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Adoption of intercropping in rubber smallholdings in Kerala, India: a tobit analysis

P. Rajasekharan* & S. Veeraputhran
*Rubber Research Institute of India, Kottayam, Kerala, India, Pin-686009 (*Author for correspondence, E-mail: rajasekharan_tvm@usa.net)*

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Abstract

Natural rubber (*Hevea brasiliensis*) is one of the major plantation crops of the state of Kerala in India and intercropping is practised during the initial gestation period of the crop. In this paper a tobit model was used to study the decision making behaviour of farmers in adoption and extent of adoption of intercropping in three regions of Kerala. The availability of family labour and the type of intercrops were found significant in explaining the adoption behaviour in all three regions. The perception of profitability of intercropping was also found to influence decision on adoption. The probability of adoption of intercropping was highest for three intercrops, banana (*Musa* spp.), cassava (*Manihot esculenta*) and pineapple (*Ananas comosus*). Targeting extension efforts to groups of farmers with available family labour and popularising selected intercrops may result in higher rates of adoption of intercropping in all three regions of the state.

Introduction

Intercropping is prevalent in the plantation crop systems of the state of Kerala in India. The state lies between 8°18′ and 12°48′ N latitude and 74°52′ and 77°22′ E longitudes with a geographical area of 38,864 km^2. The state comes under per humid and humid climate types except the southern part and the eastern part, which come under moist sub humid climate type. The cropping pattern in the state is characterised by high value crop production dominated by plantation crops. Natural rubber (*Hevea brasiliensis*) is an important plantation crop in the economy of the state with a share of 14.64% of gross cropped area. The state accounts for about 93% of natural rubber production in India, which is cultivated both in the estates and smallholdings. In Kerala, 87% of natural rubber is produced in the smallholdings and the average size of holding is about 0.50 ha. The gestation period of rubber is around seven years, and intercropping in the initial years will provide food or income for the household. On smallholder, rubber plantations world-wide, food crops such as rainfed rice (*Oryza sativa*), groundnut (*Arachis hypogaea*), cassava (*Manihot esculenta*) and plantains (*Musa* spp) are grown between the rows of rubber trees during the initial years of the plantations. These crops ensure a degree of food security for the smallholders and provide a source of income (CIRAD, 1997). The rationale for intercropping is that about 75% of the total area is not effectively occupied by the roots of the main crop when the rubber trees are under three years old (Ismail and Arshad, 1988).

The experiments conducted at the Rubber Research Institute of India have demonstrated the feasibility of growing intercrops during the initial three years of rubber planting. The reported intercrops in rubber smallholdings in India include cassava, rice, banana (*Musa* spp), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), elephant yam (*Amorphophallus paeniifolius*) and pineapple (*Ananas comosus*) (Sreenivasan et al., 1987; Rajasekharan, 1989). In other rubber producing countries banana, cassava, upland rice, sugarcane (*Saccharum officinarum*), vegetables, maize (*Zea mays*) and tobacco (*Nicotiana tabacum*) are reported as intercrops (Chandrasekara, 1984). Intercropping offers advantages of reduced risk, improved use of factors of production, greater total agricultural yield per unit of land and a more even use of family labour over the agricultural cycle (Vandermeer, 1989). Intercropping is used as a risk management and food security strategy in marginal environments (Norman, 1974; Hassan, 1996), and the practice reflects farmers' traditional wisdom for rationality as applied to their cropping decisions (Norman, 1974).

Apart from meeting food requirements and supplementing income of the farmers, the agronomic advantages of intercropping in rubber are also reported. Some of the studies indicate better growth of rubber in intercropped fields compared to monocropping (Chandrasekara, 1984). Apart from superior growth of rubber, depending on the frequency of cropping, dynamic changes in the soil nutrient status were observed due to the large amount of fertilisers applied for intercrops (Zainol et al., 1993). In the intercropped fields, significant residual amounts of phosphorus, calcium and magnesium were observed.

Like any other practice or technology, all the farmers may not adopt intercropping for the whole field, instead it may be restricted to a part of the field due to lack of information about the technology or practice, risk involved or due to biophysical and socio-economic constraints. But the adaptability is greatly enhanced when the proposed technology or practice holds potential to solve perceived problems in particular locations (Raintree, 1983). In making decisions about the adoption of a technology or practice, farmers are assumed to consider the consequences of adoption against its technical and economic feasibilities. The factors influencing adoption as well as the extent of adoption decisions on intercropping in rubber have received only limited research in Kerala. The role of socio-economic factors and the perception of the farmers about the agroforestry practice on adoption in rubber smallholdings are not adequately addressed earlier. This study is an attempt to fill this gap. The identification of the factors influencing adoption or non-adoption is essential for prescribing appropriate policies designed to supplement income during the gestation period of this crop.

Methodology

Several factors such as the availability of family labour, involvement in off-farm employment, age, farm size, perceived profitability of intercropping, type of intercrops, etc. were hypothesised to influence farmer's intercropping decisions in rubber smallholdings. The availability of family labour influences positively the adoption decisions as its availability reduces the labour constraints faced by the farmer (Nkonya et al., 1997). The availability of family labour was hypothesised to influence directly on intercropping decisions.

Increasing off-farm activities indicate less time available to learn and manage unfamiliar farm practices. It could also be argued that higher income could increase adoption of practices. The estimates for 1987–1988 showed that over 45% of the males in rural Kerala were engaged in non-agricultural activities, the highest among the major states in India (Eppen, 1994). Ervin and Ervin (1982) reported an inverse relationship of off-farm income and the number of soil conservation practices adopted. In this study, off-farm activities were hypothesised to influence negatively on intercropping decisions.

Younger farmers are said to have greater flexibility in dealing with risks (Voh, 1982; Akinola and Young, 1985). However it could also be that older farmers have more experience in cultivation and can easily adopt farm practices. But recent studies have reported negative impacts of age on adoption of modern technologies or practices (Akinola and Young, 1985; Adesina and Zinnah, 1993; Nkonya et al., 1997). The influence of age was hypothesised to be negatively related to adoption of intercropping.

Smallholder farmers are expected to be more concerned with consumption or subsistence requirements, and, hence, intercropping would be expected to be more common on small farms (Lynam et al., 1986). The farm size was hypothesised to influence negatively on adoption of intercropping. The type of crops selected for intercropping was also hypothesised to influence both the incidence as well as the extent of adoption.

The farmers have subjective preferences for technology characteristics (Ashby and Sperling, 1992), and subjective assessment of agricultural technologies or practices influence adoption behaviour (Nowak, 1992). However, only very limited quantitative studies considered farmers' psychological variables like perceptions and attitudes on adoption decisions (Lynne et al., 1988, Gould et al., 1989). The perceived profitability of intercropping was assumed to have a positive influence on adoption, and it was measured as a dichotomous variable.

In most studies, adoption is categorised as dichotomous, and such analysis will not indicate the extent of adoption. In practice, a technology may be adopted fully or partially by the farmers. On the basis of a comprehensive review of adoption studies, Schutjer and Van der veen (1977) concluded that the major technology issues relate to the extent and intensity of use at the individual farm level rather than to the initial decision to adopt a new practice. A tobit model can be used to analyse such decision problems. The tobit model has an advantage that its coefficients can be disaggregated into the probability of adoption and the expected use intensity of the practice. The dependent variable for this model is the area planted with intercrops which have censored distribution since they are zero for those not planting such crops. The model assumes that many variables have a lower or upper limit and take on this limiting value for a number of respondents. For the remaining respondents, the variable takes on a wide range of values above (below) the limit (Tobin, 1958; Amemiya, 1984). Tobit models are widely used in studies on adoption (Akinola and Young, 1985; Hassan, 1996; Nkonya et al., 1997). The theoretical framework of the tobit model can be explained by the threshold concept as,

$$Y_i = Y_i^* = X_i'\beta + U_i \quad \text{if } X_i'\beta + U_i > Y_i^* \tag{1}$$

$$Y_i = 0, \quad \text{if} \quad X_i'\beta + U_i \leq Y_i^* \quad i = 1, 2, \ldots, n$$

where,

Y_i = dependent variable for the ith observation (share of intercropped area);
Y_i^* = underlying latent dependent variable for the ith observation;
X_i = vector of explanatory variables corresponding to the ith observation;
β = vector of unknown parameters associated with the explanatory variables;
U_i = error term assumed to be independently distributed as $N(0, \sigma^2)$;
N = number of observations.

The model assumes an underlying unobserved latent variable which is observed when $X_i'\beta + U_i$ is greater than Y^*. This point is called the threshold point and expressed as an unobserved index. This model can be estimated by the maximum likelihood method.

Following Tobin (1958) the expected extent of adoption is,

$$E\,Y_i = X_i'\beta\, F(z_i) + \sigma f(z_i) \tag{2}$$

where,

$F(z_i)$ = cumulative normal distribution of Z;
$f(z_i)$ = the unit normal density;
Z = $X\beta/\sigma$;
σ = standard error of the estimate.

Using the estimates of β and σ, each of the terms can be evaluated at some values of $X\beta$, and the probability of being above the limit is $F(z_i)$. Following McDonald and Moffitt (1980) the marginal effect of the variables can be decomposed into two components and used to determine both changes in the probability of being above the limit and changes in the value of the dependent variable if it is already above the threshold. It can be shown that,

$$E(Y_i) = F(z_i) \times E(Y_i^*) \tag{3}$$

$$E(Y_i^*) = X_i'\beta + \frac{\sigma f(z_i)}{F(z_i)}. \tag{4}$$

Differentiating with respect to any element of X_i,

$$\frac{\partial E(Y_i)}{\partial X_i} = F(z_i)\left[\partial E\left(\frac{Y_i^*}{\partial X_i}\right)\right] + E(Y_i^*)\left[\frac{\partial F(z_i)}{\partial X_i}\right] \quad (5)$$

The relation can be converted into elasticity form by multiplying the equation by $X_i/E(Y_i)$.

Thus, the total elasticity of a change in the level of any variable consists of two effects,

(i) The change in the probability of the expected level of the extent of intercropping and
(ii) The change in the probability of being an adopter of intercropping.

For the maximum likelihood estimate of limited dependent models, the log likelihood ratio (LR) test can be used to evaluate the significance of all or a subset of coefficients (Greene, 1993).

The LR test follows a Chi-square distribution with K degrees of freedom (where K is the number of parameters in the equation less the constant).

Variables and the area studied

The variables selected and specification for the analysis are shown in Table 1. As mentioned earlier, the dependent variable was the share of area under intercropping in the farm. The descriptive statistics (mean, standard deviation, median, minimum and maximum) of the independent variables included in the model are also shown in Table 1.

The study was conducted in three agro- climatic rubber growing regions of the state of Kerala, located in the southern part of India. The population density is 749 people per km^2, and the average size of a family was 5.3 persons. The predominant soil type is laterite or lateritic in origin. The annual rainfall range from 2,600 mm to 3,200 mm. The state is divided into four agroclimatic regions for rubber cultivation, and the selected three regions together comprise 94.10% of area under rubber in the state. The selected regions were Punalur in southern Kerala, Thodupuzha in central Kerala and Taliparamba in northern Kerala. Among the regions, Punalur and Thodupuzha are located in

Table 1. Description of variables included in the tobit model in the study of rubber intercropping in Kerala, India.

Descriptive statistics	Region	Dependent variable (SHARE)	Family labour (LABOUR)	Age (AGE)	Total area (AREA)	Crop profit (PROFIT)	Other sources of income (OFI)	Type of crop (TYPE)
		Share of inter-cropped area	1 if family labour is available, 0 otherwise	1 if age is > 50 years, 0 otherwise	Total area in hectare	1, if it is perceived as profitable, 0 otherwise	1 if other sources of income is present, 0 otherwise	1 if planted banana, cassava or pineapple, 0 otherwise
Mean	Punalur	56.71	0.59	0.67	1.48	0.62	0.51	0.31
Median		75.00	1.00	1.00	1.14	1.00	1.00	0.00
SD		45.19	0.50	0.47	2.25	0.49	0.50	0.47
Minimum		0.00	0.00	0.00	0.15	0.00	0.00	0.00
Maximum		100.00	1.00	1.00	20.00	1.00	1.00	1.00
Mean	Thodupuzha	56.09	0.59	0.50	2.00	0.71	0.19	0.35
Median		80.00	1.00	0.00	1.70	1.00	0.00	0.00
SD		46.60	0.50	0.50	1.14	0.46	0.40	0.48
Minimum		0.00	0.00	0.00	0.40	0.00	0.00	0.00
Maximum		100.00	1.00	1.00	6.0	1.00	1.00	1.00
Mean	Taliparamba	50.33	0.52	0.55	2.74	0.62	0.22	0.29
Median		45.00	1.00	1.00	2.00	1.00	0.00	0.00
SD		44.61	0.50	0.50	2.92	0.49	0.42	0.45
Minimum		0.00	0.00	0.00	0.21	0.00	0.00	0.00
Maximum		100.00	1.00	1.00	20.00	1.00	1.00	1.00

the traditional rubber growing tract while rubber is a relatively new crop in Taliparamba.

A multistage random sampling procedure was adopted for sample selection. The three regions were selected based on the maximum cultivated area under intercrops in rubber holdings. All the villages in the selected regions were listed in the descending order of area intercropped, and one village each with maximum area under intercrops was selected from the three regions. A sample of 240 rubber growers were selected from the list of farmers in the three villages with rubber planted in 1993 to 1995 by simple random sampling. For the final analysis, incomplete data from seven growers were discarded and data from 78 farms in Punalur, 78 farms in Thodupuzha and 77 farms in Taliparamba were used. Both the intercropped farms and non-intercropped farms were included in the selected samples. The farms with less than 10% of intercropped area in total area under young rubber (non yielding rubber with one to three years age) were also included under the non intercropped group. The survey was conducted during the months of February to May 1997.

Results and discussion

Existing farming system and the sample characteristics

Annual and perennial crops are cultivated in Kerala, and homesteads form the major agricultural production system. The crop production is characterised by the preponderance of perennial crops, and a multiplicity of crops, woody trees and one to two cattle are present in a typical homestead in the state.

The predominant land use system in the area studied was agrosilvopastoral, integrating crops, trees and livestock in the same land management unit. The dominant crops in the farming system were rubber and coconut followed by rice and banana. Despite being the staple food of the people, rice was cultivated only in 50 to 60% of the homesteads. The major crops cultivated in the homesteads consisted of rice, cassava, rubber, banana, Elephant Yam, pineapple, ginger, turmeric, greater yam (*Dioscorea alata*), sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), cowpea (*Vigna unguiculata*), jack tree (*Artocarpus heterophyllus*), coconut (*Cocos nucifera*), cocoa (*Theobroma cacao*), arecanut (*Areca catechu*), black pepper (*Piper nigrum*), kacholam (*Kaempferia galanga*), bitter gourd (*Momordica charantia*), cucumber (*Cucumis sativus*) and chillies (*Capsicum* spp). The major woody trees cultivated in the homesteads were teak (*Tectona grandis*) and wild jack (*Artocarpus hirsutus*). The share of area under rubber in total area of the farm household was 64% in Punalur, 68% in Thodupuzha and 41% in Taliparamba.

The major intercrops cultivated in the three regions are shown in Table 2. Altogether 15 intercrops were planted with a maximum number of 12 in Punalur, eight in Thodupuzha and 11 in Taliparamba. The popular intercrops in Punalur region were banana, cassava, greater yam and elephant yam while banana, ginger, pineapple and elephant yam were popular in Thodupuzha and cassava, ginger and elephant yam in Taliparamba. In the same field, multiple intercrops were cultivated in Punalur and Taliparamba regions. Pineapple was cultivated in the two southern and central regions while it was not popular in Taliparamba due to lack of an assured market and inexperience of the farmers in cultivation of this crop. The crops cultivated in Punalur region alone were greater yam, and cucumber, while bitter gourd was cultivated only in Taliparamba. Cassava and vegetables were not cultivated in Thodupuzha.

The mean farm size ranged from 1.48 ha in Punalur to 2.74 ha in Taliparamba (Table 3). The mean area under young rubber was highest in Taliparamba. The most popular variety of rubber planted was RRII 105[1] in all three regions. Almost 96% of the farmers in Taliparamba had cultivated RRII 105 alone, followed by 80% in Thodupuzha and 69% in Punalur. A combination of varieties including RRII 105 was planted by the remaining percentage of farmers in all three regions. The share of intercropped area in total area under young rubber was the highest in Thodupuzha with 57%. A higher proportion of farmers without intercropping was found in Taliparamba region. The rubber trees per hectare as well as the number of intercrops were the highest in Punalur.

Table 2. Number of sample farmers cultivated various intercrops in three regions of Kerala, India.

Intercrop	Scientific name	Punalur*	Thodupuzha	Taliparamba*
Banana	*Musa* spp.	37	18	10
Cassava	*Manihot esculenta*	17	0	23
Pineapple	*Ananas comosus*	11	17	0
Ginger	*Zingiber officinale*	6	22	15
Turmeric	*Curcuma longa*	1	6	4
Elephant-Yam	*Amorphophallus paeniifolius*	36	7	18
Taro	*Colocasia esculenta*	10	4	7
Cow pea	*Vigna unguiculata*	1	0	4
Bitter-gourd	*Momordica charantia*	0	0	5
Cucumber	*Cucumis sativus*	1	0	0
Chillies	*Capsicum* spp.	2	0	1
Plantain	*Musa* spp.	1	1	4
Kacholam	*Kaempferia galanga*	1	3	4

* Most of the farmers cultivated multiple intercrops in the same field, and hence the total numbers shown is higher than the sample size in these two regions.

Table 3. Characteristics of the sample farmers in three regions of Kerala, India.

Descriptive statistics	Region	Young rubber area (ha)	Sample farmers without intercrops (%)	Total area (ha)	Rubber plants/ha
Mean	Punalur	0.55	30.77	1.48	528.54
Median		0.40	0.00	1.14	512.00
SD		0.36	46.45	2.25	67.26
Minimum		0.10	0.00	0.15	400.00
Maximum		2.00	100.00	20.00	690.00
Mean	Thodupuzha	0.58	32.05	2.00	484.10
Median		0.50	0.00	1.70	488.00
SD		0.30	46.97	1.14	63.27
Minimum		0.10	0.00	0.40	348.00
Maximum		1.62	100.00	6.00	668.00
Mean	Taliparamba	0.72	36.36	2.74	491.81
Median		0.40	0.00	2.00	500.00
SD		1.05	48.42	2.92	55.48
Minimum		0.12	0.00	0.21	330.00
Maximum		8.80	100.00	20.00	625.00

* Young rubber denotes non-yielding rubber trees of one to three years age.

Determinants of adoption and the extent of intercropping

The maximum likelihood estimates are shown in Table 4. The three independent tobit models were tested using the likelihood ratio (LR) test and were found to be significantly different. Accordingly, further interpretations were made for the three models separately. The LR statistic calculated from the individual and pooled models was 27.16 and the critical value was 24.70 at the 1% probability level.

In each model of the three regions, the likelihood ratio statistic (LR) was also found to be significant at the 1% probability level. The Pseudo R^2 was quite low but this level of explanatory power was consistent with other cross section studies using censored data to explain technology adoption decisions (Goodwin and Schroeder, 1994; Nkonya et al., 1997).[2]

Table 4. Maximum likelihood estimates of tobit model on intercropping decision of farmers of Kerala, India.

Variable	Punalur	Thodupuzha	Taliparamba
Constant	2.6702 (0.1902)	–12.403 (–0.6182)	–11.194 (–0.7408)
Off-farm income (OFI)	–9.8192 (–1.0034)	–36.917** (–2.1773)	3.8167 (0.3084)
Family labour (LABOUR)	52.498*** (4.4934)	43.297*** (3.2169)	32.304*** (2.7733)
Farm size (AREA)	3.4686* (1.6696)	5.2324 (1.0272)	–6.7790* (–1.7441)
Age (AGE)	–16.578* (–1.6849)	5.0750 (0.4448)	6.9401 (0.7420)
Perception of profit (CROP PROFIT)	16.531 (1.4950)	3.9588 (0.3136)	46.795*** (3.9789)
Type of crop (TYPE)	46.063*** (4.1798)	61.261*** (5.0345)	48.707*** (4.3598)
Loglikelihood	–289.93	–286.38	–258.48
LR test	65.86***	57.82***	98.48***
McFadden's R^2	0.102	0.0917	0.1376
No.of iterations	4	3	5
Sigma	38.021	43.335	35.382

Figures in parentheses are asymptotic '*t*' ratios
*** Significant at 1% probability level; ** Significant at 5% probability level; * Significant at 10% probability level.

The variable family labour (LABOUR) was significant at the 1% probability level in Punalur with the *a priori* expected sign. The availability of labour is often mentioned as one of the variables influencing adoption of technologies or improved practices. Peak season scarcity of hired labour increases the importance of family labour. When the innovation increases the seasonal demand for labour, the adoption of that innovation may be less attractive for those with limited family labour (Akinola and Young, 1985). In Kerala, most of the agricultural operations are done during the two rainy seasons in May–June and September–October. This results in peak seasonal demand for labourers for main as well as intercrops and those households with an edge in family labour availability can meet the labour requirements adequately.[3] The coefficient of age (AGE) was found significant only at the 10% probability level. The negative sign of AGE showed that older farmers did not prefer intercropping practices. In a study on planting strategies of maize farmers in Kenya, Hassan (1996) also reported an inverse relationship of age and intercropping. Contrary to expectations, the coefficient of farm size (AREA) was positive in this region. The mean area under young rubber and total area were lowest in Punalur. The positive impact of farm size might have arisen from economies of scale since the same intercrops were planted as pure crops in paddy fields in crop rotations. Apart from rubber, most of the farmers also had paddy lands in this region. Farmers used to cultivate banana, cassava, ginger, Elephant Yams, etc. in paddy fields as pure crops after harvesting one crop of paddy. However, the coefficient was significant only at the 10% level. Even though other sources of income (OFI) and perceived profitability (PROFIT) of intercropping had the expected signs, they are not statistically significant. On the other hand, the type of crop (TYPE) was found significant in adoption decisions.

In Thodupuzha, family labour (LABOUR) and type of crop (TYPE) were significant at the 1% probability level. The variable, off-farm income (OFI) was significant with the *a priori* expected sign. The off-farm activities of the farmers include employment in the public or private sectors, self employment, business, etc. However, the variables farm size (AREA) and age (AGE) were not significant determinants in the decision on whether or not to intercrop in rubber smallholdings.

In Taliparamba, family labour availability (LABOUR) as well as the type of intercrops (TYPE) was found significant at the 1% probability level. Farm size (AREA) was significant at the 10% level. The negative sign of farm size implies that bigger farmers did not prefer intercropping practices. The intercrops cultivated were mostly food crops and the smallholder farmers had to satisfy subsistence oriented requirements from the small land unit. Hassan (1996) also observed a higher frequency of intercropping among small scale farmers in Kenya. The variable, off-farm income (OFI) and age (AGE) were not significant in Taliparamba.

The variable perceived profitability (PROFIT) was found significant in Taliparamba. This may be due to the fact that rubber cultivation is relatively new in Taliparamba region compared to the other two regions of the state and farmers are still having little apprehensions about the economic and technical feasibility of growing intercrops. This perception is dependent on the quality of information available to the farmers.

Probabilities of adoption and the extent of intercropping

In tobit models, the estimates are not directly comparable since these are expressed as indices and hence for interpretative purposes these can be converted into probabilities.

The probability and the extent of intercropping estimated by the model are shown in Table 5. The probability was estimated for a typical farmer characterised by the availability of family labour coupled with the perception of profitability of intercropping and no sources of off-farm income. The probability of planting intercrops for such a farmer was 0.99 with a share of 88% area under intercrops in Punalur region. The corresponding probability was 0.94 in Thodupuzha with a share of 70% and 0.99 with a share of 81% area under intercrops in Taliparamba region.

The probability of planting intercrops, other than banana, cassava or pineapple for a farmer characterised by the availability of family labour coupled with the perception of profitability was 0.97 in Punalur with a share of 61% of the farm area under intercropping. The probability was 0.83 with a share of 45% in Thodupuzha and 0.82 with a share of 58% in Taliparamba. Whereas the probability of planting three intercrops, banana, cassava or pineapple for such a farmer was almost 100% with entire available area, under intercrops in all three regions. The findings indicated the preference of farmers to plant these three intercrops in all the available land for intercropping.

The marginal effects were calculated for predicting the effects of changes in one of the independent variables on the probabilities of adoption and extent of adoption of intercropping. The marginal effects were derived using equation 5 and converted into elasticities. The decomposition of total elasticity had shown maximum effect for the variable, family labour, in all three regions. The elasticity of family labour ranged from 0.33 in Taliparamba to 0.55 in Punalur, and the elasticity of extent of intercropping ranged from 0.37 in Taliparamba to 0.56 in Punalur. The marginal effect of type of crop (TYPE) ranged from 0.25 in Punalur to 0.38 in Thodupuzha, and the elasticity of extent of intercropping from 0.26 to 0.38 (Table 6). A change in the perception of profitability of intercropping could increase the

Table 5. Probabilities of adoption and extent of intercropping in three regions of Kerala, India.

Region	Other sources of income (OFI = 0)		Type of intercrop (TYPE = 0)	
	Probability of adoption	Share of intercropped area (%)	Probability of adoption	Share of intercropped area(%)
Punalur	0.9938	87.91	0.9713	61.03
Thodupuzha	0.9441	70.11	0.8264	44.80
Taliparamba	0.9887	80.87	0.8232	58.30

Table 6. Marginal effects of variables on intercropping decisions (elasticities) in three regions of Kerala, India.

Variable	Punalur		Thodupuzha		Taliparamba	
	Probability	Extent	Probability	Extent	Probability	Extent
Off-farm income (OFI)	–0.0888	–0.0917	–0.1266	–0.1277	0.0167	0.0187
Family labour (LABOUR)	0.5460	0.5636	0.4552	0.4592	0.3335	0.3718
Farm size (AREA)	0.0904	0.0933	0.1866	0.1882	–0.3693	–0.4117
Age(AGE)	–0.1949	–0.2012	0.0452	0.0456	0.0752	0.0839
Perception of profit (CROP PROFIT)	0.1121	0.1157	0.0218	0.0210	0.3502	0.3904
Type of crop (TYPE)	0.2499	0.2580	0.3781	0.3813	0.2765	0.3083

elasticity of probability of adoption by 11% and by 12% in the use intensity of intercropping in Punalur. Such a change in Taliparamba could change the elasticity of probability of adoption by 35% and the extent of adoption by 39%.

The total elasticity of 0.18 for farm size (AREA) in Punalur indicates that a 10% increase in farm size will increase adoption and extent of adoption by 1.8%. A similar increase in Taliparamba will increase adoption and extent of adoption by 7.8%. The total elasticity for type of crop was highest in Thodupuzha region with a positive sign, which indicated the importance of banana, cassava and pineapple in intercropping decisions. This shows that the elasticity of adoption of crops other than these three crops will decline by 76 in Thodupuzha followed by 58% in Taliparamba and 51% in Punalur region (dummy variable). The estimates indicate that marginal changes of the variables influence the extent of intercropping more than the probabilities of adoption of intercropping in all the variables in the three regions.

Conclusions and policy implications

Intercropping, as an agroforestry practice is prevalent in the plantation dominated state of Kerala. The major intercrops cultivated in rubber smallholdings consisted of fruits like banana and pineapple, tubers like cassava, elephant yam, greater yam and taro, spices like turmeric and ginger, vegetables like bitter gourd, cucumber and chillies and medicinal plants like kacholam. The present study has identified the socio-economic factors influencing adoption of intercropping in rubber smallholdings, in three agroclimatic regions of Kerala. A tobit model was used for estimation and differences were observed in the three regions as evidenced by the significance of log likelihood ratio tests of the independent tobit models.

Understanding the rationale and decision criteria of farmers in determining the choices of intercropping is an essential element in the design of future policies. The availability of family labour, type of intercrops and the perception of profitability of intercropping were found significant in explaining the intercropping decision. The availability of family labour was a dominant variable, which influenced adoption decision in all the three regions. Among the variables included in the model, the maximum probability of adoption was obtained for family labour. The marginal probabilities ranged from 0.33 to 0.56 for different regions. Any extension activities considering the availability of family labour will likely have a higher impact on adoption decisions. A resource based classification of farmers with explicit recognition of availability of family labour may be attempted before initiating large scale popularisation of intercropping in rubber smallholdings. The limited resources available for extension activities can be targeted effectively to promote intercropping in such classified group of farmers.

Following family labour, the next important variable which explained the intercropping decision was the type of intercrops. The marginal probabilities ranged from 0.24 to 0.38. The three intercrops, banana, cassava or pineapple should be popularised for maximum extent of adoption of intercropping in all three regions. Suitable extension policies designed to change the perception of farmers about the profitability of intercropping can enhance the pace of adoption of intercropping practices in rubber smallholdings. Such policies can produce significant impact in Taliparamba compared to Punalur and Thodupuzha regions. The socio- economic variables alone, influencing adoption of intercropping were included in this study. Even though a higher growth of rubber in the intercropped fields was reported in experiments, the selected farmers were not aware of this agronomic advantage of intercropping and hence not included in the model. The reported synergism between intercropping and growth of rubber can also be made part of the extension programmes for promoting intercropping.

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Notes

1. RRII is the abbreviation for the Rubber Research Institute of India from where the variety was released and 105 denoted the variety number.
2. The Pseudo R^2 used for measuring the goodness of fit of the model was McFadden's R^2. It was calculated using the equation,

$$\text{McFadden's } R^2 = 1 - \frac{\text{Log } L_{UR}}{\text{Log } L_R}$$

Where,
Log L_{UR} is the unrestricted log likelihood function.
Log L_R is the restricted log likelihood function.

3. As pointed out by the referee, labour decisions may be made along with the decision to adopt intercropping and therefore it is likely that labour is endogenous and its coefficients could be biased upwards. This aspect is not addressed in the paper, since the econometric procedure of treating endogenous variable in tobit model is quite complicated.

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