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Effect of forestland tenure security on rural household forest management and protection in southern China

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ABSTRACT

Initiated in 2003, China's recent round of collective forest tenure reform (CFTR) aims to improve tenure security and motivate households to engage in forestry production. For the forested land allocated to households after the reforms, forest management and protection have become key in forestry production. However, few studies have analyzed the effect of different dimensions of forestland tenure security on rural household forest management and protection. Based on survey data from 766 households in southern China, the present study examines this effect using the Negative Binomial and Tobit models. The empirical results indicate that the actual tenure security derived from the possession of forestland certificates has insignificantly increased forest management frequency and management intensity. With regard to perceived tenure security, we found that if forestland is perceived to be adjusted in the future, this can have a significant positive impact on both management frequency and management intensity. In contrast, a perception that certificates may protect forestland rights would have insignificant effect on management frequency and management intensity of forestland. Specifically, for households with certificates for all forestland, perception about future adjustments on tenure security would positively affect management frequency and intensity. For households with certificates for part of forestland, the perception about certificates has a positive impact on management frequency.

1. Introduction

Forestland tenure security is considered an important factor to promote sustainable forest management (Besley, 1995; Li et al., 1998; Zhang et al., 2000; Wang et al., 2015). Over the past 70 years, China's forest policy has undergone several changes, which have decreased households' confidence in the security of forestland tenure, and affected the productivity and growing stock of collective forestland (Miao and West, 2004). According to the Ninth China Forestry Survey, the per capita forest area and the per capita forest stock volume in China represent less than one-third and one-sixth, respectively, of the world average (SFGA, 2019).

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To achieve resource growth and increase households' income in forest areas, China began implementing a new round of collective forest tenure reform (CFTR) in 2003 (Xu et al., 2010). The CFTR contains two phases, namely, the main reform and the supportive reform. The task of the main reform was to clarify forest property rights, demarcate forestland boundaries, and issue legal certificates to families to ensure that individual households had rights to manage and use their own forestland; such rights were to help improve the forestland tenure security of households (Siikamäki et al., 2015; Liu et al., 2016). By 2018, 180.33 million hm^2 of collective forestland in China have been allocated to households, representing around 99% of the area included in CFTR (SFGA, 2018). The main reform has been essentially completed. The supportive reform involved reducing forestry taxes and fees, promoting moderate forestland transfers, and allowing forestland usufruct rights as collateral, among others (Xie et al., 2016). It entitled individual households to more rights, which enabled them to transfer, inherit and mortgage their forestland (Liu et al., 2017a). It thereby further enhanced households' perception of forestland tenure security. By 2018, the area of forestland under large-scale management have reached 4 billion hm^2, and the balance of forest property mortgage loans have reached 127 billion yuan (SFGA, 2018).

The CFTR has made households the main management body of collective forests. The long growth period of forest trees requires that forestry production not only include afforestation inputs in the initial stage, but also uninterrupted management and protection for undeveloped forestland. It is important to distinguish various types of forest management activities (Xie et al., 2013). Since most of the forestland allocated to farmers in CFTR is forested land, the management and protection of such land by households has become a key link in forestry production, as well as an important way to improve the productivity level and stock volume of collective forests. However, after contracting forestland to households, the current forestry management method is still extensive and low-efficiency (Liu et al., 2017b). Although households pay little attention to forestry management and protection, they pay more attention to afforestation. Additionally, affected by factors such as resource endowment, the initial status of property rights, and village-level autonomy, the CFTR differs in its implementation across regions; thus forming a differentiated forestland tenure security situation, which makes the forestland tenure security of households inconsistent with policy expectations (Chen and Innes, 2013). This significantly affects the enthusiasm of households in the management of their forestland (Macours et al., 2010). Therefore, it is necessary to identify whether the CFTR has given farmers secure tenure, and then encourage farmers to continue to manage and protect forestland.

With the advancement of the CFTR, China's forestland tenure security and its relationship with farmers' forestry management behavior have received much attention in relevant literature. Some studies have shown that this tenure reform has enhanced the enthusiasm of farmers' forestry investment by strengthening tenure security (Holden et al., 2013; Yi et al., 2014). For instance, Shen et al. (2009) found that the uncertainty surrounding farmers' forestland property rights has been reduced after the CFTR. They analyzed data from nine villages located in three provinces in southeastern China. The results indicated that about 90% of farmers believed they had forestland rights. Liu et al. (2017a) used 1778 household samples from 18 counties in nine provinces across six consecutive years, and found that the impact of the CFTR on households' forestry input and management were generally positive. After communicating with 520 forest farmers in Fujian province, Qin and Xu (2013) pointed out that the frequent adjustment of forestland resulted in farmers having a very uncertain perception of property rights arrangements, which hampered forestry inputs. It can be seen that forestland tenure security is still a key issue and has yet to be resolved in China's collective forest areas (Qin et al., 2011). Yin et al. (2013) found that, although the reform improved the basic incentive structure, policy conflicts and inconsistencies are hindering future development. Moreover, the reform's transaction costs and policy constraints weaken the incentive effect of property rights decentralization on farmers (Wen and Chen, 2015).

The above studies explored the impact of forestland tenure security on households' forestry management behavior from different perspectives. However, although strengthening forestry management and protection is key for improving forest quality and promoting sustainable forestry development, the existing literature has seldom discussed the situation and strength of farmers' management and protection of forestry. Furthermore, many scholars have focused on analyzing the impact of tenure security on farmer behavior through only a single dimension, which is limited given that tenure security is a concept that includes three dimensions or levels: legal, fact, and perception (Van Gelder, 2010; Ma et al., 2015). Hence tenure security at different levels should have varied impacts on the behavior of farmers. At present, there are few studies that integrate forestland tenure security across these dimensions into a unified framework to understand its role in farmers' behavior. In response, this paper uses household survey data from Zhejiang and Jiangxi provinces in the southern collective forest areas, as well as employs the Negative Binomial and Tobit models, to analyze the relationship between tenure security and forestry management.

The purpose of this paper is to investigate forestland tenure security from the viewpoint of each level, and on this basis, to explore the impact of forestland tenure security on households' forestry management and protection. The rest of this paper is organized as follows: Section 2 describes the CFTR and forestland tenure security in rural China; Section 3 presents the econometric model specification; Section 4 shows the data source and descriptive statistics; Section 5 presents the estimation results; Section 6 discusses the findings; and, Section 7 concludes with policy implications.

2. Forestland tenure security and forest management decisions

2.1. Forestland tenure reforms in China

For a clear understanding of forestland tenure security, it is important to describe the historical evolvement of forestland tenure in China. The Land Reform Campaign that began in 1950 allocated forestland to households and formed a private

property ownership system of forests (Zhang et al., 2017). From 1956, with the establishment of the cooperative farming system in rural China, a large number of forests have gradually transitioned to under cooperative management (Song et al., 1997). Forest property rights were then transferred from advanced cooperatives to a higher level of advanced cooperative called the People's commune, further centralizing ownership (Dachang, 2001). However, the resulting agricultural failure and famine caused forest ownership to be returned to production teams and households in 1961−1962 (Wang and Delang, 2011). Afterwards, there was another reversal of policy on the ownership of forestland. Together, these studies suggest that the current system (contracting systems and forest-to-household models) cannot guarantee the security of forestland tenure.

Since China's reform and opening up in 1978 and the "Three Fixes" reform was applied to collective forestland, nearly 70% of such forestland was allocated to households (Wang et al., 2004; Xu and Jiang, 2009). Marginal forestland with few trees and non-forested lands were allocated as family plots (Liu et al., 2017c). For these lands, households were entitled to permanent use rights of the land and given ownership of the trees planted on the plots (Xie et al., 2014). With the Household Contract Responsibility System, households were contracted by collectives with forestland, also known as responsibility hills (Démurger et al., 2009). The benefits from these lands were shared by the collective and the households (Xu et al., 2013). But the contract period for responsibility hills was only 5−15 years, too short to manage most timber species (Holden et al., 2013). However, a massive illegal cutting of collective forests emerged after 1985 (Démurger and Yang, 2006). In response, the central government decided to suspend the allocation and encouraged the development of the collective economy, so that some of the allocated forests were converted back to collective management in 1987 (Siikamäki et al., 2015; Dachang, 2001). At the same time, the central authorities proposed to strictly implement the forest cutting quota system, timber unified purchase and sale system, and forestry tax and fee system (Yin and Newman, 1997). This would, to some extent, control households' rights to both dispose of forest and benefit from it. From 1987 to 2003, the central problems faced by China's collective forest management system included the excessive taxation of forestry activity and confusion around property rights due to their frequent changes (Liu et al., 2015). This led to higher forestland tenure insecurity, which decreased households' enthusiasm about investing in forestry (Delang and Wang, 2012).

The 2003 CFTR reform was launched in the wake of the major changes in the internal and external conditions of collective forestry development. The original aim of the CFTR was to change the state of forestland property rights and increase tenure security; and since its beginning has provided effective legal documents for the protection of households' forestland rights, as well as issued a unified and national-level certificate for owned forestland (Yin et al., 2013). Moreover, the reform extends the contract period for farmer households to 30, 50 or 70 years (Holden et al., 2013), and provides for its renewal after the contract period expires. In recent years, the CFTR have focused on promoting the release of collective forestland management rights and promoting various forms of moderate scale management. All such conditions inform households' expectations regarding forestland property rights and encourage forestland management.

2.2. Tenure security and forest management decisions

The connotation of forestland tenure security can be understood as the risk of losing forestland rights and benefits, or the uncertainty of obtaining forestland rights and benefits (Jacoby et al., 2002). According to the modern theory of property right, security tenure promotes the favorable behavior through such functions as incentive constraints, the internalization of externalities, and optimization of resource allocations. Under a secure tenure system, households are less likely to lose forestland, which can generate relatively stable returns (Deininger and Jin, 2004). Therefore, improving forestland tenure security through the CFTR is an important policy measure that affects households' forest management decisions, i.e. to encourages them to continue to manage forestland resources.

The rural household model is used to analyze household behavior in a theoretical framework (Cheng, 2014). According to Sun (2008), the amount of household's management and protection input depends on the profit that the input can bring, and the profit of forestry production is equal to the difference between the expected income and production cost. Since the expected income is affected by the amount of input and the forestland tenure security factor, the expected income can be expressed as: $R = R(I, T)$, where I is the amount of household's management and protection input, and T is the expected forestland tenure security factor. However, the production cost is affected by the amount of input, and the forestland tenure security factor does not affect the production cost. Accordingly, the production cost can be expressed as: $C = C(I)$. Therefore, the profit of household's forestry production is created as follows:

$$\Pi(I, T) = R(I, T) - C(I) \tag{1}$$

Since the expected income and production cost increase with the increase in input, $\frac{\partial R}{\partial I} > 0, \frac{\partial C}{\partial I} > 0$. The conditions for households to optimally satisfy the maximization are:

$$\frac{\partial \Pi}{\partial I} = \frac{\partial R}{\partial I} - \frac{\partial C}{\partial I} \tag{2}$$

$$\frac{\partial^2 \Pi}{\partial I^2} < 0 \tag{3}$$

Further to the partial derivative of tenure security factor *T* in Eq. (2), we get:

$$\frac{\partial \Pi}{\partial T} \cdot \frac{\partial \Pi}{\partial I} = \frac{\partial R}{\partial T} \cdot \frac{\partial R}{\partial I} \tag{4}$$

If the forestland tenure is insecure, households will face the risk of losing the expected income of their forestland. Assuming that the probability of a household losing the expected income of forestland is $\lambda(T)$, $0 \leq \lambda(T) \leq 1$, and $\frac{\partial \lambda}{\partial T} < 0$, the safer the forestland tenure, the lower the probability that households will lose the expected income of the forestland. Then, the expected income can be further expressed as:

$$R(I, T) = [1 - \lambda(T)] \bullet V(I) \tag{5}$$

In Eq. (5), $V(I)$ is the expected income when forestland tenure is secure, and $\frac{\partial V}{\partial I} > 0$. That is, the greater the amount of input, the greater the expected income when forestland tenure is secure.

From Eq. (5) can be derived: $\frac{\partial R}{\partial T} \cdot \frac{\partial R}{\partial I} = -\frac{\partial \lambda}{\partial T} \cdot \frac{\partial V}{\partial I} > 0$

So $\dfrac{\partial \Pi}{\partial T} \cdot \dfrac{\partial \Pi}{\partial I} > 0$

Therefore, we can get $\dfrac{\partial I}{\partial T} = -\left(\dfrac{\partial \Pi}{\partial T} \cdot \dfrac{\partial \Pi}{\partial I}\right) \bigg/ \dfrac{\partial^2 \Pi}{\partial I^2} > 0 \tag{6}$

Eq. (6) shows that the amount of household's management input is positively correlated with the forestland tenure security. Thus, the following hypothesis is proposed:

H1. *Forestland tenure security will affect the forest management behavior of households, and secured tenure will stimulate the enthusiasm of households for forest management and improve the forest management level*

However, influenced by factors such as relevant laws, the economy, and customs in different regions, researchers have different perspectives on land tenure security, including legal tenure security, actual tenure security and perceived tenure security (Ma et al., 2015). Legal tenure security includes formal institutions such as land tenure laws, regulations, and national policies (Van Gelder, 2010). The definition of the legal level is fundamental to safeguarding land tenure security. Actual tenure security refers to the actual control of property rights by owners and reflects the results of formal institutions of property rights at the grassroots level (Brasselle et al., 2002). Perceived tenure security is the subjective feeling of households regards tenure security (Broegaard, 2005). It is considered to be the most direct reflection of tenure security. Because land tenure needs to be shaped by the perception of tenure security by households, then it can play a role in influencing households' decisions (Sjaastad and Bromley, 2000; Ma et al., 2016). Perception regarding tenure security is key to understanding households' behavioral decisions. While the laws, regulations, and policies of the CFTR in the collective forest area are the same, and there are nevertheless great differences between the actual and perceived tenure security. Thus, this paper discusses the actual and perceived security of forestland tenure. As households' perception of security regards forestland tenure is formed through changes in the tenure system, actual tenure risks, and their personal experiences and preferences, each household will have differing perceptions when facing the same actual tenure security status. This has led to deviations between actual tenure security and perceived tenure security. In other words, actual tenure security may also be regarded by households as insecure. However, there are interconnections between tenure security at different levels; moreover, the implementation effect of the tenure system will have an impact on the subjective perception of households (Van Gelder, 2010) and thus indirectly affect households' behavior. Based on this, the following hypothesis is offered:

H2. *Actual tenure security and perceived tenure security have different impacts on forest management, and the effect of perceived tenure security on forest management is affected by the actual tenure security.*

3. Econometric model specification

3.1. Model specification

Due to the long production cycle of forests, in addition to the large amount of investment required during afforestation, it is necessary to optimize the management of forests, covering weeding, fertilizing, fire-prevention, insect-prevention, and guarding against thieves. Therefore, to examine the forestland management behavior of peasant households, this paper analyzes the behavior in two aspects: management frequency and management intensity. The annual household's management frequency, defined as the number of times a household go to their forestland for fire, insect, and theft prevention every year, is used to characterize management frequency. Based on the findings of the field surveys, this measurement is an important way for households to protect their forestlands. While the annual household labor input per unit area, which is

mainly used for weeding and fertilizing their forestland, is used to represent management intensity. Our basic model for estimating the impact of forestland tenure security on peasant household forest management is defined as:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \sum \beta_{3j} D_{ji} + \varepsilon_i \tag{7}$$

Eq. (7) identifies two sets of models, in the first model, Y_i denotes the forest management frequency of household i; X_{1i} and X_{2i} are, respectively, the actual and perceived forestland tenure security of household i; D_{ji} denotes other control variables that affect household's forest management frequency. Based on the existing literature as well as the characteristics of collective forest tenure reform and household behavior, the following variables have been identified as relevant control variables: the household characteristics, forestland characteristics, village characteristics, policy regulation, and regional characteristics. β_0 is the constant term, while β_1, β_2 and β_{3j} are the parameters to be estimated; and, ε_i is the error term. In the second model, Y_i denotes the forest management intensity of household i, and the remaining variables are same as those included in the first model.

Furthermore, to explore the interaction effects of actual and perceived forestland tenure security, a cross term was introduced to estimate another model, which is specified as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{1i} X_{2i} + \sum \beta_{4j} D_{ji} + \varepsilon_i \tag{8}$$

In Eq. (8), β_3 is the coefficient of the cross term. It reflects the indirect impact of actual tenure security on forest management through its effects on perceived tenure security. It needs to be pointed out that the addition of the cross term recognizes the combined effects of actual and perceived forestland tenure security; nevertheless, it is difficult to identify changes in the impact of perceived tenure security while changes are occurring in actual tenure security. Referring to the practice of Li et al. (2017), this paper calculates the partial effect of perceived tenure security on the forest management of households at different actual tenure security value points.

In the above model, since the forest management frequency of households conforms to the characteristics of the count data, a count model was used to estimate the equation for management frequency. The general counting model includes the Poisson and Negative Binomial models. However, the limitation of the Poisson model is that the expectation and variance of the Poisson distribution must be equal, or "equidispersion," which is often inconsistent with the actual data. For "over-dispersion" data, the Negative Binomial model can be used for regression. The Negative Binomial model has more discrete parameters than the Poisson model, which can explain the heterogeneity of the data.

The labor input per unit area to manage forestry and which represent management intensity, is a continuous variable. But the data structure has a truncation on the left side at 0, resulting in a limited value of the dependent variable. A Tobit model was thus used to estimate the equation for forest management intensity. In the data set, 37.6% of the samples were left-censored for management intensity, while 62.4% of the samples were uncensored. The Tobit model is well suited to deal with corner solutions.

3.2. Variable definition

The variables were divided into forest management, forestland tenure security, and control variables; the control variables consist of household characteristics, village characteristics, forestland characteristics, policy regulation, and regional characteristics.

Forest management: As mentioned above, forest management by households is defined as the rearing, management and protection of forested land after afforestation. It can be measured by two different indicators, i.e. forest management frequency and management intensity. Forest management frequency refers to the average number of times that households protect their forestland against fire, insect prevention and theft per year. It measures households' management of forestry in terms of protection. Forest management intensity refers to the average annual laborers that households invest in weeding and fertilizing their forestland, which measures the forest management inputs by rural households.

Forestland tenure security: Forestry tenure security is examined at both the actual and perceptual levels. Due to difficulties in defining forest tenure and the implementation deviation of local policies, the fact that forestland certificates are not issued often appears. It is clear that households' ownership of forestland certificates (or not) reflects the efficacy of the forestland property rights system. Possession of forestland certificates is thus used to measure actual tenure security. Possession of forestland certificates takes the value 1 if a household did not possess a forestland certificate, 2 if a household possessed a certificate for part of their forestland, and 3 if a household possessed a certificate for all of their forestland. In addition, based on existing research and combined with the characteristics of collective forest tenure reform, perceived forest tenure security is measured by the perception of households about forestland adjustments and forestland certificates. Perception about forestland adjustments takes the value 1 if a household thinks that the forestland will be adjusted in the next 10 years, 2 if a household is uncertain whether forestland adjustments will take place in the next 10 years, and 3 if a household does not think that the forestland will be adjusted in the next 10 years. As the level of perception increases from 1 to 3, households are more certain that their forestland will not be adjusted in future, and subsequently, the level of their perception regarding forestland tenure security increases. Perception about forestland certificates takes the value 1 if a household thinks that a

forestland certificate protects forestland rights, and 0 if the household does not think so. However, a household's forestry management may affect their perception of tenure security, which can lead to an endogeneity problem. To deal with this problem, village-level perceptions about forestland adjustments and forestland certificates were used to represent perceived tenure security according to the practice of Ma et al. (2016). It is defined as the average perception about two tenure security of the sampled households from the same village. The reason is that the forest management decisions of one household do not affect the forestland tenure security perceptions of others (Ma et al., 2016).

Household characteristics: Household characteristics consist of the age of the household head, the number of family laborers, and the value of a household's fixed assets. In terms of the age of the household head, older household heads have stronger feelings toward their land; thus they prefer to manage their forestland. Households with greater laborers are more likely to manage their forestland. These two variables reflect differences in human capital. Households with more fixed assets are less dependent on forestry, so resulting in less forestry management.

Village characteristics: Village characteristics include the village off-farm income ratio and the distance from the village to the nearest town. The village off-farm income ratio refers to the average off-farm income ratio (off-farm income/total income) of households in the village, which is used as a measure of the development of off-farm employment. A higher off-farm income ratio in rural household reduces farmers' dependence on forestland and weakens the incentives for farmers to manage them. However, the direct introduction of the household off-farm income ratio will lead to endogenous problems; therefore, this paper uses the village off-farm income ratio to reflect the impact of off-farm employment on households' forest management. Distance to the nearest town is an indicator of market access (Rao et al., 2016). Farmers living closer to town have more off-farm employment opportunities. Meaning they may show less enthusiasm for managing forestry.

Forestland characteristics: These characteristics include forestland area, forestland quality, the average distance from forestland to home, and type of forests (Timber forest or economic forest). Differences in resource endowment is one of the factors that affects household behavior. Farmers are more likely to manage larger plots of forestland and better-quality land; contrariwise, homes being far from forestland will inhibit households' enthusiasm for forest management. There are also differences in the management of different forest categories. The long growth cycle of timber forests makes farmers less willing to manage them, whereas households pay more attention to economically-driven forest management because it has a short management period and faster investment returns.

Policy regulation: Policy regulation refers to the forest logging quota. Under the current logging system, obtaining the logging quota is the only legal way for households to earn money from forestry. Therefore, the easiness to apply for forest logging index is the main indicator for measuring the forest logging quota. The logging quotas make it impossible for farmers to manage forestry in view of maximizing profits; this causes losses to farmers' expected returns on forestry activity, and directly discourages the management enthusiasm of farmers.

Regional characteristics: Three county dummies were introduced in this paper's analysis to control the impact of unobserved differences between regions on household forest management.

4. Data and descriptive statistics

4.1. The study area

This study uses data from household surveys conducted in Zhejiang and Jiangxi provinces in August and September 2017. Zhejiang and Jiangxi provinces are the typical forestry regions in southern China, where forest coverage in 2018 was estimated at 59.4% and 61.2%, respectively (NBSC, 2018). The two provinces, given their ranking for forest cover, have been selected as pilot regions for the CFTR. They have significant differences in their level of economic development, forestry development and progress in forest tenure reform. After consideration of factors such as forest resources and forest tenure reform, four forest-dependent counties were selected as research areas, namely, Anji and Suichang in Zhejiang province, and Chongyi and Suichuan in Jiangxi province, as shown in Fig. 1. They are key priority forest counties and advanced counties that have taken the lead in promoting the CFTR in China. Hence, they are representative, to a degree.

Zhejiang has a relatively well-developed economy. With the new reform document issued in 2006, Zhejiang has achieved remarkable results. 8% of China's forestry output was produced in Zhejiang, with on 2% of the country's forestland (Zhang, 2016). It provided valuable experience for national forestry reform and development. Anji county, with an area of 1886 km^2, is located in the mountainous area in north-western Zhejiang province. In 2018, its GDP reached 5780 million USD (ACBSC, 2018). With 70.2% forest cover and forestland of 135,313 hm^2 (71.7% of the county's total land area), forestry plays an important role in the economic structure of the county (ACBSC, 2018). It is known in China as "bamboo county" (Xu et al., 2013). Since the reform was officially initiated in Zhejiang, Anji county has shown great vitality and was awarded the title of "model county of CFTR in Zhejiang province". Suichang county is located in south-western Zhejiang, and its GDP totaled 1666 million USD in 2018 (SCBSC, 2018a). It owns 221,300 ha of forestland, accounting for 87.1% of the total land area (SCBSC, 2018b). It is thus a traditional forestry county. In 2006, Suichang was listed as the pilot county for forest tenure reform; 90% of the county's collective forestland have been granted rights to farmers; and the rate of issuing forest rights certificates has reached 97% (Hua, 2010).

Jiangxi has more abundant forest resources, but is less developed economically. It started the new reform in 2004, which aimed to optimize forestry production, liberate forestry productivity and mobilize the enthusiasm of farmers to manage forestry. Chongyi county is located in the southwest of Jiangxi province and had a GDP of 1314 million USD in 2018 (CCBSC,
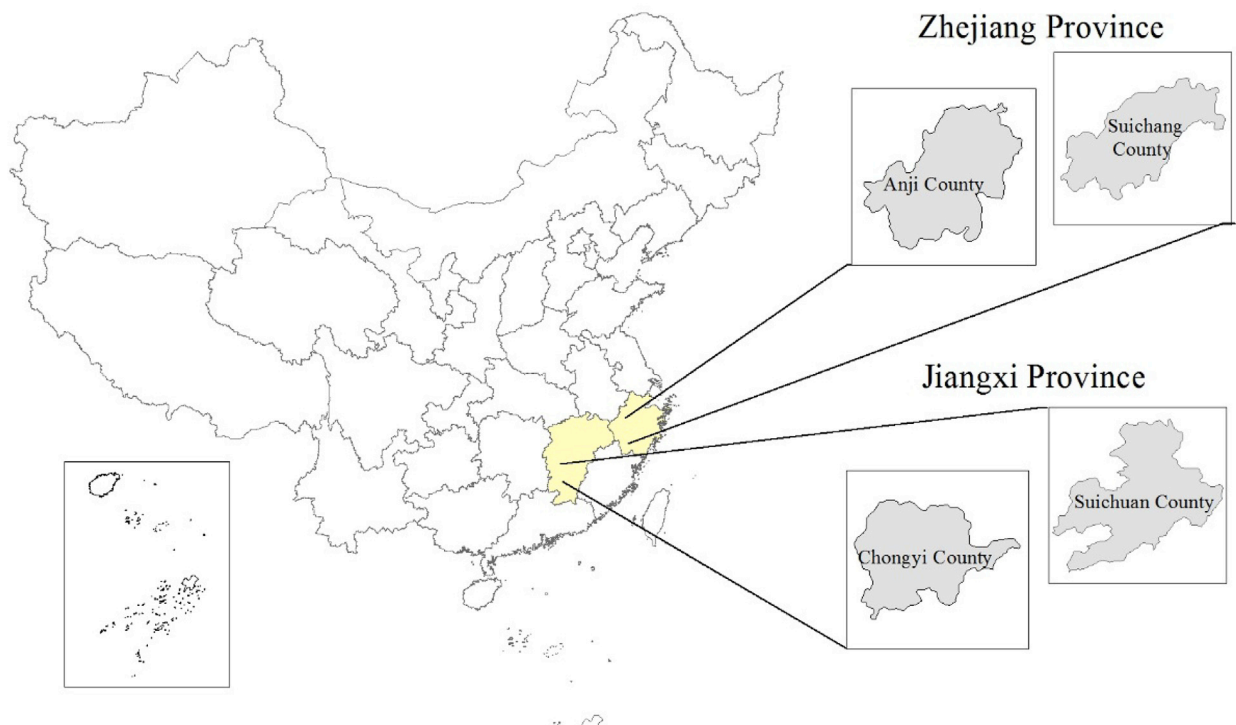
Fig. 1. Geographical distribution of sample areas in rural China.

2018). It is comprised of 179,333 ha of forestland, accounting for 89.3% of the total land area (CCPGC, 2018). In August 2004, Chongyi was designated by the provincial government as a pilot county for the CFTR. Suichuan is another county in south-western Jiangxi, with a GDP of 1852 million USD as of 2018 (SCPGC, 2018). It contains 246,000 ha of forestland, accounting for 78.2% of the total land area (JCPGC, 2018). Suichuan is also one of the pilot counties for forest tenure reform in Jiangxi. A total of 77,856 forest rights certificates were issued to farmers during the reform period (Xie et al., 2009).

4.2. Data collection

As for the configuration of the sample (see Table 1), the random sampling method was adapted. Based on the forestry production in each county, three towns were randomly chosen from each county, and 4 villages were selected randomly from each town. Then 15−20 farmers in every village were chosen as the final respondents according to the size of the village. To ensure the study's quality, the final questionnaire was designed and revised through several discussions and the feedback results of pre-tests. Moreover, a face-to-face interview method was used to collect the information from farmers. In this survey, 793 questionnaires were issued and 766 valid samples were collected after deleting the questionnaires containing missing values. Our questionnaire included sections on basic household information, the characteristics of forest resources, forest management and production, and the status of forestland tenure. The regional distribution of the valid samples is presented in Table 1.

4.3. Data description

Descriptive statistics of the data are shown in Table 2. Among the 766 households, there are 566 (73.9%) households with positive concern for forestry; moreover, the number of households with labor inputs regards forest management is 478 (62.4%). On average, the management frequency of forestry across households is 13.43 times, while the labor input per unit area is only 7.65 day/ha. This shows that rural households are not managing forestry very well, and the way they manage is still relatively inefficient, which does little to mobilize the enthusiasm of households for forest management.

In this study's sample, most of the rural households possess a forestland certificate, and the average value of village perceptions about forestland adjustments equals 2.32, which shows that a large number of households are uncertain whether their forestland would be adjusted. 72% of the households feel that forestland certificates can protect forestland rights, indicating that certificates are still important to households. The average age of the household head is 58 years old; the number of family laborers is 2.47; and the value of fixed household assets equals 389,000 yuan on average. The average proportion of off-farm income in the sample villages is 72%; and the distance to the nearest town is 5 km. Each household has

Table 1
Regional distribution of valid samples.

Province	Zhejiang		Jiangxi	
County	Anji	Suichang	Chongyi	Suichuan
Number of samples	201	185	194	186
Share of samples (%)	26	24	26	24

1.97 ha of forestland on average; 22% of the forestland has good soil quality; and the distance from the forestland to the households was 3 km on average. 29% of the households primarily manage timber forest, and 20% of the households manage economic forest. Additionally, the average value of the forest logging quota variable is 2.14, implying that the application for forest logging index in recent years has been less difficult than before. However, most households still regard the application for logging index as uneasy task.

Table 3 presents the forest management of households under different states of forestland tenure security. This study found that as much as 88% of the households stated they have certificates for all their forestland, while only 4% of the households said they possess certificates for only part of their forestland, and 8% of the households said they do not have any certificates. The management frequency and intensity of the households with certificates for part of their forestland are both higher than that of households without certificates, as well as those with certificates for all their forestland. The frequency and intensity of households without certificates were the least. With respect to the perceived tenure security, nearly 43% of the households do not think that the forestland will be adjusted in the next 10 years, whereas only 11% of households think that there will be forestland adjustment. As households become more certain that their forestland will not be adjusted, the management frequency of households gradually increased. In contrast, about 72% of the households believe that forestland certificates protect forestland rights, while 28% of the households hold the opposite belief. Furthermore, the study found that households who believe that certificates can protect forestland rights have higher management frequency and intensity.

5. Estimation results

In this paper, Stata14.0 statistical software was used to explore the impact of forestland tenure security on forest management frequency and the management intensity of households. On the analysis of forest management frequency, it is necessary to discriminate whether there is "overdispersion" in the data. The results show that the mean value is significantly smaller than the variance, and the alpha test has a P value of 0.000 (<0.05), which passed the significance test. It indicates that the data has "overdispersion," and follows the Negative Binomial distribution. This paper therefore used the Negative binomial model for estimation. The Tobit model was used to analyze the forest management intensity of households.

Table 2
Variable meaning and descriptive statistics.

Variable		Definition	Mean	Std.
Forest management	Management frequency	Management frequency of forestry (times)	13.43	44.63
	Management intensity	Labor input per unit area to manage forestry (day/ha)	7.65	10.95
Actual tenure security	Possession of certificates	3 = with certificates for all forestland, 2 = with certificates for part of forestland, 1 = without certificates	2.80	0.57
Perceived tenure security	Village perception about adjustments	Average perception about forestland adjustments of the sampled households from the same village	2.32	0.21
	Village perception about certificates	Average perception about forestland certificates of the sampled households from the same village	0.72	0.17
Household characteristics	Age	Age of household head (year)	57.81	10.64
	Laborers	Number of family laborers	2.47	1.18
	Fixed asset	Value of fixed assets (thousand yuan)	389.23	381.95
Village characteristics	Village off-farm income ratio	Average forestry income ratio (off-farm income/total income) of the households in village	0.72	0.17
	Distance to town	Distance from village to the nearest town (km)	4.96	3.66
Forestland characteristics	Forestland area	Forestland area in the household (ha)	1.97	3.49
	Forestland quality	Good quality forestland area/total forestland area	0.22	0.40
	Distance to home	Average distance from forestland to home (km)	2.93	2.07
	Timber forest	1 = timber forest area account for the most, 0 = otherwise	0.29	0.45
	Economic forest	1 = economic forest area account for the most, 0 = otherwise	0.20	0.40
Policy regulation	Forest logging quota	3 = easy to apply for logging index, 2 = not too easy to apply for, 1 = difficult to apply for	2.14	0.76
Regional characteristics	Anji	1 = Anji county, 0 = otherwise	0.26	0.44
	Suichang	1 = Suichang county, 0 = otherwise	0.24	0.43
	Chongyi	1 = Chongyi county, 0 = otherwise	0.25	0.44

Table 3
Forest management under different states of forestland tenure security.

Forestland tenure security			Share of households(%)	Management frequency	Management intensity
Actual tenure security	Possession of certificates	Without certificates	8	5.87	0.42
		With certificates for part of forestland	4	17.79	0.98
		With certificates for all forestland	88	13.96	0.50
Perceived tenure security	Perception about adjustments	Forestland will be adjusted	11	11.00	0.57
		Uncertain	46	11.31	0.43
		Forestland will not be adjusted	43	16.33	0.57
	Perception about certificates	Certificate cannot protect forestland rights	28	8.97	0.50
		Certificate can protect forestland rights	72	15.18	0.51

5.1. Effect of actual and perceived tenure security on forest management

Table 4 reports the regression results for the forest management of households. This study found that the possession of certificates had no significant impact on forest management frequency and intensity. This indicates that actual tenure security, i.e. holding a forestland certificate, does not incentivize households' management behavior. In other words, households who have official certificates for all their forestland have not significantly increased their management frequency and intensity in forestry. The reason is that the issuance rate of forestland certificates in the study area has gradually increased in recent years. Among the 766 interviewed households, only 63 households do not have forestland certificates and 28 households have forestland certificates for only part of their forestland. Therefore, even if forestland certificates can ensure that the expected income from forestland is not threatened by others or interfered with by external factors (Liu, 2011), its impact on the forest management of households is not significant. Moreover, the weak nature of forestry makes it difficult for rural households to obtain forestry income in the short term. In the presence of external selection, households with forestland certificates may be more inclined to put labor into other off-farm industries to obtain more income, thereby weakening the incentive effect of actual tenure security on forest management frequency and intensity in households.

From Table 4, it can be seen that the village perception about adjustments has a positive and statistically significant impact on forest management frequency and management intensity. It shows that households who perceive no forestland adjustments display a higher likelihood of managing forestry. Which is to say, perception about forestland adjustments is an

Table 4
Regression results for forest management.

Independent variable		Management frequency (Negative binomial)		Management intensity (Tobit)	
		Coef.	Std. Err.	Coef.	Std. Err.
Forestland tenure security	Possession of certificates	0.192	0.132	0.025	0.071
	Village perception about adjustments	0.663*	0.340	1.007***	0.205
	Village perception about certificates	0.884	0.560	0.189	0.316
Household characteristics	Age	0.013*	0.007	−0.004	0.004
	Laborers	0.153***	0.058	0.022	0.034
	Ln (fixed asset)	−0.174**	0.067	−0.064	0.041
Village characteristics	Village off-farm income ratio	0.114	0.384	−0.270	0.236
	Distance to town	0.070***	0.019	0.020*	0.011
Forestland characteristics	Forestland area	0.007***	0.002	−0.001*	0.001
	Forestland quality	0.829***	0.166	0.150	0.099
	Distance to home	−0.106***	0.033	0.031	0.019
	Timber forest	−0.172	0.183	−0.012	0.106
	Economic forest	0.073	0.224	0.289**	0.125
Policy regulation	Forest logging quota	0.325***	0.087	0.023	0.051
Regional characteristics	Anji	0.759***	0.264	0.298*	0.155
	Suichang	0.032	0.208	−0.042	0.124
	Chongyi	0.163	0.203	0.440***	0.117
	Constant	−0.832	1.454	−1.638*	0.856
	Number of obs	766		766	
	LR chi2	160.74		89.14	
	Prob > chi2	0.000		0.000	
	Log likelihood	−2332.548		−879.827	

Notes: *, **, and ***denote statistical significance at 10%, 5%, and 1% levels, respectively.

important factor affecting households' forest management. A possible reason is that, in the process of household decision making, households will first distinguish and review relevant information, which will then guide their decision-making (Niu and Zhou, 2014). Therefore, when households understand forestland tenure, they feel that the risk of future adjustments to their forestland is lower and the expected income from such lands is more certain. Thus, they worry less about managing forestland. This strengthens the incentives for households to manage and protect forestland (Yi et al., 2014), which not only increases households' management frequency but also improves the management intensity of households. However, the village perception about certificates has no significant impact on forest management frequency and management intensity. This may be explained by the changes to the collective forestland tenure system in China. Frequent changes have led to households' lack of security in terms of property rights for collective forests (Holden et al., 2013). When a village decides to retract a land certificate, no matter how strong the household thinks it has a right to protect the land, it will lose the land (Qin and Xu, 2013). It can be seen that the attributes of forest resources cause the government to have strong control over forest resources. Thus, the protection of forestland rights by forestland certificates is at present primarily to draw a clear line and prevent other households from infringing. That said, it has not played a role in protecting against forestland adjustments and expropriations by the government. Thus, the perception about forestland certificates as a means of protecting forestland rights has no obvious incentive effect on the forest management of households. Overall, perceived tenure security is more encouraging for households' forest management than actual tenure security. When forestland tenure is transformed into households' subjective perception of forestland tenure, the forest management behavior of households can be better understood. The primary purpose of the CFTR is to encourage households to manage forestry through increasing the security of forestland tenure. But deviations in policy implementation and a lag in forestry market conditions has affected households' perception of forestland tenure security, leading to low enthusiasm for households regards forest management. In addition, compared to the existing literature (e.g. Yang et al., 2018), our results, on the one hand, confirm that the possession of certificates is not a strong incentive to improve the level of forest management. On the other hand, we found that the village perception about adjustments can significantly increase the frequency and intensity of forest management, but the village perception about certificates does not.

With respect to household characteristics, the age of the household head has a significant positive effect on forest management frequency, showing that elderly household heads tend to look after their forestland. Laborers also has a significant positive impact on management frequency, indicating that households with more laborers have higher forest management frequency. The fixed assets of households are negatively correlated with management frequency. Which is to say, households which have more fixed assets are less dependent on forestry. Regarding village characteristics, the distance from a village to the nearest town positively affects management frequency and management intensity, as expected. Such means that the farther the rural household is from town, the higher the management frequency and the greater the labor input. This is because households that are living far away from towns are not easily exposed to new things, and therefore tend to depend on the forests.

Regards forestland characteristics, forestland area positively affects management frequency, while having a significant negative impact on management intensity. A possible reason is that to achieve scale management, households are more inclined to protect large areas of forestland, which lead to a reduction in labor cost and help to increase forest management frequency. Forestland quality also has a positive impact on management frequency, indicating that the higher the proportion of good quality forestland, the higher the management frequency of households. The distance from forestland to homes is negatively correlated with management frequency. Such shows that households are reluctant to protect forestland that is far away; inversely, nearby forestland are more likely to be managed and protected, and allow households to engage in off-farm production. Economic forest positively affects management intensity, meaning that households prefer to manage economic forest, given its short growth cycle. Additionally, forest logging quotas have a significant positive impact on management frequency. When the logging index is easy to apply to, households increase management frequency. Finally, regional dummy variables have different degrees of influence on forest management frequency and management intensity.

5.2. Interaction effect of actual and perceived tenure security on forest management

Table 5 reports the regression results after introducing the cross-term of actual and perceived tenure security. The results show that the significance and direction of the variables are consistent with Table 4. The interaction term between the possession of certificates and village perception about adjustments has an insignificant effect on management frequency, while it has a significant positive impact on management intensity. Regards the village perception about certificates, the interaction term is found to have a significant negative effect on management frequency, but not on management intensity. This indicates that actual and perceived tenure security do not show a consistent interaction effect on households' forest management.

This study further calculated the average marginal effects of perceived tenure security on forest management under different states of actual tenure security, as shown in Table 6. With the possession of certificates, ranging from no certificate to having certificates for all forestland, the marginal effects of the village perception about forestland adjustments on the two management variables are all on the rise. In other words, improvements in the possession of certificates reinforce the positive effect of village perception about forestland adjustments on forest management. Specifically, the village perception about adjustments tends to have a significant positive impact on management frequency and management intensity for households who possessed certificates for all their forestland, but not for those who did not possess certificates or possessed certificates

Table 5

Regression results for introducing cross-term.

Independent variable		Management frequency (Negative binomial)		Management intensity (Tobit)	
		Coef.	Std. Err.	Coef.	Std. Err.
Forestland tenure security	Possession of certificates	0.070	0.151	0.023	0.077
	Village perception about adjustments	0.634*	0.351	0.930***	0.208
	Village perception about certificates	0.771	0.571	0.183	0.316
	Possession of certificates × Village perception about adjustments	0.024	0.097	0.095**	0.047
	Possession of certificates × Village perception about certificates	−0.171**	0.076	−0.014	0.035
Household characteristics	Age	0.013*	0.007	−0.004	0.004
	Laborers	0.149**	0.057	0.021	0.034
	Ln (fixed assets)	−0.182***	0.068	−0.059	0.040
Village characteristics	Village off-farm income ratio	0.060	0.386	−0.274	0.236
	Distance to town	0.065***	0.019	0.021*	0.011
Forestland characteristics	Forestland area	0.006***	0.002	−0.001*	0.001
	Forestland quality	0.816***	0.165	0.152	0.099
	Distance to home	−0.098***	0.033	0.030	0.019
	Timber forest	−0.183	0.182	−0.012	0.106
	Economic forest	0.077	0.226	0.273**	0.125
Policy regulation	Forest logging quota	0.340***	0.087	0.025	0.051
Regional characteristics	Anji	0.723***	0.263	0.275*	0.155
	Suichang	−0.055	0.212	−0.030	0.125
	Chongyi	0.173	0.203	0.436***	0.116
	Constant	−0.175	1.487	−1.467*	0.867
	Observations	766		766	
	LR chi2	166.38		93.19	
	Prob > chi2	0.000		0.000	
	Log likelihood	−2329.730		−877.803	

Notes: *, **, and ***denote statistical significance at 10%, 5%, and 1% levels, respectively.

Table 6

Average marginal effects for perceived tenure security.

Variable		Management frequency (Negative binomial)		Management intensity (Tobit)	
		Coef.	Std. Err.	Coef.	Std. Err.
Village perception about adjustments	Possession of certificates = 1 (without certificates)	3.702	22.143	−0.213	0.325
	Possession of certificates = 2 (with certificates for part of forestland)	6.507	11.456	0.121	0.172
	Possession of certificates = 3 (with certificates for all forestland)	10.183*	5.476	0.465***	0.090
Village perception about certificates	Possession of certificates = 1 (without certificates)	56.041	36.948	0.189	0.301
	Possession of certificates = 2 (with certificates for part of forestland)	30.678**	14.599	0.128	0.174
	Possession of certificates = 3 (with certificates for all forestland)	6.129	8.966	0.065	0.141

Notes: *, **, and ***denote statistical significance at 10%, 5%, and 1% levels, respectively.

for only part of their forestland. Hence, it can be concluded that it is only when households possess certificates for all their forestland and believe that the forestland will not be adjusted in the future that they will be more certain about the future expected income from forestry. This means that management frequency and management intensity will be strengthened at the same time. Contrarily, there is a downward trend in the marginal effect of the village perception about forestland certificates on the management variables, with the possession of certificates ranging from no certificate to having certificates for all forestland. In terms of significance, households which possessed certificates for only part of their forestland, the perception about certificates' ability to protect forestland rights positively affected management frequency. A possible reason is that these households are more likely to expect to possess certificates for all their forestland to protect their land rights, which motivates them to increase their management frequency; nevertheless, households who already have certificates for all their forestland are less likely to strengthen management because the protection from certificates is limited.

Furthermore, for the interaction effect of actual tenure security and perceived tenure security on forest management, our results go further beyond those of Yang et al. (2018), which focused on the interaction effect of possession of certificates and perception of household on adjustments. More specifically, our study introduced the interaction term of possession of certificates and village perception about adjustments, and the interaction term of possession of certificates and village perception about certificates, respectively. Based on this, our study calculated also the average marginal effects of village

perception about adjustments and village perception about certificates on forest management under different states of possession of certificates.

6. Discussion

Our results confirm several findings of the related literature, but also provide results that contrast the findings of some of the existing studies. For instance, some existing studies have found that the CFTR have increased households' investment incentives through the issuance of forestland certificates (e.g. Yi et al., 2014; Liu et al., 2017a). However, the findings from the present study indicate that the actual tenure security in the current forestland tenure institutional framework, derived from the possession of forestland certificates, is not a key factor in improving the level of household forestry management. Especially, the most significant extension of this study upon previous studies is the analysis of the impact of forestland tenure security on forest management from the actual level and the perceptual level. In addition, compared to Yang et al. (2018), we further measured the perceived tenure security using the village perception about forestland adjustments and the village perception about forestland certificates. Based on this, we find that the village perception about adjustments significantly increase the frequency and intensity of forest management, but the village perception about certificates does not. This indicates that when actual tenure security is aligned with the perception of households, forestland tenure security will stimulate forest management. That said, the two perceived tenure security variables have markedly different effects on forest management. A possible reason is that no adjustments means that there will be no changes to forestland in the coming years, including the government not expropriating forestland. Households will feel that forestland tenure is thus more stable. The forestland certificate is meant to protect against occupation by other households and business enterprises, but it does not prevent the government from expropriating.

Another critical aspect is that there are differences in the influence of perceived tenure security on forest management under different levels of actual tenure security. The results indicate that increases in the possession of certificates strengthens the incentive effect of the perception about forestland adjustments to forest management; moreover, the perception that the forestland will not be adjusted significantly and positively affects management frequency and management intensity for households with certificates for all their forestland. This means that possessing certificates for all forestland and determining that the forestland will not be adjusted are indispensable for improving forest management. In contrast, increases in the possession of certificates weakens the impact of the perception about forestland certificates on forest management, indicating that the possession of certificates and the perception about certificates have a substitution effect on the impact of forest management. Additionally, the role of land certificates in protecting forestland rights has a significant positive impact on management frequency for households with certificates for only part of their forestland. This is because those households believe that holding certificates for all their forestland will better protect their land rights, thereby making them more willing to take care of their forests.

The results of this study indicate that the perceived tenure security of forestland has a greater impact on household forest management, while actual tenure security affects management indirectly by influencing perceived tenure security. It can be seen that raising awareness about the security of forestland tenure for rural households is the focus of the CFTR, especially regards improving the perception about no forestland adjustments. However, the ever-changing experience of forestland tenure in China has resulted in negative impacts on the perceived tenure security of households. Lag in the supportive reform of CFTR has also weakened the perception of forestland tenure security among households. All of which make it difficult to stimulate the enthusiasm of households toward forest management.

7. Conclusion and implications

The management and protection of forested land by rural households plays an important role in enhancing productivity as well as increasing the volume of collective forests. However, existing studies on the impact of collective forestland tenure on households' forestry production have primarily focused on afforestation, timber harvesting, and overall forest investment. Only a few studies have analyzed the effect of forestland tenure security on forest management decisions. This paper used data collected from 766 households in Zhejiang and Jiangxi province to empirically analyze forestland tenure security and forest management. Generally speaking, forestland tenure security has an impact on household forest management, but the degrees of influence between actual and perceived levels of tenure security is inconsistent.

The empirical results reveal that the actual tenure security, derived from the possession of certificates, has not significantly increased forest management frequency or management intensity. In relation to the perceived tenure security, the perception about adjustments could improve both management frequency and management intensity, whereas the perception about certificates does not. These results are consistent with the hypothesis that the effect of perceived tenure security on forest management is affected by the actual tenure security, which is obvious from the significant coefficients of the cross-terms between actual tenure security and perceived tenure security, as well as the significant coefficients of the average marginal effects of perceived tenure security on forest management under different states of actual tenure security. For households with certificates for all forestland, the results indicate that the perception about adjustments has a positive impact on both management frequency and intensity. For households with certificates for part of forestland, the perception about certificates positively affects management frequency.

Three important policy implications can be derived from this research. First, actual tenure security helps to strengthen households' perception of tenure security. Such can increase actual tenure security by deepening the CFTR's main reform, which involves improving the work of granting certifications in reforms and ensuring the full issuance of forestland certificates to enhance the value of possessing forestland certificates. The problem of forest rights disputes, left over from the historical reforms of collective forestland tenure, is recommended to be solved simultaneously. Second, perceived tenure security can be an effective tool for improving forest management. Hence policies should pay more attention to household perceptions of forestland tenure security. The local government should implement policy provisions to improve awareness about forest tenure reform, so as to avoid distortions during implementation. It is also necessary to strengthen advocacy to expand households' policy awareness, such that their effects can influence the subjective perceptions of households in a timely manner. In addition, since the perception of forestland certificates does not play a positive role in improving forest management, the local government should restrain from freely recovering existing certificates, so as to ensure that the forestland certificate currently in effect still effectively protect the rights of their holders. Finally, the CFTR's supportive reform also needs to improve to give households as many rights as possible, as well as reduce households' concerns regarding forest management. At the same time, appropriate technical and financial support should be provided to better activate their willingness to manage.

A limitation in this research is the use of cross-sectional data for analysis. The long growth cycle of forests requires panel data to analyze its management. The findings of this study are based on regional data covering only four counties in southern China. Thus, the conclusions may not apply to other places. For a broader understanding, a larger sample size and long-term panel data should be used in future research, so as to better examine the relationship between forestland tenure security and household forest management.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

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