Available online at www.sciencedirect.com
SCIENCE DIRECT®

ELSEVIER

Agricultural Economics 29 (2003) 159–168

AGRICULTURAL ECONOMICS

www.elsevier.com/locate/agecon

Factors determining intercropping by rubber smallholders in Sri Lanka: a logit analysis

P.H.M.U. Herath*, Hiroyuki Takeya[1]

Socioeconomic Science of Food Production, Graduate School of Bio Agricultural Sciences, Nagoya University, Chikusa-Ku, 464-01 Nagoya, Japan

Received 14 August 2001; received in revised form 3 June 2002; accepted 26 August 2002

Abstract

Variables related to farmers' awareness and attitudes towards intercropping of immature rubber (*Hevea brasiliensis*) stands, extension contacts, education level, and experience with farming other crops are positively associated with the probability of adoption. Higher levels of off-farm income are associated with reduced intercropping in immature rubber stands. Farmers who are sole owners of the land and engaged in full or part-time rubber farming show lower adoption rates than other land ownership groups. Social participation, family size, experience with farming rubber, immature and mature rubber stands size, and the nature of the land (flat/sloped) do not significantly influence adoption. These conclusions were obtained from a logit model estimated by employing the results of a survey of 588 smallholder rubber farmers from five major rubber-growing regions in Sri Lanka.

JEL classification: C25; Q16; O12

Keywords: Adoption; Logit model; Intercropping; Rubber; Sri Lanka

1. Introduction

Rubber (*Hevea brasiliensis*) is produced on around 8% (161,500 ha) of the agricultural land in Sri Lanka (Agricultural Crops and Livestock Survey, 1992–1993). About 33% of this area is grown in the smallholder sector (Anonymous, 1993). 70% of total rubber growers are smallholders (land size of less than 4 ha). According to the agricultural crops and livestock survey in 1992–1993, around 60% of the smallholder farmers own less than 1 ha. Hence, average smallholder rubber land size is very small compared to the estate sector where around 67% of land area is owned by 30% of the total rubber cultivators.

The small size of rubber holdings has aggravated the problems associated with the long immature period of rubber. After replanting or new planting, farmers face a gap in income of 5–7 years during which the immature rubber cannot be tapped for latex. The estate sector has solved this problem by adopting an annual replanting cycle, with the aim of maintaining less than 20% of the rubber stands in the immature phase. Because of the limited land available, this option is not very effective for smallholders, as even if they replant only part of their land, the income loss is quite considerable. After identifying this vital problem

* Corresponding author. Tel.: +81-52-789-4045; fax: +81-52-789-4042.
E-mail addresses: herathupul@hotmail.com (P.H.M.U. Herath), sdtakakeya@agr.nagoya-u.ac.jp (H. Takeya).
[1] Tel.: +81-52-789-4041; fax: +81-52-789-4042.

0169-5150/$ – see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/S0169-5150(03)00045-8

in the sector, in 1979 the Rubber Research Institute of Sri Lanka introduced the intercropping of immature rubber with crops such as banana, pineapple, passion fruit and coffee (Chandrasekera, 1979). The list of recommended crops grew over time to include cocoa, cinnamon, and tea. However, despite research interest for more than 20 years, survey studies show the intercropping among rubber holders is not very attractive. According to Jayasena and Herath (1986), only about 30–40% of smallholders with immature rubber stands were intercropping. Approximately 30% of smallholders, who did not intercrop, believed that the companion crop would exert a negative effect on growth of the young rubber trees. A more recent study by Stirling et al. (1998) shows that around 40% of the smallholders are engaged in intercropping. This study also identified the problems of theft and lack of knowledge as major reasons for not intercropping. However, none of these studies have attempted to quantify the factors influencing adoption of this farming system.

According to a comprehensive review on the adoption of agricultural innovations by Feder and Umali (1993), the green revolution from the 1960s to the early 1980s motivated numerous studies to explain the determinants of adoption during the early stages of the diffusion process. Thereafter, studies concentrated on agricultural innovations that have reached maturity. Mostly these included the adoption of high yielding varieties in particular and a package of interrelated technologies. In this regard, relatively few empirical studies have examined the adoption of cropping systems. Neill and Lee (1999) attempt to explain the adoption of cover crops in maize cultivation. A case study in northwest India discusses the factors influencing an agro-forestry farming system in which sugarcane, wheat, sorghum and turmeric are grown with a poplar forestry crop (Sharma and Kumar, 2000). Nganje et al. (2001) analyse the factors involved in the adoption of slash and burn agriculture versus multi- and mono-cropping systems by farmers in Cameroon. However, to our knowledge specific research on the adoption of a farming system in which perennial cash crops such as rubber are intercropped with short-term crops is not performed in the literature. Thus, the present study attempts to quantify the factors influencing this vital aspect in the smallholder rubber sector in Sri Lanka.

2. Study area and data

A sample survey was conducted between October 1997 and March 1998, covering the five major rubber-growing regions (Kalutara, Kegalle, Colombo, Gampaha and Ratnapura) where over 80% of Sir Lanka's rubber is cultivated. Intercropping is generally restricted to the immature phase of rubber. Therefore, the survey was restricted to smallholders with rubber plantations less than 6 years old. A stratified random sampling methodology was employed in selecting farmers. Following the sampling procedure of Cochran (1963), the number of farmers for each region was determined considering the cost factor and the total budget available. The number of farmers for different land sizes within a range was determined by the proportional allocation method.

Many technology adoption studies distinguish between the rate of adoption (e.g. the proportion of farmers adopting intercropping) and the intensity of adoption (defined based on the level of use of a technology, e.g. the proportion of the farmer's immature rubber land planted to other crops). In the smallholder rubber sector in Sri Lanka, farmers tend to intercrop their entire immature rubber stands when they adopt this new rubber farming system. This may be due to the very small land size and the familiarity of farmers with this farming system (around 20 years ago this farming system was introduced). Thus, the level of intercropping immature rubber is either the entire stand (100%) or not at all (0%). Hence, in this study, data have been gathered on the rate of adoption alone. Also, various other socio-economic factors and attitudes towards intercropping were recorded.

The total budget allocated to the survey was 100,000 Sri Lankan rupees (the exchange rate at the time of this study was US $1 = Rs. 70), which was divided equally between the five regions. The estimated unit cost for surveying a smallholder in the Kalutara region, which is nearest to the operational area (the Rubber Research Institute of Sri Lanka), was Rs. 125, whilst that of all other regions was Rs. 150. Consequently, the number of smallholders to be interviewed in Kegalle, Colombo, Gampaha and Ratnapura was 167, and 200 in Kalutara. However, while it was possible to interview all selected smallholders in the Kalutara region, problems with transport and the availability of farmers within the 6-month survey period resulted in fewer case studies in Colombo (88), Gampaha (70), Ratnapura (90), and Kegalle (140). Accordingly, the total sample size is 588 farmers. Questionnaire-based structured interviews were conducted for each smallholder, and a visual assessment was used to gather site information.

3. Modelling technology adoption

The decision to intercrop or not to intercrop immature rubber stands can be explained as a discrete variable. Hence, regarding choice of models, the most important aspect of the decision framework is the dichotomous dependent variable. Classical linear methods are inappropriate for dichotomous choices since they can lead to heteroscedasticity variances. This problem is typically remedied by using maximum likelihood estimation (MLE), although heteroscedasticity in MLE is also a potentially serious problem leading to inconsistent estimators (Greene, 2000). According to Wooldridge (2000), when heteroscedasticity is observed, such models require more general estimation. However, such models are not often used in practice, since logit and probit models with flexible functional forms in the independent variables tend to work well.

In making decisions about the adoption of a given technology, a farmer evaluates the new technology in terms of its incremental benefit. If the monetary benefit of using the technology is higher than the old technology, the preference or utility (U) for that technology (assuming monotonic relationship between utility and benefits) will be higher than the old technology. According to Greene (2000), random utility models address these types of individual choice situations. A common specification is the linear random utility model.

Suppose an individual farmer's utility after adopting the new technology (intercropping immature rubber stands) for a given vector of economic, social, and physical factors (Z) is denoted by U_{IC} (Z), and the utility without adoption by U_{NIC} (Z). Then, the preference for adopting or not adopting can be defined as a linear relationship

$$U_{\text{IC}}(Z) = Z\beta_{\text{IC}} + \varepsilon_{\text{IC}}$$

$$Y_{\text{NIC}}(Z) = Z\beta_{\text{NIC}} + \varepsilon_{\text{NIC}}$$

In this case, β_{IC}, β_{NIC} and ε_{IC}, ε_{NIC} are response coefficients and random disturbances associated with the adoption and non-adoption of intercropping, respectively. Assuming that the qualitative variable Y indexes the adoption decision, then it will take a value of one if the farmer adopts the technology and zero otherwise. The probability that a given farmer will intercrop his immature rubber land can be expressed as a function of Z as follows

$$\begin{aligned} P(Y = 1) &= P(U_{\text{IC}} > U_{\text{NIC}}) \\ &= P(Z\beta_{\text{IC}} + \varepsilon_{\text{IC}} > Z\beta_{\text{NIC}} + \varepsilon_{\text{NIC}}) \\ &= P\{Z(\beta_{\text{IC}} - \beta_{\text{NIC}}) > \varepsilon_{\text{NIC}} - \varepsilon_{\text{IC}}\} \\ &= P(Z\beta > \xi) = F(Z\beta) \end{aligned}$$

where P is a probability function, $\xi = \varepsilon_{\text{NIC}} - \varepsilon_{\text{IC}}$ is a random disturbance term, $\beta = (\beta_{\text{IC}} - \beta_{\text{NIC}})$ a vector of unknown parameters which can be interpreted as the net influence of the vector of independent variables on adoption of intercropping, and $F(Z\beta)$ is the cumulative distribution function for ξ evaluated at $Z\beta$.

The exact distribution of F depends on the distribution of the random term ξ. The probit model arises from assuming a normal distribution, and a logit model arises from assuming a logistic distribution. Under the standard assumptions about the error term, there is no a priori reason to prefer probit to logit estimation (Greene, 2000). Accordingly, in most applications, it seems not to make much difference. Considering all these aspects, a logit model was developed to study the factors affecting intercropping in the smallholder rubber sector in Sri Lanka.

According to the logit model, the probability of an individual rubber farmer adopting intercropping (IC) in his immature rubber stands, given economic, social, and physical characteristics (Z) is, $P(\text{IC}|Z)$ and can be specified as

$$P(\text{IC}|Z) = \frac{\exp(Z\beta + \xi)}{1 + \exp(Z\beta + \xi)}$$

where $\alpha < Z\beta < \alpha$.

The probability of not adopting intercropping, $P(\text{NIC}|Z)$, is therefore,

$$\begin{aligned} P(\text{NIC}|Z) &= 1 - P(\text{IC}|Z) = 1 - \left[\frac{\exp(Z\beta + \xi)}{1 + \exp(Z\beta + \xi)}\right] \\ &= \frac{1}{1 + \exp(Z\beta + \xi)} \end{aligned}$$

The relative odds of adopting versus not adopting intercropping in immature rubber stands are given by

$$\frac{P(\mathrm{IC}|Z)}{P(\mathrm{NIC}|Z)} = \frac{[\exp(Z\beta+\xi)][1+\exp(Z\beta+\xi)]}{[1+\exp(Z\beta+\xi)]} = \exp(Z\beta+\xi)$$

By taking the logarithms of both sides,

$$\ln\left[\frac{P(\mathrm{IC}|Z)}{P(\mathrm{NIC}|Z)}\right] = Z\beta+\xi \qquad (1)$$

The maximum likelihood approach can be used to estimate the above Eq. (1).

4. Empirical model

The farm and farmer specific factors included in the model are based on innovation diffusion theory and earlier studies. Detailed reviews of these factors are given by Feder and Umali (1993). The selected variables for this study included the farmer's experience with rubber-growing (FEXR), experience with the other crops recommended for intercropping (FEXOCRO), immature rubber land size (IMRLS—only land suitable for intercropping is considered), mature rubber land size (MARA—as a source of income), whether the rubber land is sloped or flat (TERR), availability of off-farm income (OFI), contacts with extension agents (NEVM), social participation (SOPC), decision maker's education level (DMEDUL), farm family size (FAMSIZE), nature of land ownership (OWNSHIP), distance between a farmer's residence and the rubber land (DIS—as a measure of security), and a farmer's attitude towards intercropping with immature rubber (ATT). A complete description of the variables specified and the types of measures that have been employed is given in Table 1.

Implementation of the model must account for different ecological conditions (e.g. soil quality and rainfall patterns) among the five different regions selected for the study. Therefore, regional dummy variables for four different regions are also incorporated into the preliminary estimation of the model. The Ratnapura region, where the lowest share of intercropping was recorded serves as the reference. Also, the Wald test (the equivalent of the Chow test in OLS estimates) was conducted to verify the equality of the coefficients across these regions.

In many studies, farm size has been shown to positively affect adoption decisions. A study by Negate and Parrikh (1999) indicates a positive impact of farm size on the adoption of improved wheat varieties. Also, a study by Doss and Morris (2001) revealed that the adoption of improved maize varieties is positively associated with the amount of land owned. Therefore, it is hypothesised that the sign on this variable, the immature rubber land size in the empirical model, is positive.

Mature rubber land size has been considered as a separate explanatory variable in this study as it could act as a source of income for intercropping activities in immature rubber stands. In this regard, it might have a positive impact on intercropping. However, considering problems related to mature rubber such as scarcity of tapping labour and high price fluctuations, this variable might also reduce the immature rubber activities of the farmer. Therefore, the sign of the variable mature rubber area cannot be decided a priori.

In this study, the availability of human capital is indicated by education level and years of farming experience, both in rubber and other crops. Many studies of the adoption and diffusion of innovations investigate the effect of human capital investments on adoption behaviour. Some of the rural social literature (Shoemaker, 1971) has suggested that adoption depends on the decision makers' education and information level. Mittal and Kumar (2000) find a positive impact of rural literacy on the adoption of high yielding varieties of rice and wheat in India. Also, Doss and Morris (2001) indicate that education is a significant determinant of the adoption of modern varieties of maize in Ghana. Thus, the impact of the main decision maker's education level on the intercropping of immature rubber is assumed to be positive.

The impact of experience on adoption is ambiguous a priori. As experience increases (and therefore age increases), the time horizon in which to reap the benefits of adoption decreases, while risk aversion and learning by doing with current management practices may increase. On the other hand, greater experience could also lead to better knowledge of spatial variability in the field and more accurate assessment of the benefits of adoption. Shiyami et al. (2000) find that the more experience with growing chickpea, the higher the adoption of new varieties. Considering the above factors, the impact of farming

Table 1
Description of the variables specified in the model

Variable acronym	Variable meaning	Type of measure	Expected sign
Dependent variable			
ICONOT	Whether a rubber farmer has intercropped his immature rubber land or not	Dummy (intercropped = 1, not intercropped = 0)	
Independent variables			
NEVM	Average number of visits made by an extension officer to farmer per month	Days per month	+
OFI	Whether the farmer has any off-farm income or not	Dummy (with off-farm income = 1, without off-farm income = 0)	?
IMRLS	Size of the immature rubber land	In hectares	+
MARA	Size of the mature rubber land	In hectares	?
TERR	Nature of the land	Dummy (flat land = 1; sloped = 0)	+
DIS	Average distance from rubber land to farmer's residence	In kilometers	−
SOPC	Whether a farmer is a member of any farm organization or not	Dummy (member = 1, non-member = 0)	+
FEXR	Farmer's actual involvement of growing rubber as a decision maker	Number of years	+
DMEDUL	Education level of the main decision maker of the rubber cultivation	Number of years of formal education	+
FEOCRO	Farming experience of other crops as an actual decision maker	Number of years	+
OWNSHI	Nature of land ownership and farmers Involvement in real farming	Dummy (single ownerships with full or part-time farming = 1: other type of ownerships with full or part-time farming = 0)	?
ATT	Attitudes of farmer towards intercropping	Dummy variable (farmer who feels that intercropping will have positive effects or there will not be any bad effects on cropping system = 1: feel there will be bad Impacts on rubber or not sure of the impact = 0)	+
FAMSIZE	Farm family size	Total number of members	+
D_{Colombo}	Farmers from Colombo region	Dummy (Colombo = 1: rest = 0)	
D_{Kegalle}	Farmers from Kegalle region	Dummy (Kegalle = 1: rest = 0)	
D_{Gampaha}	Farmers from Gampaha region	Dummy (Gampaha = 1: rest = 0)	
D_{Kalutara}	Farmers from Kalutara region	Dummy (Kalutara = 1: rest = 0)	

experience in rubber and the other crops is expected to be positive.

Contacts with extension agents and social participation are expected to have a positive effect on adoption based upon innovation diffusion theory. Such contacts, by exposing farmers to information, can be expected to stimulate adoption. Higher visitation rates by extension personnel reduces not only the likelihood of farmers choosing slash and burn agriculture, but also promotes movement into multi- and mono-cropping in Cameroon (Nganje et al., 2001). Therefore, the impact of variable extension contacts is expected to be positive in this model. The impact of the variable social participation is hypothesised to be positive based on a study by Sharma and Kumar (2000). Accordingly, socio-economic status has a positive impact on the adoption of agro-forestry innovations in the Haryana State of India. In this study, an index has been developed to measure the socio-economic status. Social participation is one of the major components of that index.

The role of off-farm income on the decision to adopt is not very clear. It is observed that farmers with off-farm income are less risk-averse than farmers without sources of off-farm income. Off-farm activities will reduce the management resources available for the adoption process, but access to outside information may have positive effects. Given that most of rubber small holders depend on family labour for their farming, off-farm activities might have a negative impact on intercropping. According to Dimara and Skurass (1998), an increase in the off-farm annual work units decreases the probability of adopting flue-cured tobacco varieties in Greece, but this relationship is not statically significant. Considering all these factors, it is difficult to predict the sign of this independent variable in the model.

There is mixed evidence about the impact of land ownership and full time operation of a farm on incentives to adopt a new technology. On the one hand, land ownership is hypothesised to increase incentives by lengthening planning horizons and the share of benefits accruing to the adopters while lowering the rates of time preference. In this regard, full time operators are expected to be more likely to adopt a time and management intensive technology (Cooper and Keim, 1996). On the other hand, the potential for such technologies to conserve input use, reduce cost, and provide economic benefits even in the short run could create incentives for adoption even among renters and part-time operators as observed by Lee and Stewart (1983). Accordingly, the sign of the variable, land ownership, has not been assigned.

The influence of household size on the decision to adopt is not clear. If an agricultural technology increases the seasonal demand for labour, it would be less attractive to a household with limited family labour. Besides labour demand, the other factor related to family size, mentioned as a consideration in adoption decisions, is the consumption pressure the household faces, i.e. the responsibility of the head of the household to ensure that the minimum food requirement of the family is met. If the technology is a staple crop, the direction of effect on adoption in subsistence agriculture is ambiguous. While the higher consumption pressure a larger family faces may motivate adoption, the risk involved with a new and untried variety may inhibit the head of a larger household from adopting it. Considering the above factors, the impact of family size on intercropping is assumed to be positive, as there is no increased seasonal demand of labour in the recommended major crops such as banana and pineapple; however, this could be an ideal option for dealing with consumption pressure.

Attitudes towards intercropping have been considered in the model as a psychological factor that would affect this new system of rubber farming. In the literature, attitudes have been defined as the degree of a farmer's positive or negative feelings towards an innovation. It is assumed that attitudes largely depend on household values, beliefs and circumstances (Sharma and Kumar, 2000). In this study, attitude towards intercropping immature rubber stands was evaluated by accessing the farmer's opinion directly through interviews. Farmers who have stated either that they believe that this cropping system would enhance the growth of rubber, or those who believe that there will not be any negative effects on rubber are considered to have positive feelings towards this cropping system. In contrast, farmers who believe that there would be some negative effects on rubber or those who express uncertainty regarding the consequences of this farming system are categorised as farmers with negative feelings towards the system. In this model, attitudes have been included as a dummy variable. Farmers with negative feelings towards the intercropping are considered as the base category. Farmers with positive feelings towards this farming system, hypothesised to have a positive impact on intercropping, are compared to the base category.

The distance between a farmer's residence and the rubber land is employed as a measure of security and expected to have a negative sign. This is based on previous survey studies in which theft was identified as one of the major problems in intercropping. Finally, nature of the rubber land is included in the model as a dummy variable. Farmers with sloped lands are considered as the base category. Thus, level land is hypothesised to have a positive influence on intercropping compared to this base category.

5. Empirical results

5.1. Characteristics of the sample farmers

A summary of the mean characteristics of the whole study population, adopters and non-adopters, is presented in Table 2. There is a significant difference in the mean values of the number of extension visits, off-farm income, nature of the land, farming experience of other crops (FEOCRO) and the

Table 2
Mean values of the independent variables

Variable	All farmers'	Adopters	Non-adopters	t-test for equal means	P-value
ICONOT	0.3				
NEVM	6.5	10.3	4.9	−33.1	0.0001
OFI	0.63	0.16	0.84	20.9	0.0001
IMRLS	1.91	1.95	1.82	0.64	0.51
MARA	1.7	1.52	1.72	0.83	0.40
TERR	0.34	0.43	0.25	−4.2	0.0001
DIS	2.3	1.8	2.5	1.05	0.29
SOPC	0.24	0.28	0.22	−1.41	0.15
FEXR	16.3	16.7	16.1	−0.45	0.64
DMEDUL	8.25	7.9	8.6	−1.98	0.47
FEXOCRO	2.6	6.2	1.0	−8.72	0.001
OWNSHIP	0.89	0.84	0.91	1.59	0.11
ATT	0.68	0.92	0.57	−10.69	0.001
FAMSIZE	5.39	5.48	5.35	−1.25	0.21

Source: own calculations.

attitude towards intercropping between the adopter and non-adopter populations. Extension agents visited the adopters frequently, and most of them (92%) have positive feelings towards intercropping compared to the non-adopters (57%). Most of the non-adopters have access to off-farm income (84%) compared to the adopters (16%). Adopters' farming experience with other crops (6.2 years) is higher than that of the non-adopters (1 year). About half the population of adopters (43%) has level land whereas only about a quarter of the population (27%) of non-adopters has level land. There is no significant difference between the population means of the adopters and non-adopters for the variables immature rubber land size, distance between residence and land, social participation, land ownership, decision maker's education level, farming experience with rubber, mature rubber area size, and family size.

5.2. Estimated logit model

This section presents the results of estimating the model with pooled data across all five regions. The empirical logit model (1) was estimated using SHAZAM econometric software, version 9 (Whistler et al., 2001). The estimated coefficients and the corresponding t-ratios are given in Table 3. The estimation of the parameters is obtained by the Newton–Raphson iterative procedure. To avoid the possibility of false pooling of data, the Wald test (the equivalent of the Chow test in OLS estimates) was conducted to verify the equality of coefficients across the different regions. This test fails to reject the null hypothesis that these coefficients are equal (Table 3). The estimates of the dummy variables included in the model to represent different regions also show that there are no significant differences in adoption among the regions (Table 3). The likelihood-ratio test of the hypothesis that the coefficients of all the explanatory variables are zero, has a Chi-squared value of 533.2 with 15 d.f., suggesting that the estimated model is highly significant. The goodness of fit measure, Estrella R^2 (0.8) indicates a very satisfactory fit. Estrella (1998) has suggested that this measure may be interpreted intuitively in a similar way to R^2 in the linear regression context. The model correctly predicts 95% (554 out of 581) of the responses. Correct predictions are slightly higher for the non-adopters, 95% (388 out of 407), than for the adopters, 92% (166 out of 181).

In addition to the estimated coefficients, the marginal impacts of changes in the independent variables on the probability of intercropping are also presented. The interpretations of these marginal impacts are dependent on the unit of measurement of the independent variables. For example, the marginal impacts show that for a 1% increase in extension visits per month, the probability of intercropping immature rubber stands increases by 0.05%. This implies a highly elastic response of 6.89 when evaluated at the mean values of the independent variables.

Table 3
Parameter estimates of the logit model

Variable	Coefficient estimate	Standard error	Asymptotic t-ratio	Elasticity at means	Slope[a]
NEVM	1.10	0.13	8.15***	6.89	0.046
ATT	2.31	0.55	4.16***	1.50	0.097
OFI	−2.44	0.45	−5.31***	−1.48	−0.103
IMRLS	−0.071	0.11	−0.60	−0.13	−0.003
MARA	−0.062	0.091	−0.68	−0.099	−0.0026
TERR	0.48	0.46	1.05	0.14	0.021
DIS	0.007	0.04	0.17	0.15	0.0003
SOPC	0.29	0.54	0.53	0.067	−0.012
FEXR	0.002	0.017	0.14	0.03	0.0001
DMEDUL	0.10	0.06	1.59*	0.78	0.0043
FEOCRO	0.17	0.039	4.44***	0.441	0.0074
OWNSHI	−0.93	0.65	−1.62***	−0.79	−0.039
FAMSIZE	0.004	0.20	0.023	0.024	0.0002
D_{Colombo}	−0.42	0.86	−0.48		
D_{Kegalle}	−0.31	0.82	0.37		
D_{Gampaha}	1.31	0.99	1.32		
D_{Kalutara}	−0.39	0.76	−0.51		

Log likelihood function: −74.34; log likelihood (0): −363; likelihood ratio: 577.3; Estrella R^2: 0.85 (Estrella, 1998); R^2 (adj.): 0.79; percentage of correct predictions: 0.95; Wald Chi-square statistic: 2.5, P-value: 0.47. *Source*: own calculations.

[a] Marginal effects evaluated at the sample means.

* $P < 0.1$ (one-tailed).

*** $P < 0.01$.

According to Greene (2000), the marginal effect of a binary independent variable can be estimated by simply taking the derivative with respect to the binary variable as if it were a continuous variable. Furthermore, the computation of the derivatives of the conditional mean function is useful when the variable in question is continuous. However, when the explanatory variable is a dummy, the marginal effects generally produce a reasonable approximation to the change in the probability that $Y = 1$, at a point such as the mean of the regressors. Following this, the estimated marginal effects of dummy explanatory variables could be defined. For an example, the estimated coefficient for the variable attitude implies that for the farm population as a whole, a 10% increase in the number of farmers with positive attitudes towards intercropping immature rubber will result in a 0.1% increase in the probability of intercropping, which represents an elastic response of 1.5. For most of the explanatory variables, except NEVM, ATT, and OFI, the intercropping of immature rubber stands was found to be inelastic with respect to changes in these variables. The most elastic response was observed for a change in extension visits, whereas the most inelastic response was observed for a change in variable FAMSIZE.

6. Empirical findings and policy design

Variables representing the farmers' awareness of the intercropping immature rubber stands, extension contacts, education level, and experience with farming other crops are shown to have significant positive impacts on the probability of adoption. In fact, extension contacts are shown to have the biggest impact with the highest estimated elasticity. Experience with farming rubber and the social participation of farmers are not significant. In this study social participation is approximated by the farmers' actual involvement in co-operative societies. During the survey, it was observed that the rubber farmers' main co-operative association is with rubber smallholders' co-operative societies. The main objective of these societies is to assist farmers with marketing rubber. However, our results suggest that a detailed study of the activities of these societies is needed in order to promote their involvement in other productive measures in the sector.

In this regard, an active involvement of extension officers in these societies may be useful. Furthermore, the results show that increasing farmers' awareness through extension and education programs could immensely improve intercropping practices in immature smallholder rubber stands.

The dummy variable representing the farmer's attitude towards intercropping immature rubber stands has a significant impact on the probability of adoption. The base category in this regard was the farmers who believe that intercropping would be harmful to the rubber crop or who are uncertain about the possible consequences of this new farming system. The empirical results indicate that about 82% of the total population and about 57% of the intercroppers belong to this base category, while 92% of the non-intercroppers believe that this farming practice would be harmful or are uncertain. In terms of marginal impacts, an increase of 10% in the farmers with a positive attitude towards intercropping would increase the numbered intercroppers by nearly 1%. These figures suggest how important the improvement of awareness is in order to enhance intercropping in the smallholder rubber sector in Sri Lanka.

The dummy variable representing the ownership of land shows a significant negative impact on the intercropping. This indicates that when there is single ownership and the farmer is involved full or part-time in farming, the probability of intercropping tends to be lower compared to the base category, where rubber lands have been rented or the immature rubber lands have been leased for part-time operators for farming during the immature period. According to Lee and Stewart (1983), the potential for technologies to conserve input use, reduce costs, and provide economic benefits even in the short run could create incentives for adoption even among renters and part-time operators. During this survey, it was observed that renting out rubber land during the immature period for intercropping is becoming popular among some smallholders. However, Gray (1997) concluded that most of the farmers in one of the main rubber-growing districts, Kegalle, are not aware of this land leasing system. Also, some of the farmers are hesitant to lease the land due to a lack of proper legal arrangements. Involvement by extension officers and other related government institutions could facilitate this activity.

Off-farm income is negatively associated with the probability of adoption. The impact is significant. In terms of marginal impacts, an increase of around 10% in the number of farmers with off-farm income will lead to a decline in the probability of intercropping of about 1%. This may be due to a lack of resources such as labour for farming activities due to off-farm activities. However, the farmers with off-farm income also include those who are receiving financial and other assistance under government poverty alleviation programs such as Samurdhi (prosperity movement). In fact, this survey revealed that around 70% of the farmers' main off-farm income was reported to be government assistance. Therefore, a proper co-ordination of productive farming activities with these types of poverty alleviation programs should be given due policy attention.

The distance between the rubber land and the farmer's residence (a proxy for the theft problem) lacks explanatory power. This result was unexpected as previous surveys by Jayasena and Herath (1986) and Stirling et al. (1998) reveal that theft is one of the major causes impeding intercropping activities in the sector. The present results suggest that the theft problem does not affect the intercropping decision, or it could indicate that the variable distance is not a good indicator of this problem. The effect of immature and mature rubber land size and the nature (flat/sloped) of the rubber lands is not significant in the model.

Acknowledgements

Field research for this paper was undertaken while the first author was an Agricultural Economist of the Rubber Research Institute of Sri Lanka. We are grateful to the Rubber Research Institute of Sri Lanka for facilitating this study. Collaboration of the staff of the Rubber Development Department of Sri Lanka and the participating farmers is warmly acknowledged. Valuable comments by anonymous reviewers are also highly appreciated.

References

Anonymous, 1993. Ferguson Sri Lanka Directory, vol. 125. The Associated Newspapers of Ceylon Ltd., Colombo.

Cooper, J.E., Keim, R.W., 1996. Incentive payments to encourage farmer adoption of water quality protection practices. Am. J. Agric. Econ. 78, 54–64.

Chandrasekera, B.L., 1979. Research Review of Plant Science Department, Annual Review Report 97. Rubber Research Institute of Sri Lanka.

Cochran, W.G., 1963. Sampling Techniques, vol. 2. Wiley, New York.

Doss, C.R., Morris, M.L., 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agric. Econ. 25, 27–39.

Dimara, E., Skurass, D., 1998. Adoption of new tobacco varieties in Greece: impact of empirical findings on policy design. Agric. Econ. 19, 297–307.

Estrella, A., 1998. A new measure of fit for equations with dichotomous dependent variables. J. Business Econ. Stat. 16 (2), 198–205.

Feder, G., Umali, D., 1993. The adoption of agricultural innovations: a review. Technol. Forecast. Soc. Change 43, 215–239.

Greene, W.H., 2000. Models with Discrete Dependent Variables. Econometric Analysis, vol. 4. Prentice-Hall, NJ, pp. 499–521.

Gray, A., 1997. Market impact of a potential increase in production of banana resulting from high density intercropping of banana with rubber. Report for the Institute of Terrestrial Ecology (Bangor), Natural Resource Institute, Central Avenue, UK.

Jayasena, W.G., Herath, H.M.G., 1986. Innovation Receptivity and Adoption in Rubber Mallholdings of Sri Lanka. SRRP Research Study 71, ARTI, Sri Lanka, pp. 79–88.

Lee, L.K., Stewart, W.H., 1983. Land ownership and the adoption of minimum tillage. Am. J. Agric. Econ. 65, 256–264.

Mittal, S., Kumar, P., 2000. Literacy, technology adoption, factor demand and productivity: an econometric analysis. Ind. J. Agric. Econ. 55 (3), 490–499.

Nganje, W., Schuck, E.C., Yantio, D., Aquach, E., 2001. Farmer education and adoption of slash and burn agriculture. Agribusiness and Applied Economics Miscellaneous Report No. 190, Department of Agribusiness and Applied Economics, North Dakota State University, Fargo, North Dakota.

Neill, S.P., Lee, D.R., 1999. Explaining the adoption and disadoption of sustainable agriculture: the case of cover crops in Northern Honduras, vol. 31. Working Paper, Department of Agricultural Resource and Managerial Economics, Cornell University, Cornell.

Negate, W., Parrikh, A., 1999. The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru districts of Ethiopia. Agric. Econ. 21, 205–216.

Shoemaker, F.F., 1971. Communication of Innovations, vol. 2. Free Press, New York.

Sharma, V.P., Kumar, A., 2000. Factors influencing adoption of agro forestry program: a case study from North-West India. Ind. J. Agric. Econ. 55 (3), 500–509.

Shiyami, R.L., Joshi, P.K., Asokan, M., Bantilan, M.C.S., 2000. Adoption of improved Chickpea varieties: evidence from tribial region of Gujarat. Ind. J. Agric. Econ. 55 (2), 159–171.

Stirling, C.M., Rodrigo, V.H.L., Janowsky, M., Gray, A., 1998. High-density banana rubber intercrops: productivity, livelihood, stakeholder and market analysis. Final Technical Report, Department for International Development, Plant Science Research Programme, UK, p. 41.

Whistler, D., White, K.J., Wong, S.D., Bates, D., 2001. SHAZAM for Windows, Professional Edition, Version 9.0. Econometric Software, Northwest Econometrics Ltd., Vancouver, BC, Canada.

Wooldridge, J.M., 2000. Limited dependent variable models and sample selection corrections. In: Introductory Econometrics: A Modern Approach. South Western College Publishing, USA, pp. 529–569.