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How the Risk Attitudes of Small-Scale Households Drive Forest Carbon Sequestration Supply: A Risk Experiment in China

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October, 2016

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Zhu Zhen, Shen Yueqin, Bai Jiangdi

EXECUTIVE SUMMARY

Climate change and carbon emission reductions are growing concerns all over the world. It is suggested that mitigating climate change by enhancing forest carbon sequestration (FCS) may be a relatively low-cost option and would likely yield other environmental benefits. In the last few years, China has become the country with the largest artificial afforestation area in the world, and it pays a lot of attention to FCS projects. After collective forest tenure reform in China in the last 10 years, small-scale households have become the main subject of forest management endeavors as potential suppliers of FCS.

The main objective of this study was to find out: (1) how the risk attitudes of small-scale rural households affected FCS outcomes; and (2) how the risk attitudes of households influenced their willingness to participate in FCS projects.

Through a survey of 200 households and a risk experiment in Zhejiang province, the optimal rotation length for Chinese fir (with carbon value taken into account) was found to be 28 years, which was identical to the optimal rotation length with only timber benefit. The carbon forestland expectation value (FEV) was higher than that with only timber benefit for three risk attitude groups, but the households had little incentive to change their harvest decisions at a low carbon price.

Among the three risk attitude groups, although they had the same optimal rotation age with carbon value, their carbon supply per hectare was different due to planting density difference. The risk-averse group paid more attention to and made higher investments in FCS management. Using a sensitivity analysis, the carbon rotation length and FCS per hectare were found not to change significantly unless there was a big change in carbon price, cost, and discount rate for all three groups. From the binary logit model, the results showed that the higher risk-tolerant groups were less willing to participate in FCS projects than the risk-averse group. Those with higher off-farm earnings were not attracted to FCS projects.

To encourage local small-scale households to participate in FCS projects, government policies need to be designed to encourage large-scale forest management and improve the centralization of forestland. Forestlands owned by households who have migrated to cities or that depend highly on off-farming income can be contracted to other households who need to expand their forest management areas. Given that the risk-averse group provides higher FCS per hectare, the government should pay more attention to the risk-averse group and encourage such households to develop FCS management skills through, among other things, introducing FCS projects and FCS training.

1.0 INTRODUCTION

There is growing concern over the accumulation of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), and associated global warming. Since the early 1990s, governmental and nongovernmental organizations across the globe have been discussing strategies to mitigate atmospheric concentrations of GHGs (Hedger 1998). It is widely recognized that forests play an important role in the global carbon cycle by sequestering and storing carbon, which enables the switch from more energy-intensive materials such as steel to forest products, and facilitating the substitution of fossil fuels with biofuels (Brand 1998). Compared with other technical approaches, it is suggested that mitigating climate change by enhancing forest carbon sequestration (FCS) would be a relatively low-cost option and would also likely yield other environmental benefits. It is this role of forests which influenced participants of the Kyoto Protocol[1] to allow countries to count carbon sequestered by forests in a country's emission targets (Dixon et al. 1993; Sampson and Sedjo 1997; Marland and Schlamadinger 1999).

1.1 Forest Carbon Sequestration

Forestry has been proposed as a means to reduce net GHG emissions by either reducing the sources or enhancing carbon sequestration. In the formulation of the Kyoto Protocol in 1997, forest management practices such as afforestation, reforestation, forest thinning, slash and dead wood management emerged as sources of carbon sequestration to offset the GHG emission reduction commitments of Annex 1 countries[2] (Lattanzio 2011). Also, preliminary research indicates that increasing active forest management can enhance carbon sequestration (Lisk, Perruchoud, and Karjalainen 2002; Skog, Marcin, and Heath 1996) and be cost effective. Dixon (1997) estimated that the sequestration of carbon through silvicultural practices could cost between USD 2–56 per metric ton. Furthermore, forests that are already under management for commodity production sequester additional carbon by increasing the rotation time of the trees and by producing more products with a long product life. Many authors adapted the Hartman model (Hartman 1976) to analyze the impacts of various forms of carbon payments on the optimal rotation age and on the supply of sequestered carbon (Romero, Ros, and Díaz-Balteiro 1998; Díaz-Balteiro and Romero 2001; Plantinga and Birdsey 1994; Murray 2000; Nghiem 2009; Englin and Callaway 1993; Hoen and Solberg 1994; van Kooten, Binkley, and Delcourt 1995).

Due to the immature carbon trade market, low and uncertain carbon prices reduce the incentive for forest owners to change their traditional forest management practices. In recent years, a great number of carbon projects have been developed, which caused carbon price to fall sharply as supply exceeded demand considerably. For example, the

1 The Kyoto Protocol, which was adopted in Kyoto, Japan, on 11 December, 1997, is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits Annex I parties by setting internationally binding emission reduction targets on them.

2 Annex I parties include the industrialized countries who were members of the Organization for Economic Co-operation and Development in 1992 plus countries with economies in transition (EIT), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

average price of voluntary carbon offsets reached an all-time low in 2014 at USD 3.8 (Forest Trends - Ecosystem Marketplace 2015). The carbon market in developed countries has also dropped significantly; for instance, the price of a permit to emit a metric ton of carbon dioxide in a emissions trading scheme (ETS) in the European Union fell 40% on 24 January, 2013, to EUR 2.81. For developing countries, the carbon trade market and FCS management are really new issues, which hold a lot of uncertainties about the diversity of FCS products, prices, costs, and yields. Differing information from carbon sellers/suppliers and buyers increases the risks, especially for rural carbon sellers.

Given such uncertainties in developing countries, the risk attitudes of forest dwellers may influence their willingness to participate in an FCS management project. In many developing countries, small-scale community forestry has become one of the main forms of forest tenure. These small-scale households are usually risk-averse (Wiens 1976; Dillon and Scandizzo 1978) and have to make a trade-off between their expected carbon benefit and the risk of loss in this new market, which is being promoted by national climate change policies.

Some researchers have studied risk attitudes in natural resource management. For example, Suter and Glenn (1995) have argued that current ecological assessments do not sufficiently address spatial and temporal scales for ecosystem valuation and suggest the development of ecological risk assessment to overcome this problem. Ananda and Herath (2005) have found that there was significant risk-adverse behavior by stakeholder groups (except tour operators)[3] in public forest reserve regions in Australia toward old-growth forest conservation and forest-based recreation because tourism activities or old-growth forest harvesting were banned or restricted in the reserves. Couture and Reynaud (2011) developed a multiple forest-use model to determine the optimal harvest date for a forest stand producing both timber and carbon benefits under the risk of fire. However, few researchers have looked at how risk attitudes influence participation in FCS management projects.

1.2 China as a Case Study for FCS

As the largest developing country in the world, China is currently the biggest global primary energy consumer and carbon emitter. It occupies approximately one-fifteenth of the world's land area and one-twentieth of the world's forest area (FAO 2014). Driven by the increasing pressure from the international community to reduce carbon emissions, China is dedicated to combating climate change by increasing its forest carbon sink and by paying more attention to FCS projects due to their cost-effectiveness in reducing carbon emissions.

3 The stakeholders groups not only comprised the residents who lived in public forest reserve regions, but also industry groups, landholders, conservationists, tour operators, and recreationists operating in public forest areas in Australia. These public forest areas are covered by Regional Forest Agreements.

A total of 31 FCS projects sponsored by the China Green Carbon Foundation (CGCF) have been developed. From among them, about 40% are located in the Southern Collective Forest Area,[4] which is one of the largest forest areas in China. It covers 10 provinces in Southern China, accounting for 45.02% and 31.69% of total forest area and volume, respectively. After the collective forestland tenure reform, which includes laws such as Document No. 9 of 2003 (Resolutions on Forestry Development), it is estimated that more than 2.1 billion ha or 70% of collective forestland has been assigned to individual households (Zhang and Kant 2005). On average, there are less than 3.5 ha of forestland per household. These small-scale households have forest tenure certification from the local government and have rights to private use of their forestland. Thus, China is a good study ground for FCS due to its rich experience in FCS projects and because of the fact that its small-scale households have decision-making power in forest management.

1.3 Objectives of the Study

Identifying how such risk attitudes influence smallholders' willingness to join FCS projects will be particularly useful in deciding how to motivate more small households with no FCS experience to join FCS projects not only in China, but also in other developing countries.

The main objectives of this study were to find out:

1. how the risk attitudes of households influenced their willingness to participate in FCS projects, and
2. how the risk attitudes of households affected their FCS management strategies.

This paper is structured into four parts. Part 1 is the introduction with the objectives of the study. Part 2 is on the methodology, followed by the results in Part 3. Conclusions and policy implications are discussed in Part 4.

2.0 METHODOLOGY

In this study, we surveyed 200 sample households in five counties in Zhejiang, which is one province in the southern collective forest area in China, and analyzed the risk attitudes of these households through a risk experiment. Then, we used an optimal rotation model with carbon benefit to measure the optimal rotation age, forestland expectation value, and carbon supply per hectare of different risk attitudes groups in FCS management. We also used a logit model to discuss the impact on household willingness to join an FCS project based on the different risk attitudes.

4 In China, similar to agricultural ownership, two types of forestland ownership exist: state ownership and village collective ownership. Today, collectively owned forests account for 58% of China's total forest area and 32% of China's total timber volume. A total of 10 provinces in Southern China are mainly under village collective ownership, and these 10 provinces are called the Southern Collective Forest Area (SFA 2015).

2.1 Study Sites

Zhejiang province, a developed province in Southern China, was our province of choice for the study. The total land area of this province is about 100,000 km^2, accounting for 1.06% of the land area of China. In 2014, the GDP in Zhejiang was about USD 613.4 billion. According to our sampling survey of the inhabitants, the average per capita disposable income of urban residents is about USD 1,127.9, while the average per capita net income of farmers is USD 2629.6 (ZSB 2015).

Zhejiang is a typical southern collective forest province. There are 6.61 million ha of forestland in Zhejiang, and the total volume of stumpage[5] is about 0.24 billion m^3. The forest coverage rate of the province is about 60.58% (ZFB 2015). After the collective forest reform in 2003, more than 5 million ha of forestland were divided into households, but the average forestland area per household is less than 3.5 ha (ZFB 2015).

The Zhejiang government pays a lot of attention to FCS projects as an important strategy to reduce global warming. In September 2010, the Zhejiang Carbon Fund, the first provincial carbon sequestration fund in China, was set up, and it was financed by capital from enterprises, business banks, etc. This fund was part of the China Green Carbon Fund (CGCF).

Since 2007, there have been more than four regional FCS projects financed by national or provincial carbon sequestration funds in Zhejiang; the total area involved exceeds 6,700 ha. The Chinese National Forestry Bureau and Zhejiang Forestry Bureau (ZFB) have identified some common features of these FCS projects. All of them have focused on forestation with selected local tree species, which have good carbon capture capability.[6]

Special technological standards for FCS projects have been drawn up. First of all, there must be a baseline survey of land-use change, land vegetation, human activity, and carbon stock before forestation. The land selected should be bare or degraded forestland from January, 2000. Secondly, types of trees with good carbon capture capability such as Chinese fir should be chosen (13.5 t/ha) (Zhu et al. 2008). Young seedlings from the locality are to be used and the use of machinery for forest cultivation is not allowed in a bid to reduce the consumption of fossil fuel. Thirdly, the use of chemical pesticides and herbicides is not encouraged. These are to be substituted by labor inputs and organic fertilizers. Finally, FCS management must be monitored continually over time. Any activities such as the use of machinery to cultivate the forest, transport seedlings and timber, and do thinning will be recorded along with the annual net carbon sink value.

Chinese fir is the main forest species in the studied FCS project areas. Chinese fir is mainly located in the 10 southern provinces and covers about 7.54 million ha, which is 24% of the planted forest area in China (SFA 2015). Chinese fir is the main timber wood in Zhejiang, covering about 820,000 ha or 20% of forest area in the province (ZFB 2015).

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5 Stumpage means standing timber or uncut marketable timber.

6 Tree species with a good carbon-capture capability means tree species with a high carbon-storage capacity.

It has a high carbon-storage capacity with a carbon density of about 13.5 t/ha (Zhu et al. 2008). This is why Chinese fir was chosen as the tree species for this study.

Five sample counties (i.e., Jiande, Longquan, Lin'an, Cangnan and Kaihua) in Zhejiang province were selected to analyze the potential FCS supply by small-scale household samples using stratified sampling according to location (Figure 1), forest resources, and local rural economy development (Table 1). All five case counties had plans to cooperate with the CGCF to develop FCS projects, and two of them (Lin'an and Cangnan) had already introduced regional FCS projects in 2007 and 2008, respectively.[7] The forestland involved in the FCS projects in the two case counties were managed by more than 500 local households, all of which had forestland ownership certification. Actually, the FCS projects in the two counties were managed by a company and some large-scale households who contracted the forestland from local households.[8] According to the requirements of the CGCF and FCS projects, these forestlands all had to be bare or degraded before the projects started. Households were asked to plant trees on these forestlands so it was not necessary to consider the issue of "additionality" for FCS projects in these case areas.[9]

In the five sample counties, two towns in each county were selected according to ranking (high and low income groups), and two villages in each town were then chosen using random sampling. Next, in each village, we selected 10 households with experiences in forest management (especially Chinese fir management). There were 200 sample households, and 178 valid sample households that made consistent decisions in the risk experiment.[10]

2.2 Data Collection

Questionnaire surveys were used to collect the following information:

1. demographic and socioeconomic data of households in 2013,
2. the total area of the forestland operated by each household;
3. detailed information on Chinese fir management including input-output data of Chinese fir management in one rotation cycle; and
4. household perceptions of FCS projects.

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7 In Zhejiang province, all the counties with forest resources are less developed, so the rural per capita net incomes in the case counties are lower than the average per capita net income of the whole province.

8 The FCS project in Cangnan was managed by Zhenhai Company, which contracted about 1,000 ha from local households. The FCS project in Lin'an was managed by 10 large-sized households, which contracted about 800 ha from local households.

9 "Additionality" in FCS projects refers to the net carbon credits that result from FCS projects. According to standard FCS project methodology, these net carbon credits should be increments, higher than the carbon credits in the baseline scenario. In the study areas, the forestlands were all bare or degraded before the projects started, so the carbon credits in the baseline scenario could be considered as negligible.

10 In those counties with FCS projects, we asked the village heads to provide a roster of all households involved in FCS projects. Then, we used a systematic sampling method to choose our samples. We also asked the village heads in other counties to provide a roster of all households. We then used the same method to find our samples. To analyze household willingness to participate in FCS projects, samples were taken from non-FCS villages to ensure no bias in the analysis.

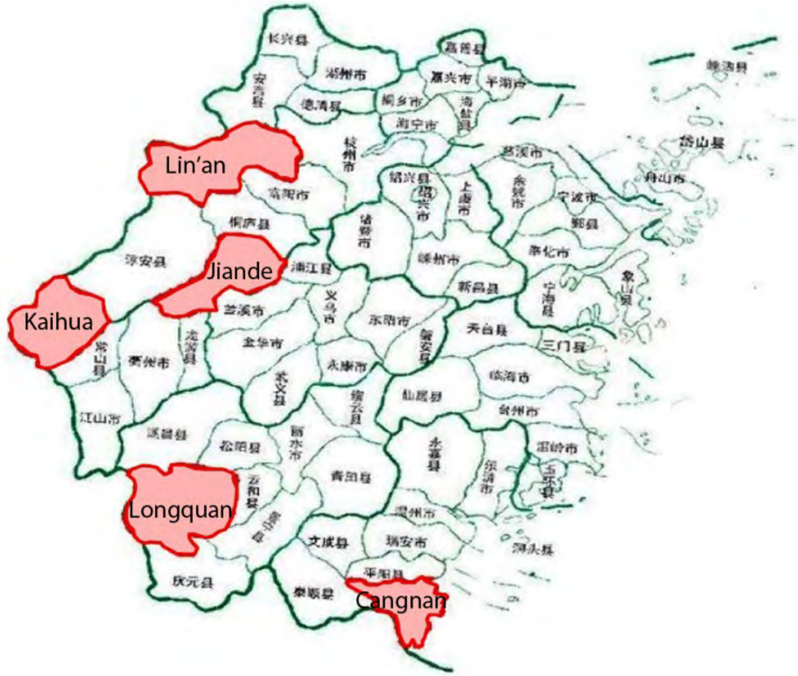

Figure 1. The location of the case counties in Zhejiang province

Source: http://image.baidu.com/

Table 1. Indicators for the five study counties in Zhejiang province

Indicators	Zhejiang	Case Counties				
		Jiande	Longquan	Lin’an	Cangnan	Kaihua
Rural per capita net income (USD)	3,129	2,595	1,672	2,832	2,054	1,707
Forest coverage (%)	–	75.66	84.2	76.55	59.95	80.4
Location	–	middle	southwest	west	southeast	southwest

Sources: ZFB (2015); ZSB (2015)

2.3 Risk Experiment

The risk experiment consisted of choosing from a multiple price list to measure the risk attitudes of sample households. The choice list was introduced by Holt and Laury (2002) to let subjects make risky decisions. Table 2 shows the 10 pairwise choices. In each choice task, subjects had to choose either Option 1 (the relatively safe option) or Option 2 (the relatively risky option).

Whereas the possible payoffs in both options were fixed in all 10 choices, the probability for the high payoff in each option increased in steps of 10 percentage points from 10% to 100%. Consequently, the probability for the low payoff decreased by 10 percentage points or from 90% to 0%. For instance, in the first decision, the respondents had to choose between Option 1 (earning either CNY 20 with a probability of 10% or CNY 16 with a probability of 90%) and Option 2 (earning either CNY 38.5 with a 10% probability or CNY 1 with a 90% probability).

The far-right column of Table 2 indicates the differences in expected payoffs. The first four and final six rows (i.e., Options 1 and 2, respectively) have higher expected payoffs. This means that a risk-neutral subject would choose Option 1 in the first four decisions and Option 2 in the last six decisions. Subjects who switch to Option 2 after the fifth choice can be classified as risk-averse, whereas subjects switching to Option 2 prior to the fifth choice can be considered as risk-takers.

After the household surveys, two interviewers (henceforth called experimenters) visited each randomly selected sample households. The household heads were invited to the village offices together with one member of the village cadre. The cadre member then kindly asked the household heads if they would like to participate in a survey and an experiment to be conducted by the two experimenters. If the household heads were willing to participate, the cadre member left before the experiment began. It turned out that 192 households were willing to participate in the survey and experiment.

Given the generally low educational level of the participants, the experimenters took great care to explain the rules of the experiment as clearly as possible. Then, the household heads who were ready to play the game were invited into an empty office one by one. This was done to avoid the presence of others influencing the answers of each individual respondent.

The whole experiment comprised three steps. In Stage 1, the experimenters invited the respondents to make decisions on the 10 pairwise choices printed on cards. The experimenters prepared 10 balls, which were either yellow or white. They explained how much the respondent would get if he drew a yellow or white ball. For example, "In Question 2, there are two yellow balls and eight white balls. In Option 1, if you draw a yellow ball, you will get CNY 20, but you will get CNY 16 if you draw a white ball. On the other hand, if you choose Option 2; if you draw a yellow ball, you will get CNY 38.5, but CNY 1 if you draw a white ball. What is your choice?"

Table 2. The ten paired lottery-choice decisions (in CNY)

Decision	Option 1				Option 2				Difference in Expected Payoff (CNY)
	Probability	Payoff (CNY)	Probability	Payoff (CNY)	Probability	Payoff (CNY)	Probability	Payoff (CNY)	
1	1/10	20	9/10	16	1/10	38.5	9/10	1	1.17
2	2/10	20	8/10	16	2/10	38.5	8/10	1	0.83
3	3/10	20	7/10	16	3/10	38.5	7/10	1	0.50
4	4/10	20	6/10	16	4/10	38.5	6/10	1	0.16
5	5/10	20	5/10	16	5/10	38.5	5/10	1	–0.18
6	6/10	20	4/10	16	6/10	38.5	4/10	1	–0.51
7	7/10	20	3/10	16	7/10	38.5	3/10	1	–0.85
8	8/10	20	2/10	16	8/10	38.5	2/10	1	–1.18
9	9/10	20	1/10	16	9/10	38.5	1/10	1	–1.52
10	10/10	20	0/10	16	10/10	38.5	0/10	1	–1.85

In Stage 2, after the household heads made 10 pairwise choices with the cards, they had to draw one ball (marked from 1 to 10) of their choice. Each ball represented the pairwise choice that the subject had made in Stage 1. The ball labeled Number 1 corresponded to the first choice, the ball marked as Number 2 represented the second choice, and so on. For example, if the respondent drew a ball numbered 5, then the fifth choice would be used by the experimenter to determine the payment. In Stage 3, after the experimenters had identified the respondents' choices, they prepared yellow and white balls for drawing. For example, if a respondent drew the second choice in Stage 2, experimenters would prepare two yellow balls and eight white balls in one package for drawing. They would then give the respondent a real payment after the experiment was over. In total, executing the three stages took about 0.5 hours. On average, participants earned CNY 25.11, which was equivalent to 15% of the daily wage for off-farm work.

Table 3 shows the relative frequency with which households chose the safer Option 1over the more risky Option 2. We report only consistent choices, meaning that we exclude all observations where a decision maker switched back at least once to Option 1 after having chosen Option 2 or where Option 1 was chosen in the 10th decision (i.e., preferring CNY 20 for sure over CNY 38.5 for sure). In total, 178 households (94.79%) made consistent decisions. Given the low educational level of our samples (compared to university students), we consider this large fraction of consistent choices a success of the experimental procedure.

The bottom row of Table 3 indicates the average number of safe choices. Recall that a risk-neutral decision maker would choose the relatively safer option four times, and then switch to Option 2. Overall, Option 1 was chosen 4.28 times, hence indicating risk aversion in the aggregate data. Risk-taking, risk-neutral, and risk-averse groups comprised 68, 35, and 75 household samples, respectively. After our experiment, we divided household samples into three groups (risk-takers, risk-averse, and risk-neutral) to compare their FCS supply between traditional and Chinese fir forests.

Table 3. Summary of risk experiment results

Groups	Options	Frequency (Persons)	Percentage (%)	Accumulative Percentage (%)	Payoff (CNY)
Risk-takers	0	19	10.67	10.44	34.55
	1	6	3.37	13.74	19.75
	2	20	11.24	25.28	23.50
	3	23	12.92	38.20	24.50
Risk-neutral	4	35	19.66	57.87	29.09
Risk-averse	5	26	14.61	72.47	26.71
	6	14	7.87	80.34	24.11
	7	10	5.62	85.96	19.40
	8	3	1.69	87.64	26.17
	9	22	12.36	100.00	19.20
Total		**178**	**100.00**	**–**	
Average	**4.28**				**25.11**

A series of key informant interviews was organized by the research team. In January 2015, five experts were invited from Zhejiang Agriculture and Forestry University, the Chinese Academy of Forestry, and Auburn University (Alabama, USA) to help us understand the main differences between FCS and traditional forest management. For the different conditions of the study sites, these experts helped revise the stand condition parameters of the Chinese fir growth model.

2.4 Econometric Model

The Faustmann (1995) model is usually used to analyze the maximization of forestland expectation value (FEV) and optimal rotation age of traditional forest management. Some researchers like Murray, McCarl, and Lee (2004) and Hoen and Solberg (1994) revised the Faustmann model. Taking these into account, different risk attitudes (risk-takers, risk-averse, and risk-neutral) were considered in this study to find out how risk attitudes influenced the carbon supply of small-scale households. The model equation used was as follows:

$$FEV_{carbon\text{-}risk(i)} = \left\{ P_t Q(T) e^{-rT} - R + \int_0^T P_c C'(t) e^{-rt} dt - \left[P_c C(T) \int_0^D d(s) e^{-rs} ds \right] e^{-rT} \right\} (1 - e^{-rT})^{-1} \quad \text{Equation (1)}$$

where:

$FEV_{carbon-risk(i)}$	=	bare FEV for FCS with Chinese fir for *i* kind of risk attitude;
T	=	rotation age;
$Q(T)$	=	timber volume after harvesting at year *T*;
R	=	afforestation cost;
P_t	=	price of timber;
P_c	=	price of carbon (we used the market carbon price of CNY 18 or [USD 3] per metric ton);[11]
$C(t)$	=	amount of carbon (*C*) sequestered as a function of stand age (*t*);
r	=	discount rate to show the time preference of small-scale households (we set 3%, which is the one-year deposit interest rate in China);
$d(s)$	=	delayed carbon emission from forest products *s* years after harvesting; and
D	=	delayed years for carbon emission, which was set at 30 years based on research on the life cycle of forest products.

The optimal rotation period was determined by the bare land value function with respect to *T*, which is derived from Equation (1). This is the first-order condition of the Faustmann model.

11 Alibaba, which is the largest electronic business company in China, purchased (forest sequestered) carbon credits in Zhejiang at the cost of CNY 18 per ton in 2011.

$$P_t Q'(T) + P_c C'(T)\left[1 - \int_0^D d(s)\, e^{-rs}\, ds\right] + r\left[P_c C(T) \int_0^D d(s) e^{-rs}\, ds\right] = \quad \text{Equation (2)}$$

$$r\,[P_t Q(T)] + r\,[FEV]$$

At the optimum, the marginal revenue of extending the rotation another year just equals the marginal cost of rotation delay. The marginal revenue of rotation delay includes three successive terms on the left-hand side of Equation (2), representing the following components: (1) additional value from timber growth, (2) the net value of additional *C* credits, and (3) interest on the forestalled payment of *C* debits from harvest. On the marginal cost (right hand) side of the equation, an increase in the rotation age includes interest on the value of the growing stock and the land (Murray, McCarl, and Lee 2004).

Also, the first-order condition of the Faustmann equation differs from Equation (2) only by the omission of the *C* factor and substitution of a land-value term in a timber-only regime for the land-value term in a timber-*C* regime. So compared with the traditional optimal rotation age for timber only, this means that rotations with carbon benefit will typically be delayed when *C* is priced because the benefits of additional net *C* receipts will outweigh the costs of holding land and growing stock for another period (Hoen and Solberg 1994; Murray 2000; van Kooten, Binkley, and Delcourt 1995).

According to Equation (1), for measuring the FEV and optimal rotation age in FCS projects, the timber volume of Chinese fir ($Q(T)$) with different ages of Chinese fir was calculated from the growth model. The equations are as follows:

$$Q_T = F(t) = b_1 SI^{b_2}\,[1 - \exp(-kt)]^{c} \quad \text{Equation (3)}$$

$$\overline{D}_T = 1.77871\ SI^{1.38791}\,[1 - \exp(-0.011672\,t)]^{0.80127} \quad \text{Equation (4)}$$

$$\overline{H}_T = 14.8032\ SI^{0.42132}\,[1 - \exp(-0.00942\,t)]^{0.76261} \quad \text{Equation (5)}$$

where:

- Q_T = timber volume of Chinese fir after harvesting at year *T*;
- $\overline{D}_T$ = diameter at breast height (DBH) of Chinese fir after harvesting at year *T*;
- $\overline{H}_T$ = height of Chinese fir after harvesting at year *T*;
- SI = site index of forestland (it was set according to the different levels of stands [high = 16, medium = 12, and low = 8] by experts)

All other parameters of growth model were quoted from Chen (2010), b_1 = 4.53547, b_2 = 1.60931, c =3.720004, and k = 0.096004.

Another important step in measuring the amount of *C* sequestered from Chinese fir was to get the *C* credits from the carbon density model by Zhu et al. (2008) as shown in the equations below.

$$C(t) = C_i \times \overline{I} = \sum W_i \lambda_i \times \overline{I} \quad \text{Equation (6)}$$

$$W_1 = 3.4166 \times 10^{-2}\ \overline{D}_T^{\,1.7202}\ \overline{H}_T^{\,1.1057} \quad \text{Equation (7)}$$

$$W_2 = 4.3570 \times 10^{-2} \left(\overline{D}_T^{\,2}\ \overline{H}_T\right)^{0.7172} \qquad \text{Equation (8)}$$

$$W_3 = 1.3987 \times 10^{-2}\ \overline{D}_T^{\,2.35555}\ \overline{H}_T^{\,-0.2717} \qquad \text{Equation (9)}$$

$$W_4 = 0.9780 + D_T^{\,2}\left(-8.4058 \times 10^{-3} + 4.0595 \times 10^{-3} H_T + 1.9195 \times 10^{-4}\ \overline{H}_T^{\,2}\right) \qquad \text{Equation (10)}$$

where:

$\sum W_i \lambda_i$	=	sum of dry organ biomass (trunks, roots, branches and leaves) for Chinese fir;
$C(t)$	=	amount of *C* sequestered as a function of stand age (*t*);
C_i	=	carbon density of an individual plant;
$\overline{I}$	=	planting density of Chinese fir for the different risk groups;
W_i	=	biomass of dry organs (trunks, roots, branches and leaves) for Chinese fir [the biomass of different dry organs can be calculated from Equations (7), (8), (9), and (10)];
λ_i	=	carbon storage ratio; based on Zhu et al. (2008), the carbon storage ratio of trunks, roots, branches, and leaves in Chinese fir are 52.34%, 47.22%, 49.95%, and 51.28%, respectively;
$\overline{D}_T$	=	DBH of Chinese fir after harvesting at year *T*; and
$\overline{H}_T$	=	height of Chinese fir after harvesting at year *T*.

To identify the factors (especially the risk attitudes of households), we ran the regression model of Chinese fir management using the number of safe options in addition to socioeconomic and regional variables, which were explanatory variables (Jin, Wang, and Pham 2015). The estimated reduced form of the model is as follows:

$$Y_i = \alpha + \beta_i \sum_{i=1}^{n} X_i + \varepsilon_i \qquad \text{Equation (11)}$$

where:

Y_i	=	dependent variable representing the volume per hectare of Chinese fir on the largest plot owned by household *I*;
α	=	Y-intercept;
β_i	=	set of coefficients to be estimated;
X_i	=	a set of hypothesized explanatory variables, which is based on theory and related empirical work and influences the outcomes of Chinese fir management, with the safe option as the key variable; and
ε_i	=	error term.

In terms of environmental value, FCS has the characteristics of a public good. Many studies have found determinants affecting the willingness to pay for public goods, such as preference attitudes, individual differences, social capital, and institutional support (Tsai 2007; Pender, Marre and Reeder 2012). Thus, when we discuss the determinants of small-scale households' FCS supply and willingness to participate in FCS projects, these factors should be considered:

1. *Preference attitudes.* These are the risk attitudes of households that depend on the social role of individuals (e.g., occupation), which in turn affects the supply of public goods.
2. *Individual differences.* Different income levels and inputs can affect the supply of public goods.
3. *Social capital.* The social capital owned by households can affect the supply of public goods. For example, if the household head is an officer of the village, the household may get more support from the government or social networks for FCS management.
4. *Institutional support.* The supply of public goods should be supported by the government. Policies and institutions can solve the problems of market failure and free-riders.

The binary logic model was used to find out how the risk attitudes of households influenced their willingness to participate in an FCS project. The model used was as follows:

$$L_n \left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \sum \beta_j x_{ij} + \varepsilon \qquad \text{Equation (12)}$$

where:

P_i	=	the probability of household *i* being willing to participate in an FCS; project (willing = 1, unwilling = 0);
$1 - P_i$	=	probability of household *i* not being willing to participate in an FCS project;
x_{ij}	=	the independent variables including the risk attitudes of households, family characteristics of households, and whether or not households got training in or subsidies for forest management;
β_j	=	parameters to be estimated; and
ε	=	error term.

3.0 RESULTS

3.1 Financial Analysis

The FCS projects in Cangnan and Lin'an on Chinese fir were contracted by a company and large-scale households, respectively. However, almost none of the local households in Cangnan have traditional experience in Chinese fir management. Thus, the financial analysis for Chinese fir management was made for households in the other four counties that had experience in Chinese fir management. The total number of household respondents with Chinese fir management experience was 145, comprising 57 risk-taking households, 28 risk-neutral households, and 60 risk-averse households. From Table 4, it can be seen that the average age and number of years of education of respondent household heads were about 56 years and 6.4 years, respectively.

Table 4. Descriptive statistics of households with different risk attitudes

Groups	HH	Indicators	Ave Age of HH Head (Years)	Ave Educational Years of HH Head (Years)	Ave Labor of HH (Person)	Income per Capita of HH (USD per Person)	Ave Area of Forestland (ha)
Total	145	Mean	56.08	6.41	3.96	3,742.78	4.28
		Min	33.00	0.00	2.00	215.32	0.08
		Max	86.00	17.00	7.00	15,781.73	86.67
Risk-takers group	57	Mean	55.24	6.37	4.00	4,277.03	4.74
		Min	35.00	0.00	2.00	215.32	0.08
		Max	77.00	12.00	7.00	2,1505.32	40.00
Risk-neutral group	28	Mean	54.83	7.35	3.78	3,705.10	2.24
		Min	33.00	0.00	2.00	741.94	0.08
		Max	69.00	12.00	6.00	6,451.61	80.00
Risk-averse group	60	Mean	56.35	6.22	3.97	3,545.66	3.74
		Min	42.00	0.00	2.00	688.98	0.07
		Max	86.00	14.00	7.00	7,103.23	51.00

Table 4 continued

Groups	HH	% Population Participating in Trainings for Chinese for Management	% of HH Receiving Subsidies for Forest Management	Average Man-Days for Chinese Fir management (Man-Days/ha)	Average Capital Input for Chinese Fir Management (USD/ha)[a]
Total	145	20.93	33.33	448.68	1,990.34
Risk-takers group	57	24.07	33.33	469.35	1,965.45
Risk-neutral group	28	21.70	56.50	467.80	1,960.36
Risk-averse group	60	23.33	25.00	422.87	2,023.72

Note: (a) Based on the largest plot that each household owned, we calculated the annual man-days and discounted capital input at a 3% discount rate using the average man-days and capital input for the long rotation of Chinese fir management (which ranged from 18-25 years from household to household). The capital inputs were seedlings, fertilizers, pesticides, and irrigation. The man-days were the working days for employees and self-employment.

The average number of laborers per household was about 3.96 persons, and the per capita income of households was USD 3,743, which was much higher than those of households at the provincial level (i.e., USD 3,407). Chinese fir management and off-farming incomes accounted for 70% of the households' total income. The average income of the risk-takers' group was 20.67% higher than the risk-averse group. The former's off-farming income was 18.26% higher than the latter's. The average forestland size for small-scale households was about 4.28 ha, but 62.02% of the respondents had less than 1.30 ha. Also, the average forestland size of the risk-takers was 26.79% larger than the risk-averse group. The main reason is because the risk-takers took a more aggressive Chinese fir management strategy through contracting additional forestland. According to our results, 46.87% of the sample who contracted forestland was from the risk-takers group.

According to traditional Chinese fir management practice, there are four types of input costs in the cultivation:

1. planting costs (for seedlings, fertilization, and labor);
2. replanting costs, which happen in the second year (for seedlings, fertilization, and labor);
3. weeding costs (for labor and pesticides), which help the trees grow faster and are incurred in the first four years of the rotation cycle; and
4. logging and transportation costs (for labor and fuel), which take place during thinning and harvesting.

Although the rotation age of Chinese fir is about 20 years, according to the survey, planting, replanting, and weeding costs were mainly incurred in the first four years of a rotation cycle.

We collected information on the costs and benefits of Chinese fir management based on the largest plot owned by the households. Earnings from Chinese fir management can be divided into two thinning and harvest earnings. Households do thinning when the diameter of the trees at breast height (DBH) is less than 6 cm, but they harvest and sell the timber when the DBH is more than 20 cm. The costs and earnings of Chinese fir management for the different risk groups are shown in Table 4.

After the first four years, the Chinese fir can grow with little attention and cost until harvest. According to the results of the F-test, there was no significant difference between the risk-averse and risk-takers groups for the total input costs, but the input in the fourth year for the risk-averse group was much higher than that of the risk-takers group.

Compared with other groups, the risk-averse group generally had a higher private cost-benefit rate for Chinese fir management. On average, 70.82% of the group's total income came from Chinese fir. Chinese fir management is a traditional practice in the study sites and a high tendency toward risk aversion is part and parcel of this.

The investment difference can also be found in the planting density. The planting densities of the risk-averse, risk-neutral, and risk-takers group were 3,256 plants per hectare; 3,073 plants per hectare; and 2,971 plants per hectare, respectively. The planting density of the risk-averse group was much higher than that of the risk-takers group with higher input costs. The risk-averse households do their best to maximize benefits from traditional forest management.

In the regression model, to find out how the determinants influenced the outcome of Chinese fir management, especially the risk attitudes of households (Table 5), the results showed that the coefficient related to the safe option was positive and significant at 10%. This indicates that households with risk-averse attitudes were more likely to get a better outcome from Chinese fir than the other risk attitude groups. This result corresponded to the evidence that the risk-averse group had a higher cost-benefit rate and planting density (Table 6). The capital input per hectare had a positive impact on the outcome of Chinese fir. Also, households that took subsidies for forest management from the government had a higher income from Chinese fir than those who did not. Finally, there was a significant difference in the planting density of Chinese fir among the different case areas; for example, the volume per hectare of Chinese fir in Kaihua was significantly higher than in Jiande.

3.2 Optimal Rotation Age and FCS Supply

Based on the revised Faustmann model, Table 7 presents the optimal rotation age and FEV calculated. At a discount rate of 3%, the optimal rotation length was 28 years, and there was no difference found among the risk attitudes groups. The FEV of the risk-neutral group was highest with a timber value of about 3,086 per hectare, and there was no significant difference in FEV between the risk-averse and risk-takers groups. If the carbon value was taken into account, the optimal rotation lengths of the different groups were identical. At a carbon price of USD 3 per metric ton, the carbon FEV was higher than the Faustmann FEV for the three risk attitudes groups.

To sum up, we found that

1. FCS management had investment value since the carbon FEV was higher than the Faustmann FEV for all risk attitudes groups; and
2. FCS management did not prolong the optimal rotation age, and households with different risk attitudes did not necessarily change their harvest decisions in FCS management.

Table 5. Parameter estimates of the regression model

Attribute	Dependent Variable: Volume (per hectare) of Chinese Fir on the Largest Plot Owned by Each Household			
	Measurement	Estimate	t-value	p-value
Safe option	Numbers	0.0111*	1.72	0.092
Total number of laborers	Man-days/ha	−0.0001	−0.78	0.435
Ln capital input	CNY/ha	0.0783**	2.14	0.034
Family labors	Persons	0.0045	0.10	0.921
Ln income per capita	CNY/person	0.0119	0.30	0.766
Age of household head	Years	−0.0038	−0.74	0.460
Education of household head	Years	−0.0085	−0.61	0.545
Whether or not the household head is a village officer	1 = Yes ; 0 = No	−0.0472	−0.35	0.727
Whether or not the household attends training	1 = Yes ; 0 = No	−0.0543	−0.46	0.649
Whether or not the household receives a subsidy	1 = Yes ; 0 = No	0.2396**	2.58	0.011
Case areas (Reference: Jiande)				
Kaihua		0.3979***	3.14	0.002
Longquan		0.2467*	1.92	0.057
Lin'an		0.0133	0.09	0.929
Constant		3.9360***	5.56	0.000
Adjusted R^2	0.1678			

Notes: (1) ***, **, and * represent values at 1%, 5% and 10% levels of significance. (2) Ln = natural logarithm

Table 6. The average annual cost and benefit of Chinese fir management for households with different risk attitudes

Types	HH Samples	Cost					Earnings			
		Forestland Managed Area (ha)	Year 1 (USD/ha)	Year 2 (USD/ha)	Year 3 (USD/ha)	Year 4 (USD/ha)	Thinning & Harvest Cost (USD/ ha)	Harvest & Transport Cost (USD/ha)	Thinning Income (USD/ha)	Harvest Income (USD/ha)
Total	145	4.28	4,446.45	2,013.33	1,121.96	3,86.52	91.80	382.51	2,915.85	17,600.10
Risk-takers	57	4.74	4,502.11	2,143.21	1,245.44	370.77	72.33	340.42	2,927.70	17,323.80
Risk-neutral	28	2.24	4,316.67	1,745.23	893.01	284.27	75.74	417.83	2,301.45	17,146.80
Risk-averse	60	3.74	4,520.57	2,151.56	1,227.44	504.51	116.72	408.37	3,150.15	18,043.80
F-test		0.21	0.09	0.37	0.40	2.40**	1.90*	0.91	0.12	0.12

Note: ***, **, and * represent values at 1%, 5%, and 10% levels of significance.

Table 7. Comparison between FEV, decision making, and FCS supply of households with different risk attitudes

Types	Timber Only		With Carbon		
	FEV（USD/ha）	Optimal Rotation Age（Years）	FEV (USD/ha）	Optimal Rotation Age（Years）	Carbon Supply（T/ha）
Risk-takers group	1,868.60	28	2,136.31	28	515.18
Risk-neutral group	3,086.47	28	3,363.35	28	532.83
Risk-averse group	1,700.04	28	1,993.49	28	564.70

This finding (i.e., carbon sequestration does not affect the rotation duration) differs from that of van Kooten, Binkley, and Delcourt (1995), who found that the rotation age increased by about 20% over the level where no carbon cost and benefit were considered. This is because of the nature of the fast-growing trees in our study, whereas the native tree species in the van Kooten study had totally different patterns of growth. Carbon uptake and timber growth are stronger in the early years for Chinese fir. Therefore, in our study sites, it appears that it is better to cut and replant trees earlier to maximize profits from selling timber and sequestering carbon. Another possible reason for the different finding is that the timber price is much higher than carbon price,[12] thus the opportunity cost of a rotation age change would be so low that the households would not change their forest management practice.

Using Equation (3), we calculated the carbon supply per hectare for the different risk attitude groups. Although the groups had the same optimal rotation age with carbon value, their carbon supply per hectare was different due to their planting density differences. The risk-averse group could supply a maximum FCS of 564.7 t/ha, whereas the risk-neutral group could supply 532 t/ha. The risk-takers group could provide a minimum FCS of 515.18 t/ha. Thus, the risk-averse group, which made higher investments in forest management, appears to be the most suitable group for FCS supply.

3.3 Carbon Price

We conducted a sensitivity analysis of the Faustmann model with carbon prices from USD 3 (CNY 18) to USD 96.77 (CNY 600) per metric ton (Table 8). The rotation age did not change significantly for the three risk attitudes groups until the carbon price was raised to CNY 400–500 per metric ton. The carbon supply per hectare only increased at a high carbon price. The main reason is that timber price is much higher than carbon price, and the opportunity cost of changes in the rotation duration for different risk attitudes groups is so small that households would not want to change their harvest time decision at a low carbon price. However, the carbon FEV of the three groups increased with a rising carbon price with the carbon FEV of the risk-averse group increasing the most.

This finding differs from those of van Kooten, Binkley, and Delcourt (1995) and Nghiem (2009), who all found that the optimal rotation age decreased significantly with an increasing carbon price. However, our finding is consistent with the results of Diaz-Balteiro and Rodriguez (2006), which states that a much higher carbon price had an impact on the rotation age with no clear pattern in optimal rotation.

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12 The timber price is USD 200/m^3 at a DBH > 20 cm and a timber density of about 0.45 t/m^3. This price is equivalent to USD 444.4/t, which is much higher than the carbon price.

Table 8. Sensitivity analysis results of rotation age with constant carbon prices

Types	Carbon Price (CNY/T)	FEV (USD/ha)	Optimal Rotation Age (Years)	Carbon Supplied (t/ha)
Risk-takers group	16	3,355.86	28	515
	32	4,843.13	28	515
	48	6,330.40	28	515
	64	7,817.67	28	515
	80	9,304.93	29	530
	96	10,792.20	29	530
Risk-neutral group	16	4,624.71	28	535
	32	6,162.94	28	535
	48	7,710.18	28	535
	64	9,239.42	28	535
	80	10,777.65	29	550
	96	12,315.89	29	550
Risk-averse group	16	3,330.29	28	565
	32	4,960.53	28	565
	48	6,590.78	28	565
	64	8,221.02	29	580
	80	9,851.27	29	580
	96	11,481.51	30	615

3.3.1 Discount rate

The discount rate represents time preference. We did a sensitivity analysis of the Faustmann model with discount rates from 1%–5% in order to find out how time preferences would affect the optimal rotation age and carbon supply (Table 9).[13] It was found that the optimal rotation age decreased with an increasing discount rate. When the discount rate increased from 1% to 2%, the optimal rotation age of the risk-averse group decreased slightly by one year. The carbon supply per hectare of the risk-averse group decreased 6% with discount rates from 1% to 5% for all the risk attitudes groups. Thus, the optimal rotation age is sensitive to the discount rate. But the carbon FEV of all three groups decreased with an increasing discount rate. At a 4% discount rate, the carbon FEV of all risk attitude groups became negative, which means that there was no investment value for FCS management at this discount rate. It can be concluded that when the discount rate increases, FCS households with a strong time preference will have a higher opportunity cost, thus they will give up FCS management for a small investment return.

13 Since 2008, keeping a low interest rate has been a remarkable feature of the monetary policy in China. The five-year deposit rate is about 3.25% in the Chinese financial market and banks, so we considered a discount rate interval from 1%–5% for this sensitivity analysis.

Table 9. Sensitivity analysis results of rotation age with discount rates

Types	Discount Rate (%)	FEV (USD/ha)	Optimal Rotation Age (Years)	Carbon Supplied (t/ha)
Risk-takers group	1	31,834.04	29	530
	2	9,437.18	29	530
	3	2,136.31	28	515
	4	–1,385.98	28	515
	5	–3,396.89	27	500
Risk-neutral group	1	33,878.72	29	550
	2	10,869.74	29	550
	3	3,363.35	28	535
	4	–262.85	28	535
	5	–2,337.18	27	517
Risk-averse group	1	31,578.92	29	580
	2	9,266.40	28	565
	3	1,993.48	28	565
	4	–1,516.39	27	565
	5	–3,520.48	27	550

3.3.2 Forest management costs

We conducted a sensitivity analysis of the optimal rotation age with management costs from 20%–+20% from current costs (Table 10).[14] The optimal rotation age did not change significantly until the cost increased by 20%. This means that the carbon supply per hectare for the different risk attitudes groups will decrease until the cost increases by 20% from the current level. Thus, the opportunity cost for a rotation age change for FCS will increase when the cost increases.

Meanwhile, the FEV for all three groups decreased with increasing forest management costs. The FEV turned negative for the risk-averse and risk-takers group when the cost increased by 20%. This means that the demand for investment in FCS management for households will decrease when the management costs increase.

14 Actually, the management costs, including labor and fertilization, will change in FCS. Also, monitoring costs will be additional in FCS management compared to tradition forest management. Although the monitoring cost is paid by the local government, the labor cost in FCS will generally be higher than that in timber rotation only. For measuring the carbon storage to be traded in future, all the carbon emissions from the management activities such as cultivation, thinning, and harvesting will be recorded by equipment and experts during the whole FCS project period.

Table 10. Sensitivity analysis results of the rotation age with forest management costs

Types	Management Cost Change (%)	FEV (USD/ha)	Optimal Rotation Age (years)	Carbon Supplied (t/ha)
Risk-takers group	+20	–740.16	27	500
	+10	698.07	28	515
	–10	3,574.54	28	515
	–20	5,012.77	28	515
Risk-neutral group	+20	836.20	28	517
	+10	2,099.78	27	535
	–10	4,626.93	28	535
	–20	5890.51	28	535
Risk-averse group	+20	–929.87	27	550
	+10	531.81	28	565
	–10	3,455.16	28	565
	–20	4,916.84	28	565

3.4 Willingness Analysis

To help the respondent households decide whether they wanted to participate in an FCS project, we gave detailed information and training to teach those without any FCS experience about FCS technological standards and management. For instance, we told them the price for carbon storage for Chinese fir and how the afforestation costs could change with FCS technological standards.[15]

Then we asked questions such as "Would you want to take up FCS and change your traditional management choices or practices, such as substituting fertilizer cost with more labor, and monitoring the growth of your tree species?" There were three answers they could choose from: willing, unwilling, and uncertain. If a household chose FCS management, then we would ask the question, "How many years can you afford to prolong the rotation age of Chinese fir if required to do so under the FCS project?"

According to the survey results, a total of 178 valid respondents took part in the risk experiment. Most of the households (73.60%) announced that they were willing to take up FCS management, believed that the carbon prices would be higher in future, their incomes did not depend highly on forest management, and they could afford the increased cost (Table 11). There was no significant difference between the risk-takers and risk-averse groups. A total of 51 households, accounting for 75% of the risk-takers group were willing to take up FCS management, while 61 households (81.33%) from the risk-averse group were willing to do so. There was no significant difference in the lengthening of the rotation age for FCS management between the risk-takers and the risk-averse; about 8.41 and 7.8 years, respectively.[16]

15 Afforestation costs could go up to USD 15–20 per metric ton, which is nearly 30%–40% higher than traditional management costs, based on the estimation from the key informant interviews.

16 FCS projects in Cangnan and Lin'an were contracted by companies and large households, respectively. All the respondent households had no experience in FCS management, so there was no bias between the different counties when we analyzed their willingness to participate in FCS projects.

Table 11. Descriptive statistics of willingness to participate in an FCS project

Types	Variables	Unwilling	Willing	Uncertain	Total
Total	Frequency/ person	38	131	9	178
	Percentage	21.35	73.60	5.05	100%
Risk-takers group	Frequency/ person	16	51	1	68
	Percentage	23.53	75	1.47	100%
Risk-neutral group	Frequency/ person	10	19	6	35
	Percentage	28.57	54.29	17.14	100%
Risk-averse group	Frequency/ person	12	61	2	75
	Percentage	16	81.33	02.67	100%

The relationship between willingness to do FCS management and characteristics of households is displayed in Table 12. There was no significant relationship between willingness to take up FCS and household characteristics. The average annual income per capita of the unwilling group was much higher than those of the other two groups. The unwilling group depended highly on off-farming income. More than 68% of their annual income per capita came from off-farming work, so they were less concerned about FCS management.

Based on the logit model in Section 2, the estimated results are given in Table 13. The regression results showed that a household's risk attitude was a significant determinant in its willingness to participate in an FCS project. The coefficient was positive, suggesting that risk-averse households were more willing to undertake FCS. Risk-averse group do not have many different means of livelihoods, so they usually pay more attention to their traditional livelihood source, namely, forest management. They believe that the return on investment for FCS is stable, and they can get carbon benefits in addition to timber benefits.

The number of plots owned by the households had a significantly positive impact on their willingness to undertake FCS. The variable of "off-farming income" had a negative impact on the willingness to participate in an FCS project. Households that depended more on off-farming income were less willing to participate in FCS management.

Table 12. Descriptive statistics of the relationship between willingness to participate in FCS and household characteristics

Household Variables	Unwilling	Willing	Uncertain
Average age of heads of households (years)	58.16	55.67	52.33
Risk attitudes of households (households)			
Risk-takers	16	51	1
Risk-neutral	10	19	6
Risk-averse	12	61	2
Average education years of households' heads (years)	6.37	6.08	7.22
Percentage of village officers (%)	7.89	8.40	11.11
Average laborers per household (persons)	3.92	3.97	4.33
Average ratio of forest income / total income for households (%)	12.72	6.86	11.12
Average number of forestland plots per household (plots)	4.90	3.76	3.78
Average forestland per household (ha)	2.13	2.27	6.57
Average annual income per capita of households (USD/person)	9,167.1	8,301.99	7,346.41
Average off-farming annual income per capita of households (USD/person)	6,278.64	4,410.34	3,096.65
Average forestry working months per year for household heads (months)	5.21	4.42	6.67

Table 13. Parameter estimates of the binary logit model

Variables	Willingness to Participate in FCS Projects			
	Measurement	Estimate	p -value	dy/dx
Risk attitudes				
Safe option		0.1529**	0.047	0.0178
Household characteristics				
Forestland area per household	ha	0.0164	0.579	0.0019
Family laborers per households	persons	0.2354	0.170	0.0274
Average forestry working months per year for households	months	−0.1043*	0.096	−0.0122
Off-farming income as part of the total income of a household	%	−0.0267**	0.013	−0.3110
No. of forestland plots per household	plots	0.1624 **	0.052	0.0189
Age of household head	years	−0.0349	0.165	−0.0041
No. of years of education of household head	years	−0.0514	0.502	−0.0060
Whether or not the household head is an officer of the village	1 = Yes, 0 = No	1.0114	0.299	0.0869
Organization system				
Whether or not the household participates in training	1 = Yes, 0 = No	0.4528	0.507	0.0482
Whether or not the household receives a subsidy	1 = Yes, 0 = No	0.4633	0.470	0.0506
Area (Reference group: Jiande)				
Kaihua	1 = Yes, 0 = No	−0.4029	0.598	−0.0511
Longquan	1 = Yes, 0 = No	0.3270	0.713	0.0356
Lin'an	1 = Yes, 0 = No	−1.1306	0.158	−0.1671
Cangnan	1 = Yes, 0 = No	−0.9388	0.243	−0.1350
Constant		4.2913	0.061	
−2 log likelihood	−75.445085			
Pseudo R^2	0.1826			

Note: ***,**, and * represent values at 1%, 5%, and 10% levels of significance.

4.0 CONCLUSIONS AND POLICY IMPLICATIONS

This research studied the optimal forest management decision making of small-scale households with different risk attitudes in Zhejiang province. A revised Faustmann formula was applied to determine the optimal rotation age and carbon supply for different risk attitudes groups. A binary logit model was applied to find out how the risk attitudes of the households affected their willingness to participate in an FCS project.

The results revealed that, compared with timber benefits only, FCS projects will generate more investment returns. Although the three risk attitude groups had the same optimal rotation age with carbon value, their carbon supply per hectare was different due to planting density differences. The risk-averse group paid more attention to and made higher investments in FCS management as they believed that forest investment was less risky and gave stable returns. Thus, this group will be the most suitable target group for an FCS project.

We used a sensitivity analysis to examine the optimal rotation age with changing carbon prices, discount rates, and management costs. The rotation age and FCS per hectare did not change significantly unless there was a significant change in the carbon price, discount rate, and management costs for all three risk attitude groups. The main reason for this was that the timber price was much higher than the current carbon price, and the opportunity cost of a change in rotation age for the different risk attitude groups was so small that households did not want to change their forest management decision.

From the binary logit model, the results suggested that compared with the risk-averse group, the probability of households being willing to take up FCS management will be smaller for the risk-takers group. In addition, risk-takers with higher earnings from off-farming activities are not attracted to FCS projects.

FCS projects are a great opportunity for developing countries with rich forest reserves. A set of insurance products should be provided by insurance companies for reducing management risks involved in long forest rotations. Meanwhile, governments should provide several kinds of subsidies for households that want to purchase such insurance schemes.

This study has shown that the risk-averse group would provide higher FCS per hectare, but it is difficult to identify who are risk-averse in real life. A helpful indicator would be that small-scale households whose livelihood come mainly from forestry tend to be risk-averse, so the government should pay more attention to this group and encourage such households to take up FCS. One effective way would be to introduce FCS projects and give FCS training for interested households.

Another way is to expand forestland. Forestland owned by households that have migrated out of the area or depend highly on off-farming income can be contracted out to other households that desire to expand their forestland and take up FCS.

However, there are some limitations in this research. Firstly, because we focused only on one tree species and due to the strict protocol and high cost of the risk experiment, we could only get limited samples to analyze how risk attitudes impacted FCS supply. Secondly, it is difficult to get cost-benefit data from a household survey for such a long rotation age. Although we helped the households to fill out their questionnaires, we could not ensure that all the data from the respondents was precise, so outliers were replaced by averages when we processed the data. Finally, one important assumption in this research was that the risk attitude of an individual was an exogenous variable, which would not be affected by changes in the characteristics of the individual.

There are many tree species that are suitable for FCS management, but based on the socioeconomic view of the households, future research should be done to compare how the risk attitudes of individuals impact the selection of different tree species for FCS projects. Also, it is necessary to evaluate and simulate the effect of policies and market services to reduce the risks for small-scale households in FCS projects.

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