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Willingness of smallholder rubber farmers to participate in ecosystem protection: Effects of household wealth and environmental awareness

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ABSTRACT

The rapid expansion of natural rubber farming in southern China has led to negative environmental consequences, such as soil erosion and biodiversity loss. Therefore, local governments have made the restoration and protection of ecosystems a major policy issue. However, such efforts will only be successful if local communities participate. Using cross-sectional data on 612 smallholder rubber farmers in Xishuangbanna, this study investigates the willingness of smallholder rubber farmers to participate in ecosystem protection. We employ a multivariate probit regression model to estimate three ways of participating in environmental protection: (i) through monetary contributions of rubber farmers, (ii) by reducing rubber areas, and (iii) through the provision of free labor. The results show that most rubber farmers are willing to participate in local ecosystem protection. While wealthier households tend to participate by contributing money and providing free labor, poorer households prefer to reduce their rubber planting areas. Approximately 10% of the farmers believe that rubber cultivation has positive environmental effects and therefore abstain from participating in ecosystem protection measures. Our findings have important implications for policymakers who want to implement programs to restore and protect ecosystems in Xishuangbanna and other rubber planting regions in southern China.

1. Introduction

With the increasing expansion of natural rubber (*Heveabrasiliensis*) farming in the Mekong region, including Xishuangbanna Dai Autonomous Prefecture (XSBN) of southwestern China (Fu et al., 2009a), the controversy related to its sustainability has intensified in recent years (Qiu, 2009). Natural rubber is one of the very few industrial raw materials to be produced with a beneficial economic and environmental impact (Diaby et al., 2013). On the one hand, rubber cultivation has significantly improved the livelihood of smallholders (Guo et al., 2002; Liu et al., 2006; Fu et al., 2009b; Herrmann and Fox, 2014; Min et al., 2017a). On the other hand, the rapid expansion of smallholder rubber farming, most of which is grown in monoculture (Fox et al., 2014), has triggered the loss of virgin forest and has caused ecological degradation (Xu, 2006; Zhang et al., 2007). At present, the negative effects of rubber farming on local ecosystems, including decreasing biodiversity and soil erosion, are widely recognized by scholars and policymakers (Liu et al., 2006; Xu, 2006; Hu et al., 2008; Fu et al., 2010; Yi et al., 2014). Restoring and protecting the local ecosystems that are threatened by rubber farming have become urgent issues.

In the context of the “New Normal Theory”, which was outlined by Chinese President Xi Jinping in 2014, government authorities have emphasized that agricultural development must be environmentally friendly and conducive to the conservation of ecological conditions (Chen, 2015). The local government of XSBN aims to restore and protect local ecosystems by promoting sustainable rubber cultivation. According to the twelfth five-year plan generated by XSBN's biological industry office, approximately 500,000 mu[1] of low-productivity and high-altitude rubber plantations should have been transformed from rubber production into more sustainable land use by 2015. The “Environment-Friendly Rubber Plantation” program, which was proposed in 2009, has been gradually implemented by the local government. The main components of this program are the reduction of rubber plantations on unsuitable land and the establishment of a rubber-based agroforestry system (Xiao et al., 2014; Zhang, 2015). Moreover, the natural rubber eco-certification recognized as the path with least resistance has also been proposed to improve the sustainability of rubber plantation (Kennedy et al., 2017). However, as of now, the adoption of natural rubber eco-certification is few and with little attention in XSBN.

Most previous studies on the implementation of environmental

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[1] 15 mu = 1 ha.

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conservation policy tend to investigate farmers' participation willingness under Payments for Ecosystem Services (PES) themes (Yin et al., 2013; Pan et al., 2017). Given the significant contribution of natural forests through ecosystem services (Reed et al., 2017), PES themes have attracted broad international attention as a novel approach of using economic incentives to mitigate deforestation, forest degradation, and biodiversity loss (Yin et al., 2013; Phan et al., 2017). The rapid emergence of PES in China has also been reported widely (Guo et al., 2014; Pan et al., 2017). However, according to the polluter pays principle (Palmer, 1998; He et al., 2012), smallholder rubber farmers also need to pay for the negative environmental consequences of rubber cultivation. Thus, under the theme of PES, the decision on using economic incentives to encourage smallholder rubber farmers to protect ecosystem threatened by rubber farming should be made carefully. Wallander et al. (2017) indicated that voluntary land conservation programs depend upon the willingness of land owners to participate, while the study of Khanal et al. (2017) found that some landowners in USA would participate in carbon sequestration even with little or no incentive. Thus, a question is raised whether smallholder rubber farmers are willing to participate in ecosystem protection without any economic incentive, which can provide useful information for the design of future payment schemes (Mislimshoeva et al., 2013).

For sustainable rubber cultivation policies to succeed, the participation of smallholder rubber farmers is essential. In XSBN, > 50% of rubber plantations, accounting for nearly all of the rubber planted in ecologically sensitive land areas, are operated by local smallholders. Currently, smallholders' attitudes toward environmental protection remain unclear. While there are numerous studies on the participation of individuals in environmental conservation programs (Flores and Carson, 1997; Vanslembrouck et al., 2002; Cooper, 2003; Torgler and Garcia-Valiñas, 2007; Ma et al., 2012; Lankia et al., 2014), to our knowledge, no such study exists related to rubber. Existing studies have analyzed the willingness to pay (WTP) for the preservation of original landscapes and indigenous species among urban residents of XSBN (Ahlheim et al., 2013, 2015) and Shanghai (Ahlheim et al., 2014).

The objectives of this research are the following: (i) to assess the willingness of smallholder rubber farmers to participate in ecosystem protection measures and (ii) to examine the roles of household wealth and environmental awareness in the farmers' participation. Hereby, we investigate three possible ways for smallholders to contribute, namely, by reducing the size of their rubber plantation areas, by making voluntary financial contributions and by providing free labor for implementing ecosystem protection measures. Based on cross-sectional data collected from 612 smallholder rubber farmers in Xishuangbanna in 2013, we estimate a simultaneous equation model to account for the likely correlation between the three ways of farmers' participation.

Our main findings are that farmers' awareness of environmental problems determines their willingness to participate in environmental programs. Although most smallholder rubber farmers are willing to participate in local ecosystem protection, wealthier households prefer to participate by contributing money and labor, while poorer households are more willing to reduce their rubber areas.

This paper is organized as follows. In the next section, we present the theoretical framework and our hypotheses. In section three, we introduce the circumstances of the study region and the data collection procedure. We also present basic statistics on smallholder rubber farmers' household wealth, environmental awareness, and willingness to participate in ecosystem protection. In section four, we develop econometric models to estimate smallholders' willingness to participate in ecosystem protection and empirically test the hypotheses. In section five, we present and discuss the results, focusing on the effects of household wealth and environmental awareness. The final section concludes the paper and discusses several policy implications.

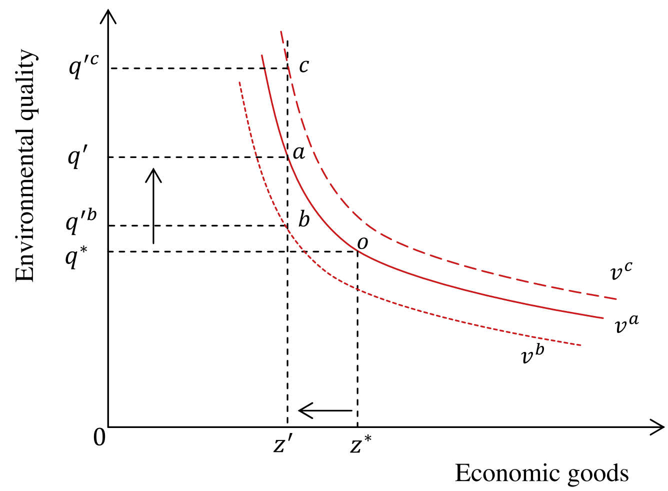

Fig. 1. Consumption trade-offs between economic goods and environmental quality.

2. Theoretical framework and hypotheses

A farmer's willingness to participate in environmental protection measures can be modeled by means of a utility maximization framework that combines the consumption of market goods and non-market environmental services (Vanslembrouck et al., 2002; Dupraz et al., 2003; Plassmann and Khanna, 2006; Ma et al., 2012). The corresponding trade-offs can be illustrated by an indifference curve analysis (Hicks and Allen, 1934; Israel and Levinson, 2004). Inspired by previous studies, in this section, we first discuss the trade-offs between the consumption of economic goods and the improvement of environmental quality when an environmental program has been introduced. Second, by incorporating a farmer's producer and consumer behaviors, we attempt to derive a conceptual model that determines the willingness of smallholder rubber farmers to participate in ecosystem protection measures. We present two central hypotheses in the following section.

2.1. Indifference curve analysis

In Fig. 1, we illustrate the usual trade-off between economic and environmental goods for a defined level of utility. We suppose that o is the initial optimal point at which a smallholder rubber farmer maximizes utility, subject to certain budget constraints and exogenously fixed environmental quality. The optimal consumption of economic goods is $\boldsymbol{z}^*$, while v^a is the indifference curve. Farmer participation in an environmental program may require farmers to forgo a certain amount of economic goods, which is denoted in Fig. 1 as the move from $\boldsymbol{z}^*$ to $\boldsymbol{z}'$. The equivalent environmental improvement is shown as the move from q^* to q', which will maintain the level of utility v^a.

However, farmers with different attributes, $\boldsymbol{x}$, are likely to have heterogeneous expectations about their participation in an environmental program. First, if a farmer anticipates that her participation can only increase the environmental quality to q'^b, the new optimal choice will be the point b at which the farmer achieves the new maximum utility v^b. Compared with the initial point o, the increased utility of improved environmental quality cannot fully substitute for the utility loss of the reduced economic goods, and hence the utility v^b is less than the initial utility v^a. In such a case, the farmer would not be willing to participate in the environmental protection program. Second, if the farmer expects that the environmental quality can reach q'^c, the optimal choice is at c,the maximum utility v^c. In this case, the increase in utility that results from increasing environmental quality exceeds the loss of utility from reducing economic goods, making the utility v^c larger than the initial utility v^a. Therefore, the farmer will be willing to participate in the environmental protection program.

In summary, when an environmental protection program is introduced, heterogeneous expectations of environmental improvement will result from different expectations of utility change and will thereby result in further differences in the farmers' decisions to participate.

2.2. Utility maximization

To illustrate the willingness of smallholder rubber farmers to participate in ecosystem protection, we use a utility maximization framework to present a conceptual model. Following Hanemann (1991), a farmer's preference for economic goods is denoted by the vector **z**, and the preference for environmental goods (Mackenzie, 1993) is denoted by Q. The latter refers to the quality of local ecosystem services, such as food from natural resources, water supply, microclimate, pollinator populations, and landscape amenities (for tourists). These factors are assumed to be exogenously fixed, i.e., Q is homogeneous for all local farmers and is inelastic in its supply. Other observable characteristics of smallholder rubber farmers that reflect their preferences are denoted by the vector $\boldsymbol{x}$ (Hanemann, 1984). Although Q is homogeneous for all smallholder rubber farmers, their perceptions of ecosystem services ($Q^{'}$) are likely different due to the heterogeneity in their characteristics ($\boldsymbol{x}$) and environmental awareness (e). Here we define environmental awareness (e) as the farmers' awareness of the environmental effects of rubber cultivation, and thus can simply express $Q^{'} = \gamma(Q, e|\boldsymbol{x})$. Assume that $\Delta q$is the change in ecosystem services that is the result of farmers' ecosystem protection efforts. Thus, the maximum quality of local ecosystem services (q) that farmers perceive is the sum of $Q^{'}$ and Δq, and the utility function can be written as u (**z**, $q|\boldsymbol{x}$). In the presence of participation in local ecosystem protection, the budget constraint (I) is determined by the profit derived from farm activities (π) and household wealth (w_0), which is assumed to be exogenous. Thus, the utility maximization problem is expressed as:

$$\underset{z,q}{Max}\, u\,(\boldsymbol{z}, q \mid \boldsymbol{x}) \tag{1}$$

$$s.\ t. \quad \boldsymbol{pz} + p_c \Delta q \leq I \tag{2}$$

$$q = \Delta q + Q' \tag{3}$$

$$I = \pi + w_0 \tag{4}$$

$$\pi = f\,(\boldsymbol{R}, \boldsymbol{O}, \boldsymbol{P}' \mid \boldsymbol{x}) \tag{5}$$

where the vector $\boldsymbol{p}$ ($\boldsymbol{p} > 0$) denotes the market prices of the economic goods vector $\boldsymbol{z}$. The variable $p_c (p_c \geq 0)$ is the shadow price of the change in ecosystem services (Δq). p_c can be treated as the level of compensation payments for ecosystem protection efforts (Vanslembrouck et al., 2002) and is defined as $p_c = p(Q^{'},\ e|\boldsymbol{x})$. The vectors $\boldsymbol{R}$ and $\boldsymbol{O}$ denote the characteristics of rubber farming and the production of other crops, respectively, such as farm area, labor, capita and other inputs, as well as the corresponding productions. The vector $\boldsymbol{P}^{'}$ ($\boldsymbol{P}^{'} > 0$) includes the prices of input factors and farm products. The vector $\boldsymbol{x}$ can condition the production function of the smallholder rubber farmer (Ma et al., 2012) and thus influences the profit function.

If $q = Q^{'}$, the vector $\boldsymbol{z}$ of economic goods can be expressed as a demand function $\boldsymbol{z} = h(\boldsymbol{p}, Q^{'}, I|\boldsymbol{x})$. Following Ma et al. (2012), the optimal choice of economic goods level ($\boldsymbol{z}^*$) and ecosystem services ($Q^{'}$) can be further represented as an indirect utility function v:

$$u(\boldsymbol{z}^*, Q' \mid \boldsymbol{x}) = u\,[h^*(\boldsymbol{p}, Q', I \mid \boldsymbol{x}), Q' \mid \boldsymbol{x}] = v(\boldsymbol{p},\, Q',\, I \mid\! \boldsymbol{x}) \tag{6}$$

The costs incurred through participation in ecosystem protection are denoted by (C), and hence the budget constraint I for $\boldsymbol{z}$ will decrease to $I - C$. Therefore, the maximum increase in the quality of ecosystem services amounts to $\Delta q = C/p_c$, with other factors remaining constant. Thus, the utility function with protection measures can be expressed as:

$$u(\boldsymbol{z}^*, q^* \mid \boldsymbol{x}) = u\,[h^*(\boldsymbol{p}, Q', I - C \mid \boldsymbol{x}), (Q' + \Delta q) \mid \boldsymbol{x}] = v(\boldsymbol{p},\, p_c,\, Q',\, C,\, I \mid\! \boldsymbol{x}) \tag{7}$$

Eq. (8) represents the change in utility due to smallholders' participation in ecosystem protection:

$$\Delta u = u(\boldsymbol{z}^*, q^* \mid \boldsymbol{x}) - u(\boldsymbol{z}^*,\, Q' \mid\! \boldsymbol{x}) = v(\boldsymbol{p},\, p_c,\, Q',\, C,\, I \mid \boldsymbol{x}) - v(\boldsymbol{p},\, Q',\, I \mid\! \boldsymbol{x}) \tag{8}$$

Thus, the difference in the utility (Δu) can be used as a basis for referencing the farmers' participation decision (Hanemann, 1984; Lankia et al., 2014). If Δu is positive, respondents will express their willingness to participate in ecosystem protection (Park et al., 1991; Ma et al., 2012); otherwise, they will demonstrate reluctance.

When we insert equation $p_c = p(Q^{'}, e|\boldsymbol{x})$, equation $Q^{'} = \gamma(Q, e|\boldsymbol{x})$, Eqs. (4) and (5) into Eq. (8), the reduced-form model of Δu can be expressed as:

$$\Delta u = v(\boldsymbol{p},\, Q,\, e,\, C,\, \boldsymbol{R},\, \boldsymbol{O},\, \boldsymbol{P}',\, w_0 \mid \boldsymbol{x}) \tag{9}$$

The market prices of conventional market commodities ($\boldsymbol{p}$) and the prices of input factors and farm products ($\boldsymbol{P}^{'}$) among smallholder rubber farmers in a specific region can be assumed to remain constant. Thus, the function (9) can be further simplified as:

$$\Delta u = v(Q,\, e,\, C,\, \boldsymbol{R},\, \boldsymbol{O},\, w_0 \mid \boldsymbol{x}) \tag{10}$$

Eq. (10) measures the expected utility change Δu, which can reflect the willingness of smallholder rubber farmers to participate in ecosystem protection.

2.3. Hypotheses

The study of Jalan et al. (2009) found that individuals would be willing to pay for private or public measures that can improve their environmental quality only if they are aware of the associated risks and can afford to pay for prevention. The study of Håbesland et al. (2016) also indicated that people's environmental attitudes could affect their willingness to participate in environmental conservation program. Similarly, based on the analytical framework presented above and previous studies, we present three central hypotheses.

The first hypothesis (H1) refers to the impacts of farmers' environmental awareness (e) on their willingness to participate in ecosystem protection. We expect that farmers perceiving that rubber farming has positive environmental effects, will hinder farmers' willingness to participate in ecosystem protection.

The second hypothesis (H2) concerns the impacts of household wealth (w_0). As real incomes increase, the demand for environmental quality by citizens can be expected to increase substantially (Ready et al., 2002). Therefore, we predict that wealthier rubber farmers are more likely to participate in local ecosystem protection compared with poorer farmers.

The third hypothesis (H3) is that wealthier rubber farmers are more willing to contribute money and less willing to reduce their rubber planting areas than poorer farmers. This is because wealthier farmers can be assumed to operate on more productive rubber land and to have less liquidity constraints.

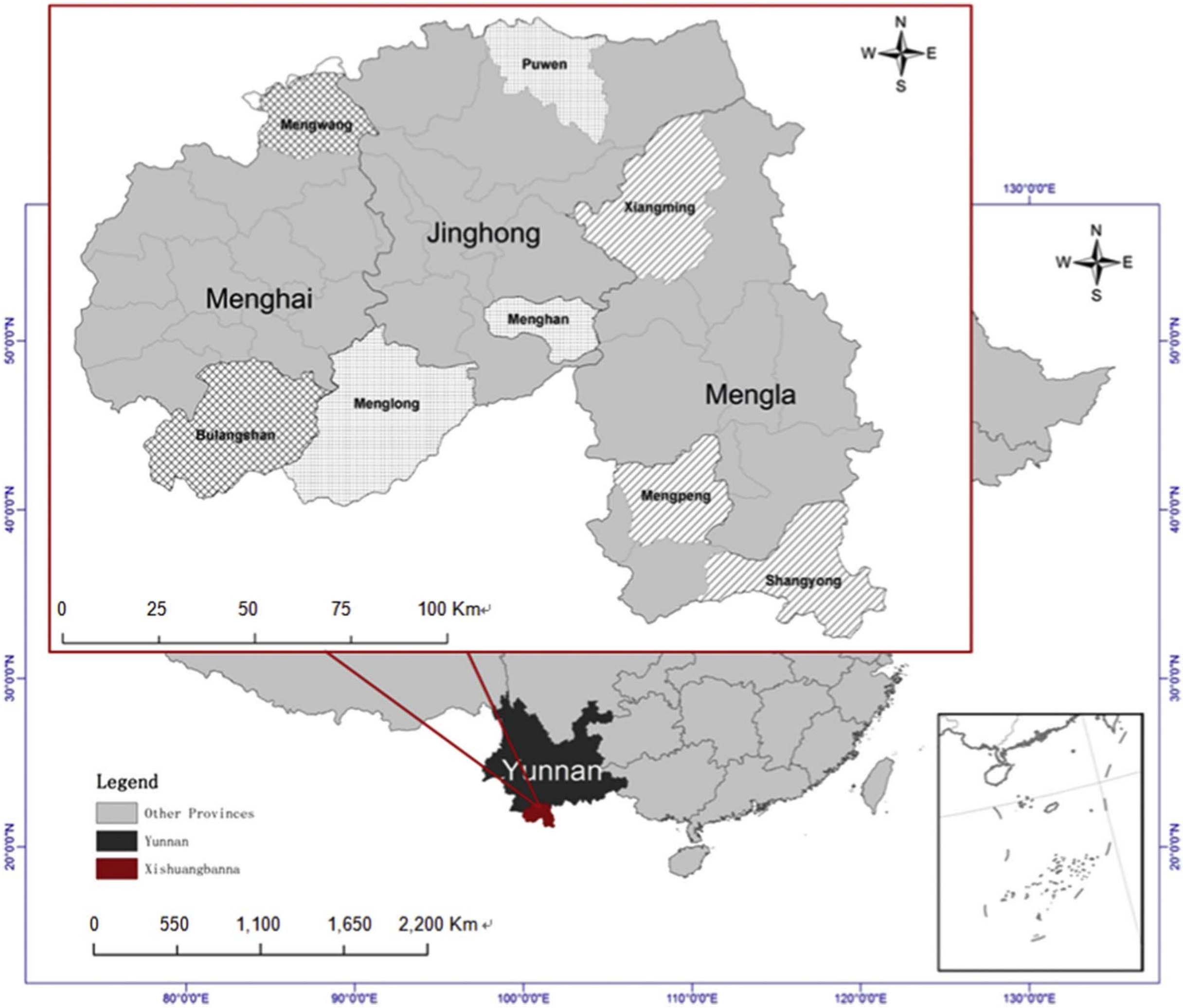

Fig. 2. Map of the study region and sample distribution.
Source: Min et al. (2017c).

3. Data and descriptive statistics

3.1. Study area

Xishuangbanna Dai Autonomous Prefecture (XSBN) is located in the southern region of the Yunnan province of China (Fig. 2), bordering Laos in the south and Myanmar in the west. XSBN covers approximately 19,124.5 km^2, an area that is > 95% mountainous regions with an altitude between 475 and 2429.5 m above sea level (MASL). XSBN is the most biodiversity-rich region in the tropical zone of southwestern China. Although XSBN covers only approximately 0.2% of the land area of China, it contains approximately 25% of the country's plant species (Xu, 2006).

In the 1950s, the Chinese government introduced natural rubber planting to XSBN for strategic purposes (Fox and Castella, 2013) by establishing large-scale state farms (Hu et al., 2008). Driven by the agricultural reforms of the 1980s, increasing numbers of rubber trees were planted by smallholders (Xu, 2006). In 2012, rubber cultivation areas in XSBN reached up to 4.34 million mu (Bureau of Statistics of Xishuangbanna Dai Autonomous Prefecture, 2014). As one direct environmental consequence, ecologically rich rainforests and evergreen forests were largely cleared to plant rubber trees (Shapiro, 2001). As of today, pristine forests remain only in nature reserves and some state forests (Xu et al., 2005). While the rapid development of rubber farming has contributed to a growth in income for rural households in XSBN (Fu et al., 2009b), its negative effects on the local natural environment and ecosystems pose a threat to the sustainability of local ecosystems.

3.2. Data collection

In March 2013, we performed a comprehensive socioeconomic survey of smallholder rubber farmers in XSBN. The household questionnaire used in the survey includes detailed information on the socioeconomic characteristics of all family members, rubber farming activities during an entire production period, farm and non-farm income sources, productive and consumptive assets, environmental awareness, willingness to participate in the restoration and protection of the local ecosystem, and several other questions relevant to rubber.

To obtain a representative sample of smallholder rubber farmers in XSBN, we applied a stratified random sampling approach, taking into account the density of rubber planting (rubber planting area per capita) and the distribution of rubber planting areas across townships (Min et al., 2017b). As shown in Fig. 2, eight townships were chosen from one city (Jinghong) and two counties (Menghai and Mengla) in XSBN.

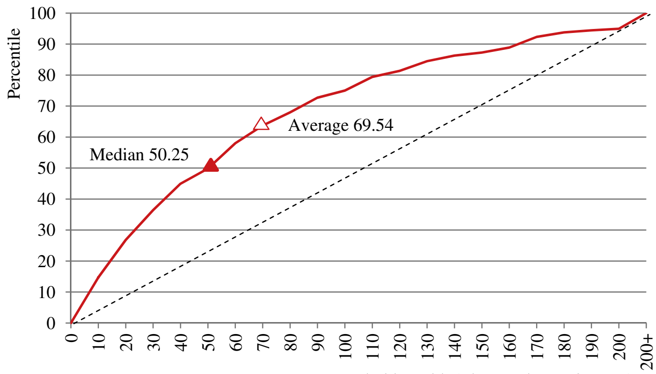

Fig. 3. Cumulative distribution of household wealth.

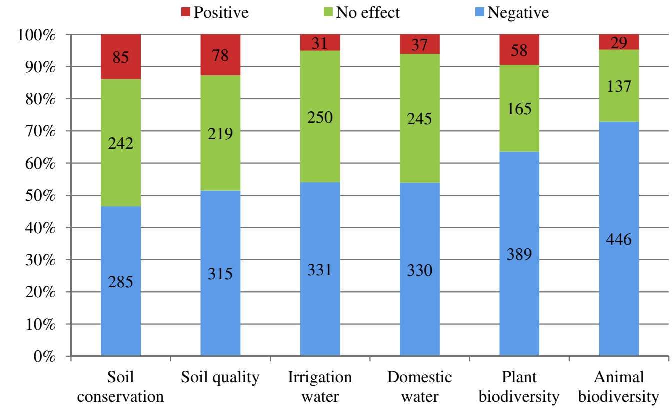

Fig. 4. Smallholders' awareness of the environmental impacts of rubber cultivation.

Due to the relatively low intensity of rubber distribution in Menghai, only two townships were included in the sample, while three townships were selected from Jinghong and Mengla. A total of 42 villages were drawn from the sample townships. Finally, sample households were randomly selected based on a list of smallholder rubber farmers in each village (Min et al., 2017c). In total, we administered a household survey with 612 smallholder rubber farmers in 42 villages, eight townships, and three counties of XSBN.

3.3. Descriptive statistics

In the following section, we present some basic descriptive statistics related to smallholder rubber farmers' household wealth, their awareness of the effects of rubber cultivation on the local environment, and their willingness to participate in ecosystem protection.

3.3.1. Household wealth and environmental awareness of smallholder rubber farmers

In line with Teklewold et al. (2013), we define household wealth as the total value of all non-land productive and consumptive assets. In Fig. 3, based on the cumulative distribution of household wealth, it can be seen that the median of household wealth is 50.25 thousand Yuan/person, which is 27.74% lower than the average wealth (69.54 thousand Yuan/person). Additionally, the Gini coefficient of household wealth is 0.507, meanwhile the Lorenz curve of household wealth (Appendix Fig. A1) further shows that a relatively large income gap exists among smallholder rubber farmers in XSBN and that most smallholders' wealth is skewed toward the lower wealth level.

In terms of environmental awareness, we asked smallholders to subjectively assess the effects of rubber cultivation - using the past situation as a reference point - on six aspects of the local ecological environment, i.e., soil conservation, soil quality, supply of irrigation water, supply of drinking water, plant biodiversity, and animal biodiversity. Our results show that while the negative impacts of rubber cultivation are widely discussed among researchers and policymakers (Liu et al., 2006; Xu, 2006; Hu et al., 2008; Fu et al., 2010; Yi et al., 2014), on average, only approximately half of smallholders are aware of them (Fig. 4). Among the six negative impacts, farmers primarily recognize the effect of rubber farming on animal biodiversity. Surprisingly, < 50% of smallholders recognize the negative effect on soil conservation, approximately 40% are unaware of any negative effects of rubber farming, and > 10% even expect rubber farming to have positive effects on the environment.

3.3.2. Farmers' willingness to participate in local ecosystem protection

To assess smallholders' willingness to participate in local ecosystem protection, we asked them three simple questions: (1) Are you willing to contribute money to restore and protect the local ecosystem threatened by rubber farming? (2) Are you willing to reduce your rubber planting area to restore and protect the local ecosystem threatened by rubber farming? and (3) Are you willing to provide free labor to restore and protect the local ecosystem threatened by rubber farming? As previous studies have suggested that different willingness-to-pay question formats and payment types may affect respondents' decisions (Xu et al., 2006; Hossack and An, 2015), the three questions used here may better capture farmers' choice preference for local ecosystem protection. Accordingly, the results show that approximately 75%, 31% and 88% of smallholder rubber farmers are willing to participate in local ecosystem protection by contributing money, reducing their rubber planting areas and providing free labor, respectively.

Fig. 5 shows the willingness of smallholder rubber farmers to participate in multiple ecosystem protection measures. For instance, approximately 7.35% of smallholder rubber farmers are not willing to participate in local ecosystem protection, implying that > 92% of smallholder rubber farmers are willing to participate by contributing money, reducing their rubber planting areas or providing free labor. Furthermore, > 75% of farmers are willing to participate in more than two ways.

Fig. 6 shows a Venn diagram of these three ways of participation, demonstrating all possible logical relations among them. Only a few choose one way, i.e., approximately 2.45% choose to contribute money, 1.45% to reduce rubber areas and 12.25% to provide free labor. In fact, farmers often tend to participate in local ecosystem protection by combining different ways of contributing. For instance, as shown in Fig. 6, 46% of respondents are willing to contribute money and provide free labor.

Table 1 presents farmers' willingness to participate in ecosystem

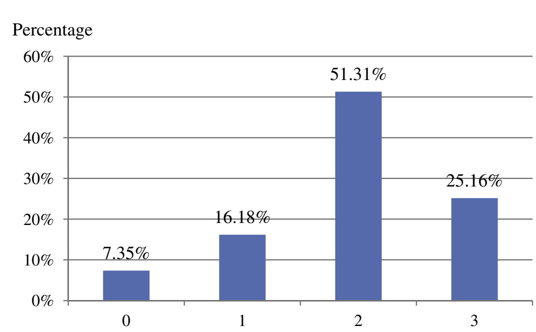

Fig. 5. Willingness of smallholders to participate in multiple ecosystem protection measures.

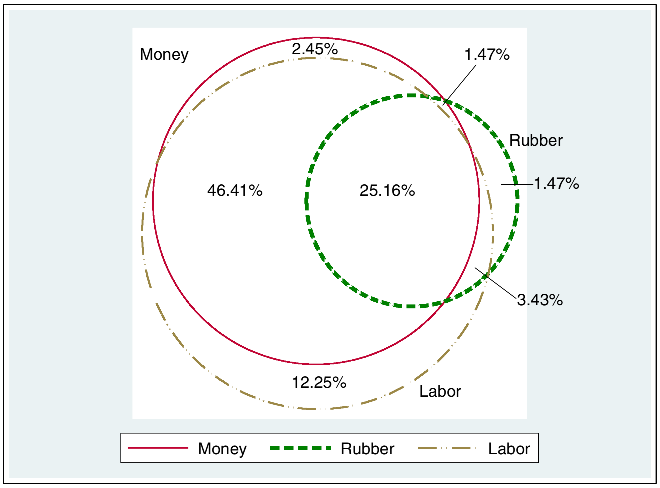

Fig. 6. Venn diagram of farmers' willingness to participate in ecosystem protection.

Table 1
Willingness to participate in environmental programs by different categories of household wealth and by perception of environmental effects.

Categories	Cumulative willingness	% of smallholders willing to		
		Contribute money	Reduce rubber planting area	Provide free labor
w_0: Household wealth (1000 Yuan/person)				
Poor (0 < wealth ≤ 26.35) #	1.86	67.34	33.67	85.43
Middle (26.35 < wealth ≤ 76.20)	2.02*	79.90***	35.29	86.76
Rich (76.20 < wealth)	1.94	78.94***	24.88*	90.43
e: Environmental awareness				
Perception of negative effects (number of items)				
Low (0 ≤ number ≤ 2) #	1.93	73.15	31.94	87.96
Middle (3 ≤ number ≤ 4)	1.94	77.00	29.41	87.17
High (5 ≤ number ≤ 6)	1.96	76.56	32.06	87.56
Perception of no effects (number of items)				
Low (0 ≤ number ≤ 2) #	1.93	75.38	31.66	86.93
Middle (3 ≤ number ≤ 4)	1.99	75.89	33.33	89.36
High (5 ≤ number ≤ 6)	1.90	75.34	27.40	87.67
Perception of positive effects (number of items)				
Low (0 ≤ number ≤ 2) #	1.97	76.95	31.38	88.65
Middle (3 ≤ number ≤ 4)	1.79	60.61**	39.39	78.79*
High (5 ≤ number ≤ 6)	1.27***	53.33**	6.67**	66.67***

Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively. The statistical test used is the mean-comparison test between the group and the reference group # in each category.

protection according to household wealth and environmental awareness. As shown, only a few significant differences were found. Wealthier farmers tend to participate in environmental programs more, and they prefer to contribute money and provide free labor rather than reduce their rubber planting areas. Significant differences can be found among smallholders in terms of awareness of the positive environmental effects of rubber cultivation. Smallholder rubber farmers who perceive rubber farming to be positive for the local environment are significantly less willing to participate in local ecosystem protection.

4. Econometric model and estimation

This section outlines the econometric models used to estimate the farmers' willingness to participate in ecosystem protection. First, we specify the dichotomous choice models concerning whether farmers are willing to participate in ecosystem protection. Second, we establish a model to estimate farmers' willingness to participate in multiple ecosystem protection measures. Third, a simultaneous estimation procedure is presented that employs a multivariate probit regression model (Greene, 2008). Finally, we describe the definitions and statistics of the variables used in the analysis as well as the estimation procedures of these empirical models.

4.1. Model specification

4.1.1. Model (1): farmers' willingness to participate in ecosystem protection in general

According to Eq. (10), which was derived from our theoretical framework, the model expressing whether smallholder rubber farmers are willing to participate in local ecosystem protection (y_1) can be specified as:

$$y_1 = \alpha + \alpha_1 C + \alpha_2\, e + \alpha_3 w_0 + \alpha_4 \boldsymbol{x} + \alpha_5 \boldsymbol{R} + \alpha_6 Q + \varepsilon \quad (11)$$

Where y_1 is a dichotomous variable, wherein $y_1 = 1$ if a smallholder is willing to participate; otherwise, $y_1 = 0$.The participation cost (C) here is not quantified and is measured by the specific way of participating in ecosystem protection. Thus, the vector C is further set to include three dummy variables: $C_1 = 1$ if the participation way is monetary contribution, $C_2 = 1$ if the participation way is reduction of rubber planting area, and $C_3 = 1$ if the participation way is provision of free labor; otherwise, C_1, C_2,C_3 will equal zero.

Following our first hypothesis, we define environmental awareness (e) as the amount of awareness of the positive effects of rubber cultivation on the six aspects of environmental impact, and we split it into three groups consistent with the descriptive statistics in Table 1. Similarly, in line with the setting in Table 1, household wealth (w_0), which trisects all samples, is set as three dummy variables, which represent the 33% relatively poorest households, the 33% middle-class households, and the 33% relatively richest households. As we are interested in assessing the effects of household wealth and environmental awareness on smallholders' participation in ecosystem protection, these two factors are prioritized to be included in the explanatory variables.

In Eq. (11), $\boldsymbol{x}$ denotes a vector of socioeconomic characteristic variables of respondents and households, $\boldsymbol{R}$ represents the size of farming rubber, Q is a vector of variables reflecting the specific local environmental condition, and $\boldsymbol{O}$ is excluded in the empirical model due to the possible collinearity between it and $\boldsymbol{R}$.

4.1.2. Model (2): farmers' willingness to participate in multiple ecosystem protection measures

Considering that we proposed three ways to participate in ecosystem protection, the willingness of smallholder rubber farmers to participate in multiple ecosystem protection measures may be an alternative dependent variable (y_2), which can also reflect the variances of their willingness to participate (Fig. 5 and Table 1). Hence, model (2) is specified as:

$$y_2 = \beta + \beta_1\, e + \beta_2 w_0 + \beta_3 \boldsymbol{x} + \beta_4 \boldsymbol{R} + \beta_5 Q + \mu \quad (12)$$

where y_2 denotes the number of participation ways that a smallholder is willing to undertake. According to the descriptive statistics in Fig. 5, the range of the count variable y_2 is from zero to three. Because model (2) does not involve a specific participation way, the vector C in Eq. (11) is excluded, while other variables are consistent in Eqs. (11) and (12).

Table 2
Variable definitions and sample means.
Data source: Author's survey.

	Variables	Definitions	Means
Characteristics of respondents and households			
$\boldsymbol{x}$	Age	Age of respondent (years)	41.58
	Education	Education level of respondent (years)	6.72
	Ethnicity	Ethnicity of respondent (1 = Han majority; 0 = minorities)	0.05
	Importance	Rubber income as a share of total household income	0.47
$\boldsymbol{R}$	Rubber	Rubber plantation area (hectares/person)	0.70
$\boldsymbol{Q}$	Project	Implementing the "Comprehensive control of rural environment" project (1 = yes; 0 = otherwise)	0.37
	Tourism	Are any tourists coming to the village? (1 = yes; 0 = otherwise)	0.28
	Elevation	Elevation of household location (meters above sea level (MASL))	
	Low	Elevation ≤ 600 MASL (1 = yes; 0 = otherwise)	0.20
	Middle	600 MASL < Elevation ≤ 800 MASL (1 = yes; 0 = otherwise)	0.47
	High	800 MASL < Elevation(1 = yes; 0 = otherwise)	0.33
	County		
	Menghai	Menghai county(1 = yes; 0 = otherwise)	0.14
	Jinghong	Jinghong city/county (1 = yes; 0 = otherwise)	0.45
	Mengla	Mengla county (1 = yes; 0 = otherwise)	0.41

4.1.3. Model (3): farmers' willingness to participate in ecosystem protection in specific ways

To model smallholder rubber farmers' willingness to participate in local ecosystem protection in specific ways, we further define three dichotomous dependent variables: $y_{31} = 1$ indicates that a farmer is willing to contribute money, $y_{32} = 1$ indicates that a farmer tends to reduce rubber planting area, and $y_{33} = 1$ means that a farmer prefers to provide free labor to protect the local ecosystem; otherwise y_{31}, y_{32} or y_{33} will equal 0. Considering the potential correlations between the three choices of participation ways, we establish a simultaneous model as:

$$\begin{cases} y_{31} = \theta + \theta_1 e + \theta_2 w_0 + \theta_3 \boldsymbol{x} + \theta_4 \boldsymbol{R} + \theta_5 Q + \varphi & \text{if} \quad C_1 = 1 \\ y_{32} = \theta' + \theta_1' e + \theta_2' w_0 + \theta_3' \boldsymbol{x} + \theta_4' \boldsymbol{R} + \theta_5' Q + \varphi' & \text{if} \quad C_2 = 1 \\ y_{33} = \theta'' + \theta_1'' e + \theta_2'' w_0 + \theta_3'' \boldsymbol{x} + \theta_4'' \boldsymbol{R} + \theta_5'' Q + \varphi'' & \text{if} \quad C_3 = 1 \end{cases} \tag{13}$$

Thus, the probability of one smallholder rubber farmer participating in ecosystem protection by contributing money, reducing the rubber planting area or providing free labor depends on all of the included exogenous variables.

4.2. Variables

Household wealth (w_0) and environmental awareness (e) were described above. The definitions and mean values of all the other variables are provided in Table 2. On average, the age of the respondents is approximately 42 years old, and their education level is relatively low at nearly 7 years. Although the majority of people in China are ethnically Han, Han people represent only 5% of all the respondents. Considering that XSBN is a minority autonomous prefecture, the variable of ethnicity is used to examine differences in the willingness to participate in ecosystem protection between minorities and the Han majority. The importance of a farmer's rubber plantation is measured by the share of the farmer's total household income represented by rubber income. Consequently, on average, rubber plantations comprise > 47% of the total household income. Here, we hypothesize that the importance of the rubber plantation positively influences the smallholders' decisions to contribute money but has a negative effect on the likelihood of reducing their rubber planting areas. On average, the size of rubber plantations is 0.7 ha per person.

Local environmental conditions are proxied by two variables at the village level, the implementation of "Comprehensive control of rural environment" and tourism, and the elevation of household location, as well as three counties' dummy variables. Assessing the impacts of these variables on farmers' willingness to participate in local ecosystem protection has somewhat corresponding implications. Since 2011, the "Comprehensive control of rural environment" project has been implemented by the Chinese central government to facilitate the control of contiguous rural environmental pollution (Ministry of Environmental Protection of China, 2013). We defined "implementing the project in the village" as a policy variable to evaluate whether the environmental protection project has any spillover effects on smallholders' willingness to participate in ecosystem protection. Ecotourism has been gaining in popularity and is widely believed to be capable of achieving both economic and ecological objectives (Naidoo and Adamowicz, 2005). If our hypothesis is correct that the existence of tourism in the village can encourage smallholder rubber farmers to restore and protect the local ecosystem, this will support the notion that developing ecotourism in rural XSBN is a method to improve the sustainability of the natural environment in rubber planting regions. Because XSBN is in a mountainous region, the elevation of a household's location is an important factor that influences the household's decision-making. The three counties' dummy variables can reflect possible regional heterogeneities in willingness to participate in local ecosystem protection.

Furthermore, Table A.1 shows differences in the mean values of the variables between farmers who are willing to contribute money and those who are not willing to contribute, between those who are willing to reduce the rubber planting area and those not willing to reduce, and between those who are willing to provide free labor and those not willing to provide. These differences provide an indication concerning possible correlations between these variables and the choices of three participation ways. Table A.2 presents Spearman's correlations between the willingness to participate in multiple ecosystem protection measures and independent variables.

4.3. Estimation procedure

To determine the impacts of environmental awareness on the willingness to participate in ecosystem protection, the model estimation is implemented in three steps. In model (1), a probit regression is used to estimate farmers' decision to participate in ecosystem protection. Given the nature of the dependent variable in model (2), we estimate it using both Tobit regression and Poisson regression. In model (3), a multivariate probit regression is applied to simultaneously estimate farmers' choices of participation ways, including monetary contribution, reduction of rubber planting area, and provision of free labor. Robust standard error is applied in all three models to control for the potential heteroskedasticity of independent variables. Based on the estimation results of models (1) and (3), the various probabilities can be correspondingly predicted. Finally, to further check the robustness of the setting form of key variables (household wealth and environmental awareness), we reestimate these three models by changing these variables from dummy form to continuous form.

Table 3
Results of probit regression.

Variables		Coef.	Robust std. err.	Marginal effects
Participation ways				
Money[a]				
Rubber		− 1.227	0.078***	− 0.447
Labor		0.476	0.087***	0.162
Household wealth				
Poor[a]				
Middle		0.200	0.088**	0.070
Rich		0.067	0.086	
Perception of positive environmental effects (number of items)				
Low (0 ≤ number ≤ 2)				
Middle (3 ≤ number ≤ 4)		− 0.241	0.157	
High (5 ≤ number ≤ 6)		− 0.704	0.204***	− 0.273
x	Age	− 0.004	0.003	
	Education	0.011	0.015	
	Ethnicity	− 0.374	0.163**	− 0.142
	Importance	0.213	0.102**	0.076
R	Rubber	0.036	0.053	
Q	Project	0.086	0.075	
	Tourism	0.357	0.084***	0.122
	Low[a]			
	Middle	0.221	0.095**	0.079
	High	0.165	0.111	
	Menghai[a]			
	Jinghong	− 0.094	0.119	
	Mengla	− 0.299	0.116***	− 0.107
	_cons	0.509	0.241**	
Obs.			1836	
Log pseudolikelihood			− 916.545	
Wald chi^2			476.890***	
Pseudo R^2			0.231	

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.
[a] Omitted in regression.

5. Results and discussion

5.1. Farmers' willingness to participate in ecosystem protection in general

Table 3 reports the results of the probit regression model by maximum likelihood estimation (Model (1)). The Wald chi^2 test is significantly different from zero, and most of the independent variables' coefficients are significant, suggesting that the equation is statistically valid. The results confirm that smallholder rubber farmers have significantly different preferences concerning ways to participate in local ecosystem protection. Farmers tend to provide free labor, followed by contributing money, while they have the lowest probability of reducing rubber plantation.

Consistent with our expectations, household wealth and environmental awareness significantly affect farmers' willingness to participate in local ecosystem protection. While the coefficient is significant only for the middle wealth households in Table 3, rich households also have a relatively higher participation probability compared to poor households (as shown in Fig. 7). Therefore, we can confirm (H2) that wealthier farmers are more willing to participate in local ecosystem protection in XSBN. As for the impacts of environmental awareness, compared to the low group that perceives fewer than three aspects of positive environmental effects, the high group with more than four aspects has a 27.3% lower probability to participate in ecosystem protection. This result means that farmers who perceive more positive environmental effects of rubber farming will have a lower probability of participation (Fig. 8). Hence, we confirm (H1) that awareness of the positive environmental effects of rubber cultivation significantly hinders farmers' willingness to participate in ecosystem protection.

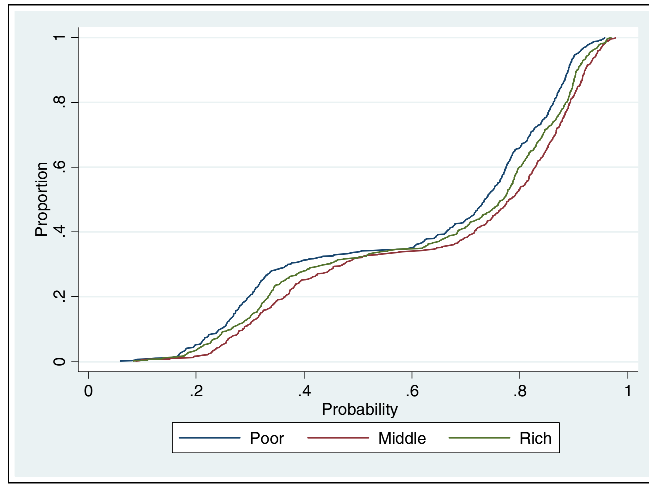

Fig. 7. Cumulative distribution of the probability of farmers' participation in ecosystem protection according to three levels of household wealth.

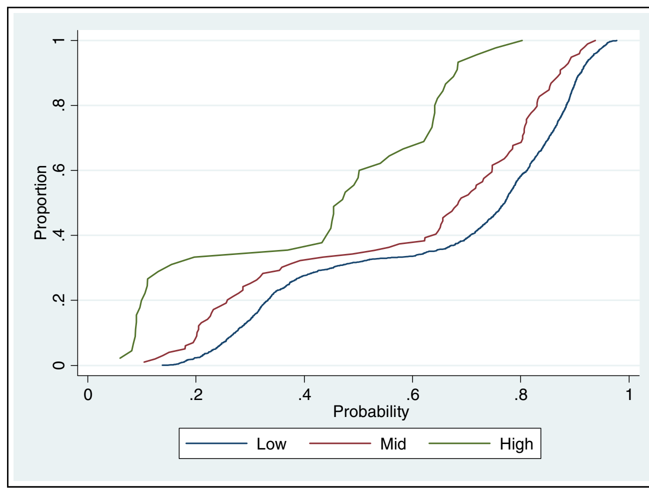

Fig. 8. Cumulative distribution of the probability of farmers' participation in ecosystem protection according to degree of perceived positive environmental impact.

Interestingly, the variable ethnicity has a significant and negative impact on the decision to contribute money, suggesting that the Han majority has a 17.3% lower probability to participate in ecosystem protection than ethnic minorities. This result might be caused by differences in traditional culture and lifestyle between Han and minorities, as the latter are indigenous to XSBN and their daily lives are highly associated with the extraction of local natural resources; e.g., various types of wild plants are often used as vegetables. To some extent, it can be argued that minorities have a closer relationship with the local natural environment, such that they are more willing to participate in local ecosystem protection.

The importance of rubber farming for household income also positively affects farmers' participation willingness. Households with a higher share of income from rubber farming are more likely to participate in local ecosystem protection, while the size of rubber area has an insignificant impact on the willingness to participate. The results also confirm that the existence of tourism in the village can encourage smallholder rubber farmers to restore and protect the local ecosystem. The farmers located in a village with tourism have a 12.2% higher probability to participate in ecosystem protection than the others. Hence, developing ecotourism in rural XSBN is likely a feasible policy

Table 4
Results of Tobit and Poisson regressions.

Variables		Tobit		Poisson	
		Coef.	Robust std. err.	Coef.	Robust std. err.
Household wealth					
Poor[a]					
Middle		0.236	0.126*	0.090	0.044**
Rich		0.039	0.124	0.029	0.045
Perception of positive environmental effects (number of items)					
Low (0 ≤ number ≤ 2)[a]					
Middle (3 ≤ number ≤ 4)		− 0.192	0.295	− 0.105	0.109
High (5 ≤ number ≤ 6)		− 0.814	0.227***	− 0.401	0.135***
x	Age	− 0.004	0.005	− 0.002	0.002
	Education	0.011	0.022	0.005	0.008
	Ethnicity	− 0.405	0.246	− 0.171	0.102*
	Importance	0.228	0.141	0.081	0.049*
R	Rubber	0.073	0.102	0.020	0.032
Q	Project	0.102	0.104	0.030	0.036
	Tourism	0.403	0.118***	0.146	0.039***
	Low[a]				
	Middle	0.262	0.132**	0.089	0.046**
	High	0.186	0.156	0.067	0.055
	Menghai[a]				
	Jinghong	− 0.087	0.168	− 0.042	0.057
	Mengla	− 0.357	0.166**	− 0.134	0.058**
	_cons	1.829	0.338***	0.587	0.120***
Obs.			612		612
Log pseudolikelihood			− 848.542		− 884.094
F/Wald chi^2			3.430***		54.3***
Pseudo R^2			0.0255		0.0099

Note: Tobit model: 45left-censored observations at $y_2 \leq 0$; 413 uncensored observations; 154 right-censored observations at $y_2 \geq 3$; *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.
[a] Omitted in regression.

design to bring smallholder rubber farmers closer to a more sustainable path. In addition, smallholder rubber farmers' willingness to participate in the local ecosystem indeed exhibits regional heterogeneity. Farmers located in the middle elevation region have a 7.9% higher probability to participate than those located at low elevations, while the farmers in Mengla County have a 10.7% lower likelihood of participating in local ecosystem protection compared with those in Menghai.

5.2. Farmers' willingness to participate in multiple ecosystem protection measures

Table 4 presents the estimation results of smallholder rubber farmers' willingness to participate in multiple ecosystem protection measures using Tobit regression and Poisson regression (Model (2)). The results show both F and Wald chi^2 tests are significantly different from zero, suggesting that both equations are statistically valid. Although the significance of most of the independent variables' coefficients is consistent between the two models, the statistical quality (joint significance) of the Poisson model is apparently slightly better than that of the Tobit model.

Although the dependent variables differ between model (1) and model (2), the results show that the significance levels of almost all the independent variables in Table 4 are consistent with those in the results of model (2) in Table 3, confirming the robust impacts of those significant independent variables on farmers' willingness to participate in local ecosystem protection.

The results suggest that middle income farmers are willing to participate in local ecosystem protection in more ways, while farmers who perceive more positive environmental effects of rubber farming tend to participate in no ways or only one way. The coefficients of "ethnicity" and "importance" are significant in the Poisson model, indicating that minorities and farmers with a greater share of income from rubber farming prefer to participate in more ways. Tourism encourages smallholders to apply multiple methods to restore and protect the local ecosystem. In addition, the willingness of farmers to participate in multiple ecosystem protection measures differs by elevation and county.

5.3. Farmers' willingness to participate in ecosystem protection in specific ways

Table 3 shows the results of the multivariate probit regression with regard to smallholder rubber farmers' willingness to participate in ecosystem protection in specific ways. The Wald chi^2 test indicates the validity of all three equations. The likelihood ratio test of rho21 = rho31 = rho32 = 0 suggests that the three ways of participating (i.e., contributing money, reducing the rubber planting areas and providing free labor) should be simultaneously estimated; otherwise, the results will be biased. Therefore, the use of the multivariate probit regression model in this study is reasonable and valid.

In Table 5, the statistics on rho21, rho31 and rho22 reveal the correlations between the decision to participate in ecosystem protection by contributing money, reducing the rubber planting area and providing free labor. The positive correlations between these factors suggest that the choice to participate in ecosystem protection by these three ways may be complementary. Based on the estimation results, we further predict the probability of farmers' participation in the three possible ways. Fig. 9 shows farmers' choice preference, confirming

Table 5
Results of multivariate probit regression.

Variables		Money		Rubber		Labor	
		Coef.	Robust Std. Err.	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
Household wealth							
Poor#							
Middle		0.361	0.143**	0.126	0.135	0.094	0.166
Rich		0.299	0.147**	− 0.285	0.140**	0.308	0.180*
Perception of positive environmental effects (number of items)							
Low #							
Middle		− 0.531	0.249**	0.241	0.238	− 0.408	0.272
High		− 0.661	0.313**	− 0.918	0.461**	− 0.886	0.327***
x	Age	− 0.002	0.005	− 0.006	0.005	− 0.003	0.007
	Education	0.036	0.026	− 0.010	0.024	0.014	0.026
	Ethnicity	− 0.599	0.266**	− 0.311	0.272	− 0.169	0.316
	Importance	0.427	0.170**	− 0.092	0.163	0.419	0.218*
R	Rubber	− 0.007	0.083	0.180	0.071**	− 0.097	0.095
Q	Project	0.213	0.125*	− 0.065	0.121	0.141	0.159
	Tourism	0.511	0.150***	0.301	0.132**	0.324	0.170*
	Low#						
	Middle	0.318	0.165*	0.119	0.158	0.240	0.192
	High	0.327	0.187*	− 0.028	0.177	0.220	0.217
	Menghai#						
	Jinghong	0.024	0.191	0.004	0.188	− 0.500	0.266*
	Mengla	− 0.107	0.186	− 0.452	0.185**	− 0.493	0.256*
	_cons	− 0.212	0.381	− 0.148	0.372	1.125	0.488**
	Rho21	0.228	0.067***				
	Rho31	0.617	0.060***				
	Rho32	0.164	0.083**				
Obs.		612					
Log pseudolikelihood		− 854.109					
Wald chi^2		131.330***					
Chi^2 (likelihood ratio test of rho21 = rho31 = rho32 = 0)		78.199***					

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

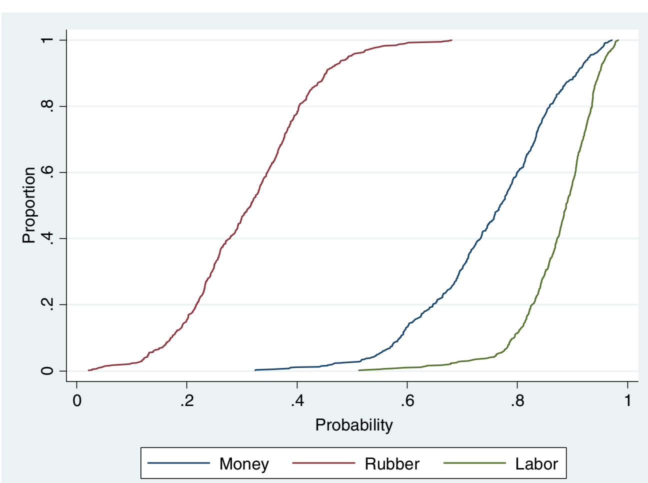

Fig. 9. Cumulative distribution of farmers' participation probabilities in ecosystem protection by the three ways.

again that providing labor has the highest probability, followed by monetary contribution, while reducing rubber land has the lowest probability.

While household wealth is found to have a significant impact on the smallholder rubber farmer's willingness to participate in ecosystem protection, the coefficients among the three equations differ in sign (Table 5). Compared to the 33% of households that are relatively poor, the 33% of relatively rich farmers are more likely to participate in ecosystem protection by contributing money and providing free labor; however, in terms of reducing their rubber planting areas, the relatively rich farmers are significantly less willing to participate. Hence, we confirm our third hypothesis (H3).

In Appendix Figs. B1, B2 and B3, the cumulative distributions of the probabilities of contributing money, reducing rubber planting and providing free labor visually reveal entirely different preferences for participation methods between the poor and rich. It seems that wealthier smallholders are more likely than poorer farmers to contribute money and free labor in exchange for the reduction of rubber planting areas.

As shown in Table 5, regardless of the ways of participation, environmental awareness always significantly affects the farmers' decisions to participate in ecosystem protection. Compared to farmers who perceive fewer than three attributes of positive environmental effects of rubber farming, farmers who perceive more than four factors always have the lowest probability of contributing money (Appendix Fig. B4), reducing the rubber planting area (Appendix Fig. B5) and providing free labor (Appendix Fig. B6). This result is consistent with the results of models (1) and (2). Hence, we consider our results to be robust. This result implies that improving smallholder rubber farmers' awareness of the negative environmental effects of rubber cultivation is a feasible and efficient strategy to encourage the participation of smallholder rubber farmers in local ecosystem protection.

In addition to the significant variables of ethnicity, importance, tourism, elevation and county interpreted in model (1) and model (2), we found two more interesting significant independent variables, i.e., "Rubber" and "Project". First, while the size of the rubber plantation does not have a significant impact on participation by contributing money and providing labor, farmers who plant more rubber plantations are more willing to reduce their rubber planting areas. Second, the

Table 6
Robust check for model (1), (2) and (3).

Variables	Model (1)	Model (2)		Model (3) multivariate probit		
	Probit	Tobit	Poisson	Money	Rubber	Labor
Household wealth	7.25×10^{-7} (4.04×10^{-7})*	2.07×10^{-6} (7.24×10^{-7})***	5×10^{-7} (1.4×10^{-7})***	2.48×10^{-6} (9.81×10^{-7})**	-2.59×10^{-6} (8.68×10^{-7})***	2.4×10^{-6} (1.19×10^{-6})**
Environmental awareness	−0.130 (0.032)***	−0.293 (0.068)***	−0.118 (0.029)***	−0.105 (0.055)*	−0.104 (0.053)**	−0.141 (0.060)**
Control for other variables	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1836	612	612		612	
F/Wald chi^2	432.61***	4.57***	68.06***		137.08***	

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively; Robust standard error in parentheses.

implementation of the "Comprehensive control of rural environment" project has a significant and positive effect on smallholders' willingness to participate in ecosystem protection by contributing money. This result confirms the existence of positive spillover effects of the government-dominated environmental protection project in rural China.

5.4. Robustness

Considering the estimation results may be affected by the manual setting forms of key variables, we further re-run the estimations for model (1), (2) and (3) through changing the variable form of household wealth and environmental awareness as continuous variables. As shown in Table 6, the coefficients of household wealth among the three models are always statistically significant, confirming that smallholder rubber farmers with more wealth are more willing to participate in ecosystem protection but are unwilling to reduce rubber plantations. The awareness of positive effects of rubber cultivation negatively affect farmers' willingness to participate in the measures of ecosystem protection including monetary contribution, reducing rubber plantation and voluntary labor. These results are consistent with our theoretical analysis and the original empirical results, which suggests that the results did not depend on the setting form of key variables. Hence, this additional analysis has helped to make our findings more stable.

6. Summary and conclusions

The participation of smallholder rubber farmers is essential to restore and protect ecosystems threatened by extensive rubber farming. Using household survey data collected from 612 smallholder rubber farmers in Xishuangbanna Dai Autonomous Prefecture, this study assesses farmers' willingness to participate in ecosystem protection by making monetary contributions, reducing their rubber plantation areas and providing free labor. The results show that most smallholder rubber farmers are willing to participate in local ecosystem protection, and their choices of the three participation ways are complementary.

While household wealth has a significant impact on the willingness of smallholder rubber farmers to participate in ecosystem protection, wealthier farmers are more likely to participate in ecosystem protection by contributing money and providing labor but are less willing to reduce the size of their rubber planting areas. However, poorer farmers demonstrate a greater willingness to reduce their rubber planting areas. Because the price of natural rubber has recently declined, we conclude that in the future, more farmers may be willing to reduce their rubber planting areas.

Although the experiment of this study did not presume any monetary incentive for participating in ecosystem protection, smallholder rubber farmers still expressed rather positive attitude to participate. Therefore, Payments for Ecosystem Services (PES) schemes should be an effective means to encourage rubber farmers to participate in local ecosystem protection and even reduce their rubber areas. This supports the notion that forest restoration is possible in XSBN when farmers are given appropriate eco-compensation (Yi et al., 2014).

We found that smallholder rubber farmers' awareness of the negative environmental effects of rubber cultivation is high, although some farmers are unaware of these effects. Positive environmental awareness of rubber farming hinders farmers' willingness to participate in ecosystem protection. Therefore, a knowledge transfer project implemented by the agricultural extension service or other research agencies to make smallholder rubber farmers more aware of the negative effects of rubber cultivation may enhance their willingness to participate in local ecosystem protection.

We also found that smallholder rubber farmers who are from ethnic minorities or who possess a larger rubber area show a higher tendency to participate in ecosystem protection. Furthermore, government-initiated environmental protection projects, such as the "Comprehensive control of rural environment" project, can promote smallholder rubber farmers' willingness to participate. Also, ecotourism could play an increasingly important role in environmental conservation in rural XSBN and similar mountainous regions in southern China.

This study did, however, have two limitations. First, farmers' awareness of the environmental effects of rubber cultivation are subjectively assessed through the comparison with the previous situation when farmers did not plant rubber. There may be some places (deforestation before planting rubber) where the environment become better due to the cultivation of rubber trees, thus the farmers were aware of positive environmental effects of rubber cultivation and not willing to reduce rubber for ecosystem protection. Hence, it is recommended to take into account the actual environmental situation in the future studies. Second, although the study on farmers' willingness to participate in the hypothetical ecosystem protection measures can provide important reference information for the future policy-making, focusing on the already proposed environmental conservation program such as "Environmentally friendly rubber plantation" and "Natural rubber eco-certification" may have more practical implications.

Acknowledgments

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Table A.1
Differences in mean values of variables.
Data source: Author's survey; mean-comparison test.

Variables	Contribute money			Reduce rubber planting area			Provide free labor		
	Yes	No	Diff.	Yes	No	Diff.	Yes	No	Diff.
Sample size	462	150		191	421		536	76	
Age	41.35	42.28	− 0.93	40.96	41.86	− 0.90	41.44	42.55	− 1.11
Education	6.83	6.40	0.43*	6.70	6.73	− 0.03	6.75	6.55	0.19
Ethnicity	0.04	0.07	− 0.04*	0.04	0.05	− 0.01	0.04	0.05	− 0.01
Importance	0.49	0.40	0.10**	0.46	0.47	− 0.01	0.48	0.40	0.08*
Rubber	0.72	0.66	0.06	0.77	0.68	0.09	0.70	0.77	− 0.08
Project	0.40	0.29	0.10**	0.37	0.37	0.001	0.38	0.32	0.06
Tourism	0.32	0.15	0.17***	0.33	0.26	0.07*	0.29	0.20	0.09*
Low	0.20	0.20	− 0.001	0.18	0.21	− 0.03	0.20	0.22	− 0.03
Middle	0.48	0.45	0.04	0.50	0.46	0.03	0.49	0.39	0.09
High	0.32	0.35	− 0.04	0.32	0.33	− 0.003	0.32	0.38	− 0.06
Menghai	0.13	0.17	− 0.05	0.16	0.13	0.04	0.14	0.09	0.05
Jinghong	0.47	0.41	0.07	0.52	0.43	0.09**	0.46	0.45	0.01
Mengla	0.40	0.42	− 0.02	0.32	0.45	− 0.13***	0.40	0.46	− 0.06

*, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

Table A.2
Spearman's correlation between willingness to participate in multiple ways of ecosystem protection and independent variables.
Data source: Author's survey.

Variables	Spearman's rho
Age	− 0.05
Education	0.04
Ethnicity	− 0.06
Importance	0.08**
Rubber	0.05
Project	0.05
Tourism	0.15***
Low	− 0.04
Middle	0.06
High	− 0.03
Menghai	0.01
Jinghong	0.08**
Mengla	− 0.09**

*, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

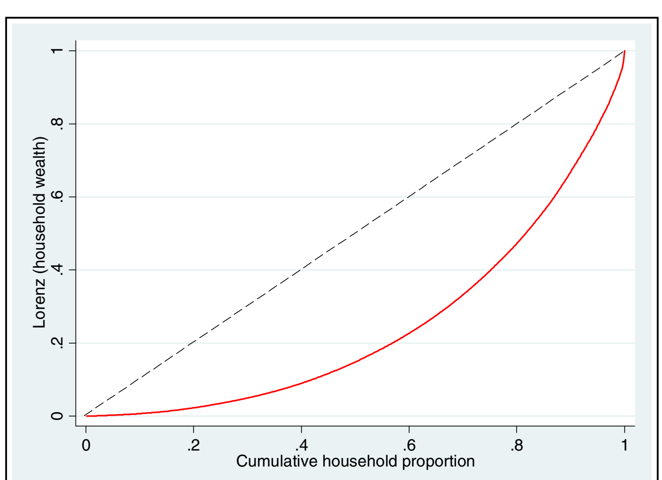

Fig. A1. Lorenz curve of household wealth of smallholder rubber farmers.

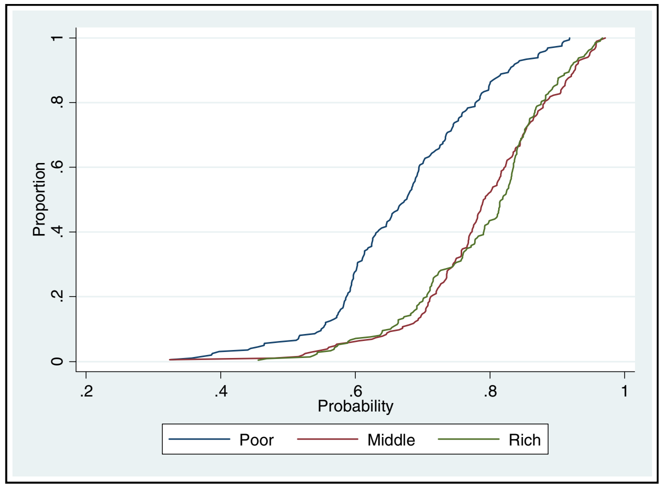

Fig. B1. Cumulative distribution of the probability of contributing money according to three levels of household wealth.

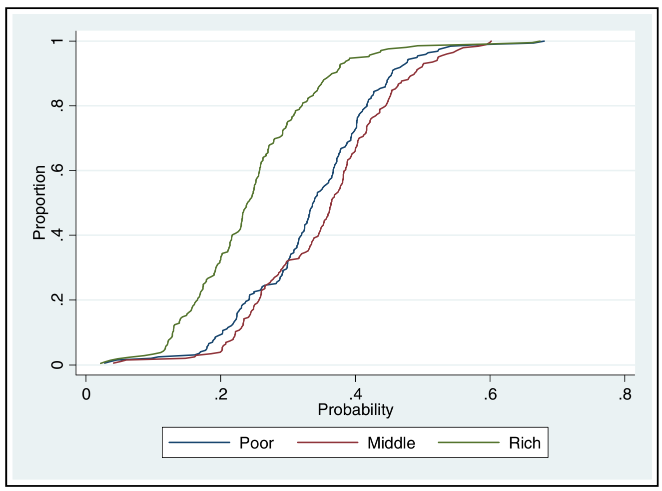

Fig. B2. Cumulative distribution of the probability of reducing rubber areas according to three levels of household wealth.

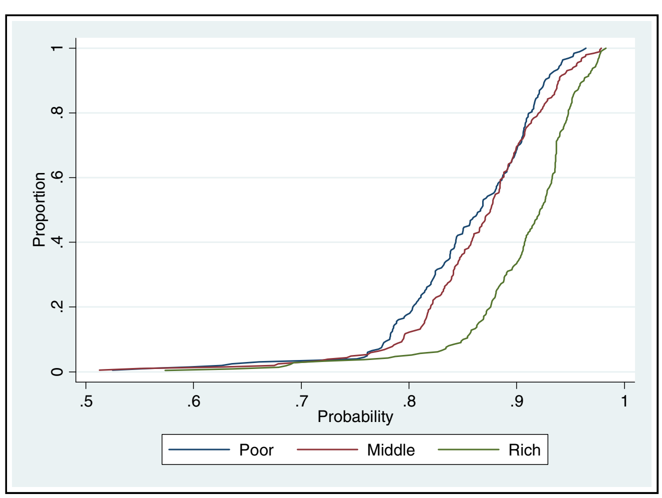

Fig. B3. Cumulative distribution of the probability of providing free labor according to three levels of household wealth.

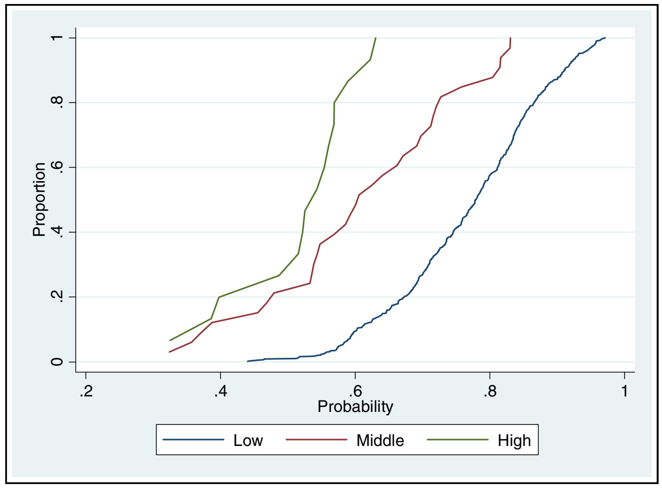

Fig. B4. Cumulative distribution of the probability of contributing money according to the degree of perceived positive environmental impact.

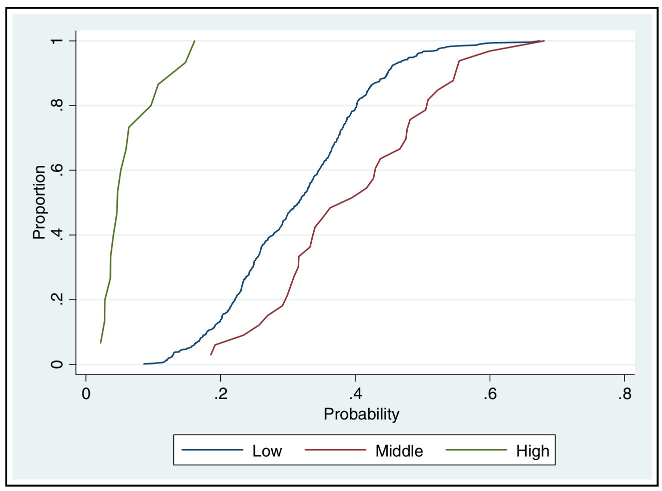

Fig. B5. Cumulative distribution of the probability of reducing rubber areas according to the degree of perceived positive environmental impact.

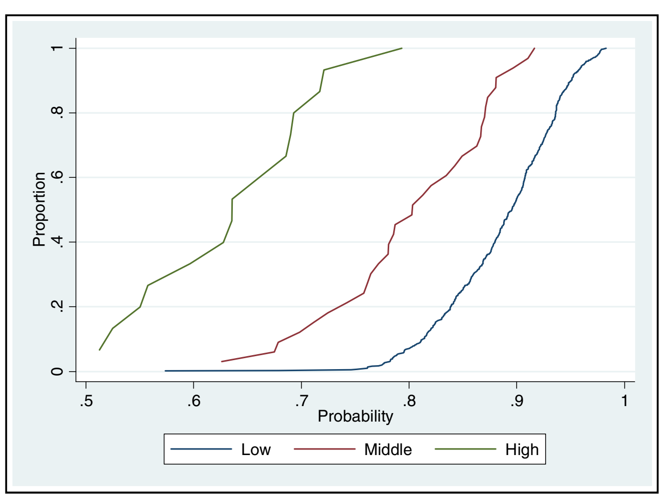

Fig. B6. Cumulative distribution of the probability of providing free labor according to the degree of perceived positive environmental impact.

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