) cropping systems in the area include maize-millet-fallow, maize-rice-fallow, and maize-vegetables. Maize, rice, and millet are the staple crops that occupy the majority of land area under cultivation in the village. Farmers also grow some coffee, bananas, and citrus.

Data and variable specification

Data for this study were collected using a household survey conducted during October 2018. The survey questions, in form of personal interview schedule, covered a range of items, including items pertaining to technology adoption. The schedule was reviewed by a panel of expert to ascertain content validility. Three female interviewers were selected and trained to conduct personal interviews with household heads. The survey questionnaire was field tested, modifications were made based on the field test, and printed for data collection. Purposive sampling was used to select respondents who had previously constructed poly houses and grew off-season vegetables. A total of 151 farm households participated in the study using our standardized questionnaire. During the interviews, we learned that many of the households had discontinued using poly house technology and had resumed using the conventional production system.

Our collected data include four groups of information based on previous adoption literature, environmental-climatic factors, market and other institutional factors that we believed might affect the adoption, and discontinuance of improved agricultural technologies at the local context- household characteristics, farm characteristics, institutional and access-related characteristics, and technology-specific characteristics.

Household characteristics

The age of the household head is used in the analysis because it is generally believed that, with age, farmers accumulate experiences and show a greater likelihood of adopting innovations (Nkamleu & Adesina, 2000). However, it may also be true that younger farmers are more flexible, interested in trying new things, and hence more likely to adopt new technologies than older farmers (Amsalu & de Graaff, 2007). We included gender of the household head as a dummy variable to capture any gender difference (Gauchan, Panta, Gautam, & Nepali, 2012). Are males more likely to adopt improved technologies than females (Mugonolaa et al., 2013)? Education data was collected as the number of years of schooling of the household head. More educated persons may be better able to process information and maintain adoption of a technology (Uaiene et al., 2009). We included the number of household members of working age, 16 to 64 years (Abebaw & Haile, 2013; Bhaumik, Dimova, & Nugent, 2011) to explore the impact of household size and composition on adoption and continued use of improved technology.

Farm characteristics

The size of the family farm, some argue, is a key factor affecting farmers’ adoption decisions. The logic goes that farmer with larger farms can better afford to try out the new technology (Kassie, Shiferaw, & Muricho, 2011; Mariano, Villano, & Fleming, 2012). We collected information on the number of vegetables grown and income generated from vegetable sales. In addition, tropical livestock unit (TLU) is included in the model because household asset-based status plays an important role in technology adoption (Bola, Diagne, Wiredu, & Ojehomon, 2012). Livestock in the cultural context are used for animal power (e.g., bullocks) for farming operations, organic fertilizer (e.g., manure), and for biopesticides and nitrogen fertilizer (urine). Therefore, farm household TLUs are expected to have a positive influence on households’ technology adoption (Cunguara & Darnhofer, 2011).

Institutional and access-related characteristics

Farmers’ participation in training on vegetable production (a proxy for extension activity) was measured and is expected to have a positive relationship with technology adoption based on diffusion of innovation theory (Bekele & Drake, 2003). Such training contacts are asserted to expose farmers to information that is expected to promote adoption (Ransom, Paudyal, & Adhikari, 2003). Membership in cooperatives has also been shown to promote farmers’ learning from one another, growing new crops, and searching for markets for their products. Some evidence suggests the importance of network effects on individual decisions in the context of agricultural innovations and highlights the benefits of farmers sharing information through interpersonal communication channels and learning from one another (Conley & Udry, 2010; Rodriguez & Andrade, 2018). Collective marketing of vegetables (through farmer-managed cooperatives) is captured in the data (0/1) and is expected to have a positive effect on technology adoption.

Technology-specific characteristics

In the study area, rainwater harvest though gutter fitting pipe and drip irrigation are two effective practices (technologies) that increase water use efficiency and could have a positive effect on the ability to grow healthy crops in the face of climate change. Data were collected to capture whether there might be a positive relationship between farmers' adoption of other technologies and their adoption of poly house technology for off-season vegetables (Biazin et al., 2012). Cattle shed improvement and improved vegetable seeds were two other technology items that were included in the technology adoption variable.

Additional variables

To capture accurately the status of households' adoption, use, and possible discontinuation of use of the technology, a farmer/household that continued using poly house technology in the study area has "Continued adoption." A farmer/household has "Discontinued adoption" if they had one or more poly house and grew off-season vegetables in 2018 but no longer used the poly house technology at the time of data collection. Not all the adopters fully allocated their time and resources to growing poly house off-season vegetables -- they also engaged in conventional farming. Our study uses the log of income from vegetable sales as a dependent variable in the second stage of the Heckman's model (Heckman, 1979).

Modeling the adoption of technology and its effect on income

Farm households normally decide to adopt new technology to maximize the utility from the adoption of improved technology. Under this assumption, a household discontinues a technology when the expected utility from adopting is less than the expected utility from not adopting the technology (Lwiza et al., 2017). These utilities are unobservable, but they can be expressed as a function of observable elements in the latent variable model as shown in Equation 1.

$$Y_i^* = X_i'\beta_i + u_i \quad with \;\; Y_i = \begin{cases} 1\ (continued\ adoption) & if \;\; Y_i^* > 0 \\ 0\ (discontinuation) & if \;\; Y_i^* \leq 0 \end{cases} \qquad (1)$$

where Y_i^* the latent variables which represent the propensities of the farm household to discontinue poly house technology, X_i' are explanatory variables that are associated with the decision to discontinue, and β_i is parameter of interest. Technology adoption decisions are likely to be endogenous to outcome variables such as household income or crop productivity. To correct this potential endogeniety, we estimated a sample selection model in two stages (Greene, 2012; Ning & Chang, 2013). The first stage, selection (Equation 1), can be represented with the following variables:

Adoption = age+gender+family size+farm size+farm income+training+membership+ market access+satisfaction_from_sale+gutterpipe+drip_irrigation+cattle shed+improved seed.

Given that our aim is to identify the determinants of discontinuation of poly house technology for off-season vegetable production and how such discontinuation may affect farm income, we state the basic relationship of the impact of the new technology adoption on farm income as a linear function of the vector of explanatory variables X_i' and an adoption dummy, variable Y_i. With consistent estimates from the first stage, an appropriate inverse mills ratio (IMR) was calculated for each decision in the entire sample to account for potential treatment selection bias (Chang & Mishra, 2008). The IMR, along with the binary indicator of discontinuation and other explanatory variables, was then included in the outcome equation in the second stage (Ghimire & Huang, 2016; Irfan, 2011). The second stage income equation can be written as:

$$I_i = \beta_0 + X_i'\beta_1 + Y_i\beta_2 + \lambda_i\beta_3 + \mu_i \quad (2)$$

where I_i is the total income from vegetables, μ_i is a normal random distribution term, and Y_i is a dummy variable for discontinuation of poly house technology. The vector X_i' represents household and farm characteristics. Outcome (equation 2) can be shown with the following variables included in it:
Income=age+gender+education+familysize+veg_area+no._of_veg_grown+livestock+membership+satisfaction_from_sale+disadoption.

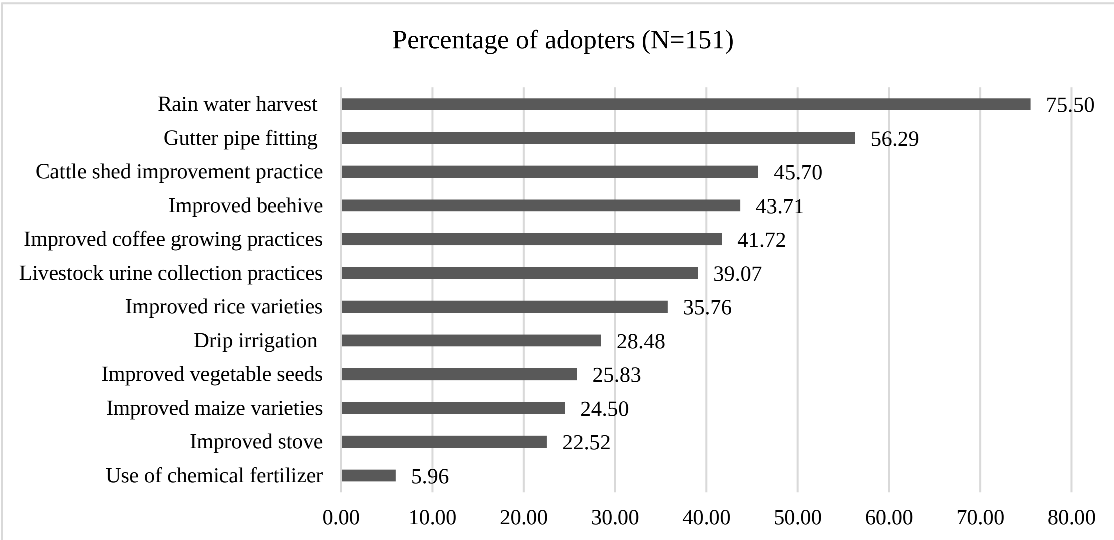
Results and Discussion

Adoption status of the additional technologies promoted by the project

Adoption status of various additional technologies and practices by their percentage of adopters is presented in Figure 2. The project promoted various technologies in addition to the poly house technology, such as rainwater harvest, plastic tunnel house, drip irrigation, cattle shed improvement, urine collection practices, and improved vegetable seeds (detailed in Figure 2) to help farmers cope with various climate change effects. These technologies are interrelated with one another and adopted in an integrated manner. The results show that the most often adopted of these additional practices was rainwater harvest, with 75.5 percent of households adopting it. Prevalence of water scarcity in the study area compels inhabitants to make provisions for acquiring water for drinking, cleaning, animal feeding, and irrigation purposes. The rainwater harvest practices collect and store water in cement and plastic tanks for later use. Similarly, drip irrigation, an efficient method to use limited water for irrigating vegetables, was promoted for use with plastic tunnel houses to grow off-season vegetables. About 28 percent of households in our study reported adopting drip irrigation.

More than half of the sample households (56.29 percent) adopted gutter fitting pipe, and 45.7 percent of sample households adopted improved livestock management practices (i.e., shed improvement). Livestock is an important component in the local farming system that provides manure as organic fertilizer and urine for use as nitrogen fertilizer and biopesticides. In addition, livestock provides animal- source food such as milk and meat for family consumption and income from sale of those animal products.

Figure 2
Descriptions of technologies promoted by the project and their adoption status



(Source: Field Survey 2018).
Note: N=Total number of households; because of multiple responses, percentages do not sum to 100.

Descriptive statistics

Table 1 presents the description of variables and the results of differences between means (two sample *t*-test and chi^2 test) of characteristics of discontinued and continued adopters of poly house technology. As observed, 46.36 percent of the sample households had discontinued use of the poly house technology for off-season vegetable production at the survey time in October 2018. There were no significant differences in the means of household and demographic characteristics (i.e., gender, education, and family size) between the discontinued and continued adoption groups. However, members of the discontinuation group appear to be older than continued adopters. Almost 80 percent of the households in both groups were headed by males, and household heads' average education was 7 to 8 years of formal schooling.

Although the average farm sizes of discontinued and continued adoption groups are approximately equal, continued adopters planted vegetable crops in significantly larger fields than the discontinued group. Area under vegetable crops, number of vegetables grown, and income from vegetable sales are significantly different between discontinued and continued adoption groups at a 1 percent level of significance. The number of livestock owned by household significantly differs (at 5 percent level of significance) between the discontinued and continued adopters, with two versus four head of livestock per household, respectively.

Table 1
Descriptive statistics of farmers based on continued adoption and discontinuation of poly house vegetable production technology.

Variables	Description	Discontinuation (n=70) (46.36%)	Continued adoption (n=81) (53.64%)	*t*-test/ chi^2 test
Age	Age of household head in years	53.09	49.10	1.78
Gender	=1 if household head is male	78.57	81.48	0.19
Education	Years of formal education of the head	7.10	7.88	-1.03
Active family labor	# of economically active family members (16-64 years)	3.01	2.86	0.51
Farm size	Total cultivated area in current year (ha)	0.59	0.69	-1.21
Vegetable area	Area under vegetable cultivation (sq. ft.)	365.63	3773.20	-5.59**
No. of vegetables	Number of vegetables grown	0.71	2.02	-6.43**
Farm income	Total income from vegetable sales per household per season (Nepali rupees)	795.71	18498.28	-4.68**
TLU[1]	Tropical livestock unit (# of livestock raised)	2.02	3.99	-2.06*
Training	=1 if received training for vegetable production	22.86	69.14	32.24**
Membership	=1 if member in farmer cooperatives	82.86	91.36	2.47
Market access	=1 if selling produce through cooperatives	34.29	62.96	12.35**
Satisfaction	=1 if satisfied from the selling through farmer-managed collection center	67.14	66.67	0.001
Gutter pipe fitting	=1 if HH uses gutter pipe to harvest rainwater	42.46	67.90	-3.17**
Drip irrigation	=1 if HH adopts drip irrigation	2.86	50.62	42.05**
Participate in CSIP	=1 if HH adopts cattle shed improvement practices (CSIP)	31.43	58.02	10.70**
Improved vegetable seeds	=1 if HH grow improved vegetables seeds	5.71	51.85	-7.04**

Note: HH= Household; n=number of respondent households; percentages are reported in the case of dummy variables. ** Significant at 1 percent, * significant at 5 percent confidence level.

Institutional variables such as training and access to market were significantly higher among continued adopters than among those who discontinued using poly house technology. Although not significantly different, membership in a cooperative by continued adopters was higher than that of the discontinuation group (93 percent vs. 83 percent). Technology- specific variables such as adoption of gutter fitting pipe, drip irrigation, cattle shed improvement practices, and improved vegetable seeds were found to be significantly different between the two categories of adoption, with higher percentages for those in the continued adoption group.

[1] Weighted measure of livestock was calculated using Tropical Livestock Unit (TLU) scores. The TLU is a metric developed by the Food and Agriculture Organization (FAO), which allows for the combination of multiple species of livestock into a weighted measure representing total body weight and potential market value. A single animal weighing 250 kg represents a single TLU (Njuki et al., 2011), providing weighting factors of 0.7 for cattle/buffalo, 0.1 for sheep/goats, 0.20 for pigs and 0.01 for chickens (Ducrotoy et al., 2017; Mosites et al., 2015).

Discontinuation of off-season vegetable production technology

Table 2 presents the results on factors of discontinuation of poly house technology for off-season vegetable production in rural settings of a developing country. The statistical values such as LR chi-square statistics, probability of chi-square, pseudo R-square, and percent correctly predicted the probability reported in Table 2 and show the goodness of fit to our data and the statistical model.

Table 2

Parameter estimates for probability of discontinuation of poly house technology.

Variables	Coefficients	z-Values	Average marginal effects
Age	-0.005 (0.016)	-0.32	-0.001
Gender	-0.661 (0.484)	-1.39	-0.091
Education	0.016 (0.044)	0.37	0.002
Active family labor	0.321 (0.121)	2.93	0.044**
Farm size	0.303 (0.705)	0.43	0.042
Farm income	-0.017 (0.004)	-4.27	-0.002**
Training	-0.792 (0.379)	-2.23	-0.109*
Membership	-0.365 (0.554)	-0.66	-0.050
Market access	-1.041 (0.490)	-2.23	-0.143*
Satisfaction	0.849 (0.526)	1.66	0.117
Gutter fitting pipe	-1.086 (0.407)	-2.94	-0.149**
Drip irrigation	-2.064 (0.654)	-3.69	-0.284**
Participation in CSIP	0.207 (0.424)	0.49	0.028
Improved vegetable seeds	-1.636 (0.544)	-3.33	-0.225**
Statistical values of the estimated model			
Log-likelihood	-36.824197		
LR $\chi 2$ (14)	129.31		
Prob > $\chi 2$	0.0000		
Pseudo R2	0.6371		
Percent correctly predicted	89.12 %		

Notes: Number of observations: 147; numbers in parentheses are standard errors of the coefficients.
** Significant at 1 percent confidence level; * significant at 5 percent confidence level.

Respondents' demographic variables -- age, gender, and education -- did not show a significant effect on the discontinuation of poly house technology for off-season vegetable production. However, the availability of family labor showed a statistically significant effect (at 1 percent level of significance) on the discontinuation of use of poly house technology. Contrary to our expectation, this result suggests that, with every additional family laborer in the family, the probability of abandoning poly house technology increased by 4.4 percent. This suggests that farm households divert use of their available labor force toward nonagricultural endeavors to a significant degree instead of using them in their low- return farming business. In the rural Nepali context, young and active family members tend to engage in nonfarm jobs, migrate to urban areas for better job opportunities, and often take overseas employment. This fits with studies that show risk-averse farmers diverting their resources toward nonfarm activities that offer higher returns and lower risk than their farming activities (Chang & Mishra, 2008). Total income from vegetable sales appeared to be significant and negatively associated with the discontinuation of poly house technology. This suggests that the income from vegetable sales motivated some farmers to continue using poly house technology and maximize the revenue from it.

Training is an important extension tool to support adoption of new agricultural technologies by the target farming communities. The negative and significant result of the training variable indicates that low levels of participation in vegetable production training by farm households are associated with a greater likelihood (11 percent) that farmers will discontinue poly house technology. During training, well-informed agricultural extension agents give relevant information and discuss how to, where, and when to adopt new technology and thereby influence farmers' decisions about adoption. Our result is in line with previous studies underlying the importance of extension and training on farmers' adoption of improved farm technologies (Arslan et al., 2014; Asfaw et al., 2012; Feleke & Zegeye, 2006; Suvedi, Ghimire, & Kaplowitz, 2017).

The results show that access to markets has a negative and significant effect on discontinuation of poly house technology (at a 5 percent level of significance). This implies that the greater the involvement of farmers in marketing activities of their products through cooperatives and farmer-managed collection centers, the less likely (by 14.3 percent) they will be to discontinue use of poly house technology for off-season vegetable production. This result is consistent with previous studies (Bola et al., 2012; Mignouna, Manyong, & Rusike, 2011) and supports the hypothesis that farmers' involvement in various cooperative activities enables them to analyze the risks and take advantage of innovations.

Other additional technology adoption factors were found to be significant in farmer discontinuation of poly house technology. Rainwater harvest through gutter pipe fitting as well as drip irrigation showed negative and significant effects on the discontinuation of poly house technology. Rainwater collected through gutter pipe is typically used by farm households mainly for washing and cleaning, and for irrigating vegetables. The probability of discontinuing poly house technology goes down 15 percent for households who adopt rainwater collection through gutter fitting pipes. Similarly, farmers who received support for adopting drip irrigation to water their vegetable crops during dry times were less likely to discontinue poly house technology for off-season vegetable production by 28 percent (statistically significant at 1 percent level). Similarly, it was found that farm households that planted improved vegetable seed varieties were 23 percent less likely to discontinue using poly house technology for off-season vegetable production.

Effects on income generation

Table 3 presents the effect of discontinuation of poly house technology and other factors on income generation for participating farm households. Generally, as mentioned earlier, respondents' demographic variables do not affect income generation from off-season vegetable cultivation. However, total area of vegetable cultivation had positive and significant effects on income generation, with an almost 3 percent increase in income for each additional unit of vegetable area. This result is consistent with previous studies (Mendola, 2007; Noltze, Schwarze, & Qaim, 2013; Takahashi & Barrett, 2014) and may explain the possible correlation between the ownership of cultivated land and farm income.

The number of vegetable types grown by farm households was found to be positively related to household income from vegetable production (Table 3). The positive and significant coefficient of this variable suggests that for each additional type of vegetable grown by a farm household, there was an increase in farmers' income of 30 percent. This indicates that the farmers who grew higher numbers of vegetable types under poly houses were able to secure more benefits than those who grew fewer types of vegetables. Our results also show that farmers owning livestock earned less income from vegetable sales, probably because they spent more of their time in managing livestock and animal husbandry, and hence did not focus on off-season vegetable production.

The discontinuation of poly house technology itself was found to have a negative and significant effect on income generation of farm households. Discontinuation of poly house technology use resulted in a 74 percent reduction in income from vegetable sales. The negative and significant coefficient of IMR indicates the presence of selection bias between two groups of respondents: continued adopters and discontinued technology users.

Table 3

Effects of poly house technology on income generation.

Variables	Coefficients	*t*-Values
Age	-0.011 (0.009)	-1.23
Gender	-0.328 (0.272)	-1.2
Education	0.005 (0.027)	0.18
Active family members	0.019 (0.063)	0.29
Total area allocated for vegetable cultivation	0.028 (0.005)*	5.28
Number of vegetables grown	0.301 (0.102)*	2.95
TLU (# of livestock raised by HH)	-0.223 (0.061)*	-3.69
Cooperative membership	0.176 (0.241)	0.73
Satisfaction with selling through farmers managed collection center	0.184 (0.237)	0.78
Discontinuation of poly house technology adoption	-0.746 (0.273)*	-2.73
Inverse mills ratio (IMR)	0.306 (0.065)*	4.75
Statistical values of the estimated model		
F (11, 129)	33.29	
Prob > F	0.0000	
Adj R-squared	0.7173	

Notes: Number of observations: 141; numbers in parentheses are standard errors.
*Significant at 1 percent confidence level.

Conclusion

This study examined whether poly house technology might be an approach to increase farm production and income of subsistence farmers in rural Nepal. These poly house structures allow farmers to grow vegetables during the off-season despite bad weather (i.e., heavy rainfall, hailstorms, or drought). We analyzed those factors associated with discontinuation of poly house technology for off-season vegetable production and income generation among farming households in the rural areas of Nepal to address the growing problem of discontinuation of technology use after a certain period of adoption.

The results reveal that farm households with higher numbers of family members/labor were more likely to discontinue poly house technology. This suggests that once some base level of farm productivity is achieved, additional family labor tends to engage in nonfarm activities, migrate to urban areas seeking better job opportunities, or seek overseas employment. That is, farm households divert their resources toward nonfarm activities that offer higher returns and lower risk than farming activities. The results also show that the level of income from vegetable sales motivates some farmers to continue poly house technology. We found that not receiving training on vegetable production was associated with farmers discontinuing use of poly house technology and vice versa. Similarly, those farmers who were least involved in farmer-managed cooperatives had increased likelihood of discontinuing use of poly house technology. Greater participation of farm households in rainwater harvest and drip irrigation practices reduced the probability of discontinuation of poly house technology. And farmers who did not have access to improved vegetable seeds and extension services such as training were more likely to discontinue use of poly house technology for off-season vegetable production.

We found that a farm household's increased area for vegetable cultivation and number of vegetable types grown had positive impacts on income generation and the continued adoption of technology. This indicates that the farmers who expand the area and the number of vegetables grown were able to secure more benefit from vegetables. As expected, the discontinuation of poly house technology had a negative impact on income generation of farm households in the rural context.

The findings of the study offer insights for the sustainability of agricultural technology adoption and household income. In particular, it seems clear that continued extension and other technological support services such as training, input supply, and market support should be part of sustainable promotion of improved agricultural technologies. Technological support services to the farmers should be provided by the government in alignment with appropriate policies and program guidelines. Additionally, technological competence of extension professionals should be strengthened through continual training and capacity development programs.

Acknowledgments

The authors thank the participating farmers and their communities as well as the Indragufa Community Development Foundation for their assistance in project implementation and field data collection. Similarly, we gratefully acknowledge and thank Michigan State University for its generous support of this project.

Declaration of interest statement

No potential conflict of interest was reported by the authors.

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