An analysis of potential investment returns of planted forests in South China

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Abstract

Financial returns of forest plantations are an important concern around the world. In this research, we focused on South China's timber investments, collected data from the Pingxiang, Guangxi Province, China, which is the demonstration zone of Fast-growing and High-yielding Timber Plantation Base Construction Program and National Timber Strategic Storage and Production Bases Construction Program, and used capital budgeting analysis method and sensitivity analysis to compare different scenarios of planted forest management. The results showed that excluding land costs, (1) the financial returns of *Eucalyptus* forest managed by small business were excellent, having an IRR of 28% per year and a LEV of $7555 per ha, but it had a high risk with fluctuations of cost, timber price and timber yield; (2) the results for the Experimental Center of Tropical Forests indicate that the *Eucalyptus* forest and *Castanopsis hystrix* forest returns were greater than those for *Cunninghamia lanceolata* forest and *Pinus massoniana* forest, with having IRRs of 24%, 21%, 13% and 10% per year respectively. The mixed planted forest of *Castanopsis hystrix×Eucalyptus* and *Castanopsis hystrix×Pinus massoniana* had the features of high profits and low risks; (3) the forest farmers had lower levels of returns for *Eucalyptus* forest management in South China, but were still in the middle rank of global comparisons. This study gave a view of China's timber investment and provided more options of improving the economic returns of planted forest management to both small businesses and forest farmers in South China.

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Introduction

Financial returns from planted forests are one of the most important business decisions for reliable future returns around the world (Cubbage et al. 2007, 2010; Wang et al. 2014). From 1990 to 2015, the world total area of planted forests increased from 167.5 to 277.9 million hectares or 4.06% to 6.95% of total forest area (Macdicken et al. 2015). As the most populated country of the world, China has made extraordinary efforts in developing planted forests during the past decades (Zhang and Song 2006). In 2015, there were 78.9 million ha of planted forest in China which accounted for 28.4% of the world's total planted forest area or 33.33% of the China's forest area. *Cunninghamia lanceolata*, *Populus* spp., *Eucalyptus* spp., *Larix gmelinii* and *Pinus massoniana* were China's main tree species of planted forest (Liu et al. 2014).

China has substantial opportunities to increase timber production in the future (Payn et al. 2015). There are some important policies promoting the further increase:

The first policy is the Natural Forest Protection Program (NFPP), which was implemented by the Chinese government in 1998 and was aimed at protecting the forest ecosystem, and strengthening eco-conservation. It strictly prohibited commercial logging of natural forests (Bai et al. 2015) and indirectly guaranteed the area growth of planted forests that potentially support natural forest conservation (Ainembabazi and Angelsen 2014; Secco and Pirard 2015). This program gradually changed the center of timber production from state-owned natural forests in North China to planted forests in South China.

The second policy is Fast-growing and High-yielding Timber Plantation Base Construction Program (2002) which was intended to solve the problem of China's timber and forest products supply. Wood consumption in China has undergone tremendous increases as a result of a booming economy (He and Xu 2011). Nevertheless, its domestic timber production was nearly constant from 2005 to 2014. The huge gap between consumption and production reached to 51.19 million m^3 in 2014 (Forestry Statistics Almanac 2015). Of all logs and lumber imported into Asia in 2013, China's imports accounted for 71% and 47% respectively (Sewall 2014). This program has constructed many plantation bases for different kinds of forest productions, such as paper pulp, wood-based panel and large diameter logs. The planted forests in southern China are increasing in importance.

The third policy is the National Timber Strategic Storage and Production Bases Construction Program, which emphasized forming a timber resources system for back-up, with basically proper mix and relatively optimized structure of tree species, in order to reduce the imbalance between supply and demand of domestic timber (SFA 2013a). Implemented in 2012, this program planned to increase the timber supply by 100 million m^3 over the following 10 years.

The fourth policy is Collective Forest Tenure reform (2003) which began to reduce the scope of collective management and increase the share of individual management (forest farmers) without changing the legal ownership, providing for more diverse planted forest management entities (Qin et al. 2011). Two types of forestland ownership co-exist in China: state ownership, which is most prevalent in North China and village collective ownership, which dominates in South China (Jiang et al. 2014). Collectively-owned forests accounted for 58% of China's total forest area and 32% of total timber volume (SFA 2013b). By 2011, the property rights of 168 million ha (92%) of collective forest land had been clarified and about 82 million households had received forestland certificates (FAO 2013). Some farmers began to pay attention to forest land management, while some farmers transferred their forest land to companies or individuals who want to manage on a large scale. In Guangxi province in South

China, there were more than 1000 small business owners whose forestland was more than 30 ha (Shaoming and Zheng 2006).

These forestry policies gave the investment of planted forests in China its own characteristics. The planted forests in South China were more important than before. Fast-growing and high-yielding plantations became more popular in South China. Furthermore, the planted forest investment from forest farmers and the private sector were motivated after the Collective Forest Tenure Reform. A diversity of planted forests management entities in South China were developed.

A number of articles have examined the investment returns of planted forests around the world. Some focused on a large set of countries and compared advantages among these countries. Sedjo (1983, 2001) calculated average investment returns for selected plantation species (*Pinus* spp., *Eucalyptus* spp*., Pseudotsuga menziesii* and *Picea abies*) in USA, Brazil, Chile, New Zealand, South Africa and Europe. Cubbage et al. (2007, 2010, 2014) compared plantation financial returns from countries in tropical, subtropical, and temperate areas of North and South America, Asia, and Oceania, used exotic species, primarily *Pinus* spp. and *Eucalyptus* spp. Some examined the investment returns for individual species or countries. Xin-Min et al. (2001) analyzed economic performance of *Pinus massoniana* forest for pulpwood in South China. Liao et al. (2009) investigated the financial performance of investments in timberland and timber and their correlations with nonforestry financial assets in the United States. Some studies focused on one to three species with different management modes in a certain research area. Maraseni et al. (2017) compared the financial returns from acacia plantations with different plantation densities and rotation ages in Vietnam. Salek and Sloup (2012) evaluated the pure and mixed stands in Central Vietnam high lands. A few other studies estimated timber investment returns for different management entities. Frey et al. (2018) compared the profitability of state forest enterprises plantations and smallholder forest plantations in Vietnam. Wang et al. (2014) analyzed of potential investment returns and their determinants of *poplar* plantations in state-owned forest enterprises of China. However, there is relatively little literature provided comprehensive knowledge and detail information of the South China planted forests investment.

This research focused on South China's planted forests investments and extended analyses to complex details, such as different management entities (state-owned forest managed by state, collective-owned forest managed by small business, and collective-owned forest managed by forest farmers); different tree species (*Cunninghamia lanceolata, Pinus massoniana*, *Eucalyptus* and *Castanopsis hystrixh*); and different management modes (pure forest and mixed forest). We collected data from Pingxiang, Guangxi Province, China, and used the cost–benefit analysis method and sensitivity analysis to compare different scenarios of planted forest management.

The objectives were to: (1) evaluate the investment returns of planted forests; (2) compare the economic benefit of different tree species and management modes, and the efficiency of different management entities; and (3) calculate sensitivity coefficients and summarize the risks among these scenarios. This research can provide information about plantation forest management in South China, and help forest farmer, small business and state forest enterprises in South China make forest investment decisions.

Materials and methods

Study area

This research's study area, Pingxiang County, is located in Guangxi Province in Southwest China. Pingxiang County has a subtropical monsoon climate, ranging geographically from 106°41′ to 106°59′E and 21°57′ to 22°16′N, characterized by wide seasonal variations in rainfall (the annual rainfall in the region is 1200–1500 mm), high temperatures (the annual average temperature varies between 20.5 °C and 21.7 °C) and high humidity (the relative humidity is 80–84%) (Jiang et al. 2015). The soil at the study area was formed from granite and is classified as red soil in the Chinese soil classification, showing pH value of 4.8–5.5 (Youjun et al. 2013).

The planted forest management in Pingxiang County is typical of that in South China. Most kinds of planted forest management ownership types, most of planted forest species and planted forest management methods exist there. Private forestry sector in Pingxiang County largely operates as part of the South China timber market (Bai et al. 2015; Dai et al. 2013). The state forest enterprises in Pingxiang County as all the state forest enterprises in South China are government-controlled.

Management regimes

We collected data by identifying the most common and important forest species and management regimes from three kinds of planted forest management entities in the region (Table 1). The data were standardized by means of the Excel spreadsheets adapted from Cubbage et al. (2007, 2010, 2014), and adjusted to include relevant management activities and costs. The Excel template is available as supplementary information in Cubbage's article (2014). The approach in the template and its capital budgeting formulas are described here.

The spreadsheet was a template with cells for species, planting and management costs, timber productivity, and timber returns, which were then used to calculate various capital budgeting metrics. The costs include all relevant forest regeneration, intermediate stand treatments and management, costs for taxes, and administration for every scenario. We collected data from a government research forest and from surveys of forest business owners and forest farmers in South China. From these research records and surveys, we chose ten species and management combinations, with typical data as the base case to produce the most representative management, cost, and return scenarios.

The cost, timber price and timber yield were the key factors influencing the returns of timber investment in China (Huang 2007; Song-Hai et al. 2016). Thus, each management regime would have these three variables with three levels (lower, basic, and higher levels) and thus 27 combinations of inputs analyzed (Table 2). This then generated groups of present value and rate of return, which indicated the range and more likely capital budgeting results.

The Experimental Center of Tropical Forests (ECTF)

The Experimental Center of Tropical Forests (ECTF) is a typical state-owned forest farm in South China that has strong research funding and scientific capacity. Owning about 16,000 ha of forests, ETCF has had experience of managing planted forests, which

Table 1 Predominant species management regimes, cost, and prices analyzed in South China

Code	Management entity	Management modes	Rotation Age (years)	MAI (m³/ha/yr)	Costs years 1–5($/ha)	Total Costs A Rotation ($/ha)	Thinnings and harvests (m³(Year))	Total Yield per rotation (m³)	Timber Prices ($/m³(cm, Length * diameter))
1	ECTF[a]	*Eucalyptus* forest	6	20	2620	7120	120 (6)	120	66.67 (200*6) 91.67 (200–260*8–12) 101.67 (200–260* ≥14)
2	ECTF	*Cunninghamia lanceolata* forest	30	6.9	1715	9685	12 (11); 30 (15); 165 (30)	207	138.33 (200–400*14) 150 (200–400*16) 158.33 (200–400*18) 166.67 (200–400* ≥20)
3	ECTF	*Pinus massoniana* forest	30	6.9	1727.5	9630	12 (11); 30 (15); 165 (30)	207	96.67 (220–280*8–12) 111.67 (220–280*14–18) 128.33 (220–280* ≥20)
4	ECTF	*Castanopsis hystrix* forest	30	9.1	1917.5	12,455	3 (7); 36 (15); 51 (19); 183 (30)	273	333.33 (220–280*14–18)
5	ECTF	*Castanopsis hystrix*×*Eucalyptus* forest	30	26.5	2740	39,852.5	120 (6, *Eucalyptus*); 120 (12, *Eucalyptus*), 120 (18,*Eucalyptus*), 105 (24, *Eucalyptus*); 105 (30, *Eucalyptus*); 225 (30, *Castanopsis hystrix*)	795	The same as 1 and 4
6	ECTF	*Castanopsis hystrix*×*Pinus massoniana* forest	30	10	1510	13,260	30 (10, *Pinus massoniana*); 45 (16, *Pinus massoniana*); 225 (30, *Castanopsis hystrix*)	300	The same as 3 and 4
7	Small business	*Eucalyptus* forest	6	20	2930	5830	120 (6)	120	The same as 1

Table 1 (continued)

Code	Management entity	Management modes	Rotation Age (years)	MAI (m³/ha/yr)	Costs years 1–5 ($/ha)	Total Costs A Rotation ($/ha)	Thinnings and harvests (m³(Year))	Total Yield per rotation (m³)	Timber Prices ($/ m³(cm, Length * diameter))
8	Forest farmer	*Eucalyptus* forest	6	17.5	3155	6567.5	105 (6)	105	The same as 1
9	Forest farmer	*Cunninghamia lanceolata* forest	30	3.5	755	755	105 (30)	105	91.67, This contract price which contained the clearcut fee, transportation fee and tax
10	Forest farmer	*Pinus massoniana* forest	30	3.5	850	850	105 (30)	105	91.67, This contract price which contained the clearcut fee, transportation fee and tax

[a]ECTF is the Experimental Center of Tropical Forests, Chinese Academy of Forest

Table 2 Three variables with three levels in ten planted forest management scenarios in research

Code	Management entity	Management modes	Adjustment coefficient								
			Cost			Price			Yield		
			−	Base	+	−	Base	+	−	Base	+
1	ECTF[a]	*Eucalyptus* forest	− 20%	Base	+ 20%	− 20%	Base	+ 20%	− 20%	Base	+ 20%
2	ECTF	*Cunninghamia lanceolata* forest	− 20%	Base	+ 20%	− 20%	Base	+ 20%	− 20%	Base	+ 20%
3	ECTF	*Pinus massoniana* forest	− 20%	Base	+ 20%	− 20%	Base	+ 20%	− 20%	Base	+ 20%
4	ECTF	*Castanopsis hystrix* forest	− 20%	Base	+ 20%	− 20%	Base	+ 20%	− 20%	Base	+ 20%
5	ECTF	*Castanopsis hystrix×Eucalyptus* forest	− 20%	Base	+ 20%	− 20%	Base	+ 20%	− 20%	Base	+ 20%
6	ECTF	*Castanopsis hystrixh×Pinus massoniana* forest	− 20%	Base	+ 20%	− 20%	Base	+ 20%	− 20%	Base	+ 20%
7	Small business	*Eucalyptus* forest	− 10%	Base	+ 10%	− 20%	Base	+ 20%	− 10%	Base	+ 10%
8	Forest farmer	*Eucalyptus* forest	− 30%	Base	+ 30%	− 20%	Base	+ 20%	− 30%	Base	+ 30%
9	Forest farmer	*Cunninghamia lanceolata* forest	− 30%	Base	+ 30%	− 20%	Base	+ 20%	− 30%	Base	+ 30%
10	Forest farmer	*Pinus massoniana* forest	− 30%	Base	+ 30%	− 20%	Base	+ 20%	− 30%	Base	+ 30%

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provided necessary data. This research focused on its six planted forest management models, which were their primary management models (Table 1).

The research materials are provided by the forest management department, ECTF, including the productive investment cost list (forestation, young growth tending, sanitation cutting, thinning, clear cutting, transportation, fire control, roads and disease control etc.), timber price list, timber harvest list, and related data from 2011 to 2013.

The data for six scenarios managed by ECTF in 2013 as the base were available as supplementary information upon request. Considering the data in 2011 and 2012 and the individual differences among each piece of forestland, for all the six scenarios managed by ECTF, the total cost was adjusted by ±20%, the timber price by ±20% and timber yield by ±20%. Although the cost, timber prices and timber yield of different scenarios for ECTF varied, we used the same adjustment coefficient for each factor, which could represent the overall volatility.

Small business

After the Collective Forest Tenure Reform, one consequence had been the fragmentation of forestlands (Zhen et al. 2018). Small business owners began to aggregate holdings in order to improve the economies of scale in forest management and reduce the fragmentation of forestland (Zhen et al. 2018). They gathered forestland by transferring the forestland from individual farmer households whose management rights of forestland were clarified after the reform (Xu and Jiang 2009).

We interviewed three small businesses who managed more than 60 ha of forest land in Pingxiang County and collected their cost and benefit data in 2013. They chose the pure *Eucalyptus* forest as their main management mode (Table 1). For the typical regime, small businesses paid land rents for 10 years or 15 years before the planting activities, and divided the management process to small parts, and contracted them to different professional teams. In the first year, they prepared the seedlings and contracted out the afforestation. The contractors got payment under the condition that the survival rate of the *Eucalyptus* forest reached 95% 1 month after planting. The timber harvest and transportation were contracted out together and paid according to how many cubic meters they had to harvest.

We chose this typical one as the base. Considering the data from the other two small businesses, we adjusted the total cost by ±10%. The timber price and adjustment followed the ECTF's because they share the same market. Timber yield was adjusted by ±10% according to the survey results (Table 2).

Forest farmers

After the Collective Forest Tenure Reform, forest farmers were given the rights for forestland management and forest tree ownership, and afforestation by individual farmer households increased significantly (Xu and Jiang 2009). However, one initial consequence of this reform was the fragmentation of forestlands (Zhen et al. 2018), with each member household being assigned approximately 1.8 ha of forestland in South China (Hou et al. 2013). Thus the owners must strive to cooperate in management and in harvesting to achieve enough volume to make operations economically practical.

In this research, we carried out a face-to-face questionnaire survey to 198 forest farmer households in 9 villages in Pingxiang Guangxi Province in 2013. According to this survey, the main management modes were *Cunninghamia lanceolata*, forest planted by 39% of

these forest farmers; *Pinus massoniana* forest was planted by 34% of the forest farmers; *and Eucalyptus* forest planted by 14% of the forest farmers.

Cunninghamia lanceolata and *Pinus massoniana* were the main tree species in previous afforestation movement launched by the local government in Pingxiang County in 1980s. These two tree species were chosen by most of local forest farmers in the following years. In recent years, the small business began to plant the *Eucalyptus* forest around the forest-land of forest farmers and obtained higher economic returns, causing some of the forest farmers to change the tree species in their forestland.

We chose planted forests of these three species and used data collected from the typical forest farmers who represented the average management level in this area.

Forest farmers' *Cunninghamia lanceolata* forest *and Pinus massoniana* forest were under extensive management. Most forest farmers only invested in the first 3 years and didn't participate in the management in the following years until the harvest time. The timber price used in this analysis is the contract price, which contained clearcut fee, transportation fee and tax. There was no capital cost for using one's own forest land. For the management of *Eucalyptus* forest, the forest farmers invest more than what with the other two tree species. The *Eucalyptus* stumpage timber price here was the market price.

We adjusted the basic data according to ranges found in the survey. The cost was adjusted by ± 30%, the timber price by ± 20% and the timber yield by ± 30% (Table 2).

Capital budgeting analysis

There are many methods to calculate returns of planted forest investment. Evison (2018) summarized the essentially two methods—some "analyses use stock market data on timberlands companies" (Ibbotson and Sinquefield 1976), and others collect typical data on costs revenues and yields so that an estimate of return can be calculated using discounted cash flow analysis and capital budgeting criteria (Ben-Horin and Kroll 2017), such as net present value (NPV), land expectation value (LEV) and internal rate of return (IRR) which were often used as indicators for assessing economic returns of planted forest (Cubbage et al. 2007, 2010; Keča et al. 2012; Klemperer 1996; Wagner 2012). In addition, Cubbage et al. (2014) and Wang et al. (2014) had used NPV, LEV and IRR to evaluate the investment returns of planted forests in China and compared the results with other countries. The respective formulas follow:

$$NPV = \sum_{n=0}^{N} \frac{B_n}{(1+i)^n} - \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} \tag{1}$$

$$LEV = NPV + \frac{NPV}{(1+i)^N - 1} \tag{2}$$

IRR: i such that

$$\sum_{n=0}^{N} \frac{B_n}{(1+i)^n} = \sum_{n=0}^{N} \frac{C_n}{(1+i)^n} \tag{3}$$

where: n = year number, B_n = benefit in year n, C_n = cost in year n, i = annual discount rate, N = lifetime of project or rotation length.

Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows at a selected discount rate (Eq. 1). NPV is used as one of the primary indicators for project evaluation (Keča et al. 2012; Rocha 1973; Tee et al. 2014). It is generally recommended as one preferred criterion in most forest economics textbooks (Klemperer 1996; Wagner 2012) and particularly useful with relatively short-term forestry investments, such as fast-grown species (Cubbage et al. 2013).

Land Expectation Value (LEV) is the extension of NPV into perpetuity for long-lived forestry investments of unequal time lengths (Eq. 2) (Cubbage et al. 2013). It was proposed by Faustmann in 1849 and is still quite widely adopted (Tee et al. 2014). A positive LEV indicates that one could pay that amount for the land and still receive a certain real rate of return at the designated discount rate.

Riskiness in the investment and time value of money are generally captured by the discount rate, which is assumed to be constant throughout the forest's lifetime (Tee et al. 2014). In China, the real interest rate was 3–4%; the inflation rate was 2–3% (National Bureau of Statistics 2014). The forest risk was 1% (Wang 2010). The range of nominal discount rates in forestry department is calculated by adding real interest rate, inflation rate and forest risk together, which was 6–8%. In previous researches about China's forestry, discount rate was chosen between 4 and 12% (Chen 2001; Chen et al. 2002; Xin-Min et al. 2001). Cubbage et al. (2007, 2010, 2014) used a discount rate of 8% in their global timber investment research. Considering the characteristics of China's forestry and prior research, we used 8% real discount rate to estimate returns for all scenarios in this research.

The Internal Rate of Return (IRR) is a discount rate that makes the Net Present Value (NPV) of all cash flows from a particular project equal to zero. IRR calculations rely on the same formula as NPV does (Eq. 3). Often owners do not know their discount rate, so IRR provides a means of comparing investments intuitively with the implied cost of capital. IRR avoids problems of project scale or length in making comparisons (Cubbage et al. 2013). IRR often is used as a proxy for annual returns in the forest finance literature, making it comparable to other asset class analyses.

Sensitivity analysis

In this research, we used a sensitivity coefficient (the same as the Elasticity which is the measurement of how responsive an economic variable is to a change in another) to value the IRR and LEV fluctuation associated with the cost, timber price and timber yield for all the planted forest management scenarios. All the IRRs and LEVs of each scenario calculated above were grouped according to the new category (variables' worst-, base- and best-case, and each group had 9 IRRs or LEVs, Table 5). By comparing each IRR and LEV in worst-case with that in base-case, and IRR and LEV in best-case with that in base-case, we got two groups of sensitivity coefficients for each variable (Eq. 4, Table 6) in each management scenario. The formula follows:

$$S_{nik} = \frac{(A_{nik} - A_{niBase})/A_{niBase}}{\left|i_{nik} - i_{niBase}\right|/i_{niBase}} \tag{4}$$

where: S = Sensitivity coefficient, A = IRR or LEV, n = Code of management scenario; n = 1.2…0.10, i = cost, price and yield, k = −, Base, +.

After that we used the Wilcoxon signed-rank test to find out the FS_{nik} (final sensitivity coefficient) in each group. This test was proposed by Frank Wilcoxon in 1945 and was especially appealing when dealing with financial data that defies the assumptions imposed by parametric methods (Taheri and Hesamian 2013). The null hypothesis of this test is that the S_{nik}s in one group were no more than (for the best-and base-case comparison) or no less than (for the worst- and base-case comparison) TS_{nik} (test sensitivity coefficient). We change TS_{nik} until the P value of a one-sided test turned out to be less than the 0.05 significance level, then we reject the null hypothesis and see this TS_{nik} as FS_{nik} (Table 7).

Results

Table 3 summarizes the capital budgeting results on basic levels for the 10 management regimes, which are shown in Figs. 1 and 2 as the band inside the box (the median) as well. Table 4 shows the variability of IRRs and LEVs of *Eucalyptus* forest managed by the ECTF depending on the assumptions in Table 2. These IRRs and LEVs contributed to the first boxes in Figs. 1 and 2. The similar extensive data for the other nine management regimes are available as supplementary information by request via email from the first or last authors. The final results of all management regimes are showed in the Figs. 1 and 2.

The IRRs of three management entities

Greater IRRs indicate preferred investments based on these financial criteria. We used IRR as one of two key metrics to compare the ten scenarios because the forestland in China was owned by state or collectively. These entities were capital owners who pay the rent to have the right to manage the planted forest rather than land owners who buy the forestland in timber investment activities. Figure 1 indicate the base return values (the median) for each regime, as well as the maximum and minimum values (the whiskers) and the 25% range on each side of mean (the box).

Excluding land costs, the financial returns of *Eucalyptus* forest managed by small business were excellent, having an IRR of 28% per year which was the maximum value among

Table 3 Capital budgeting results for the base case and levels for selected species management regimes analyzed in South China (without the land price)

Code	Management entity	Management modes	IRR $_{Base}$ (%)	LEV $_{Base}$
1	ECTF[a]	*Eucalyptus* forest	24	5321.14
2	ECTF	*Cunninghamia lanceolata* forest	13	2419.41
3	ECTF	*Pinus massoniana* forest	10	947.92
4	ECTF	*Castanopsis hystrix* forest	21	13,194.39
5	ECTF	*Castanopsis hystrix* × *Eucalyptus* forest	27	14,158.49
6	ECTF	*Castanopsis hystrixh* × *Pinus massoniana* forest	17	8547.50
7	Small business	*Eucalyptus* forest	28	7555.29
8	Forest farmer	*Eucalyptus* forest	18	3473.42
9	Forest farmer	*Cunninghamia lanceolata* forest	9	336.04
10	Forest farmer	*Pinus massoniana* forest	9	239.32

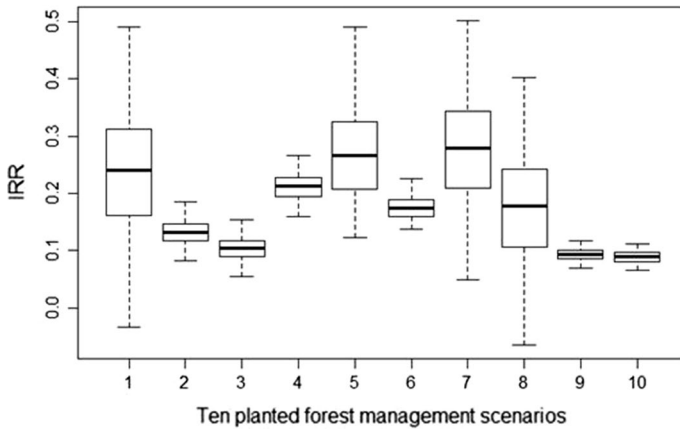[a]ECTF is the Experimental Center of Tropical Forests, Chinese Academy of Forest

Fig. 1 IRRs of ten planted forest management scenarios. *Note*: Ten planted forest management scenarios in the horizontal axis were: (1) *Eucalyptus* forest, ECTF; (2) *Cunninghamia lanceolata* forest, ECTF; (3) *Pinus massoniana* forest, ECTF; (4) *Castanopsis hystrix* forest, ECTF; (5) *Castanopsis hystrix × Eucalyptus* forest, ECTF; (6) *Castanopsis hystrixh × Pinus massoniana* forest, ECTF; (7) *Eucalyptus* forest, Small business; (8) *Eucalyptus* forest, Forest farmer; (9) *Cunninghamia lanceolata* forest, Forest farmer; (10) *Pinus massoniana* forest, Forest farmer
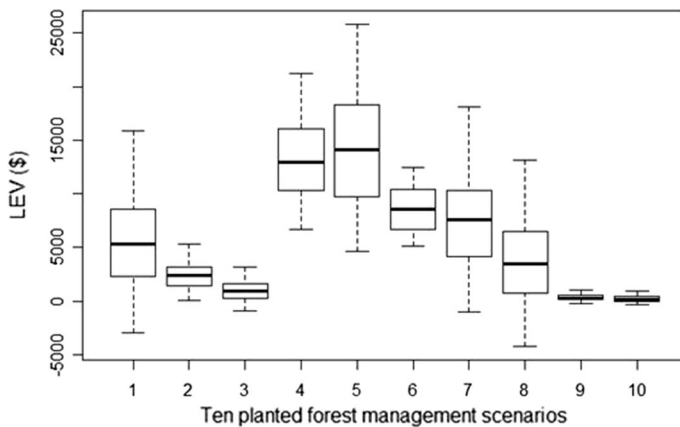

Fig. 2 LEVs of ten planted forest management scenarios. *Note*: Ten planted forest management scenarios in the horizontal axis were: (1) *Eucalyptus* forest, ECTF; (2) *Cunninghamia lanceolata* forest, ECTF; (3) *Pinus massoniana* forest, ECTF; (4) *Castanopsis hystrix* forest, ECTF; (5) *Castanopsis hystrix × Eucalyptus* forest, ECTF; (6) *Castanopsis hystrixh × Pinus massoniana* forest, ECTF; (7) *Eucalyptus* forest, Small business; (8) *Eucalyptus* forest, Forest farmer; (9) *Cunninghamia lanceolata* forest, Forest farmer; (10) *Pinus massoniana* forest, Forest farmer

that of all planted forest management scenarios. Its IRR could reach 50% under optimal condition (the cost reduced by 10%, timber price increased by 20% and timber yield increased by 10%).

The results for the ECTF indicate that the *Eucalyptus* forest and *Castanopsis hystrix* forester returns were greater than those for *Cunninghamia lanceolata* forest and *Pinus massoniana* forest, having IRRs of 24%, 21% 13% and 10% per year respectively. The IRR of

Table 4 IRRs and LEVs of *Eucalyptus* forest managed by ECTF under the 27 combinations of inputs

	Cost − 20%			Cost base			Cost + 20%		
	Yield − 20%	Yield Base	Yield 20%	Yield − 20%	Yield Base	Yield 20%	Yield − 20%	Yield Base	Yield 20%
IRR									
Timber Price − 20%	18%	24%	29%	7%	13%	18%	− 3%	2%	6%
Timber Price Base	28%	35%	40%	18%	24%	29%	9%	15%	20%
Timber Price + 20%	36%	43%	49%	26%	33%	38%	18%	24%	29%
LEV									
Timber Price − 20%	2343.05	4256.91	6170.78	− 310.05	1272.57	2855.20	− 2963.14	− 1711.76	− 460.39
Timber Price Base	5581.90	8305.48	11,029.06	2928.81	5321.14	7713.48	275.71	2336.80	4397.89
Timber Price + 20%	8820.75	12,354.05	15,887.34	6167.66	9369.71	12,571.76	3514.57	6385.37	9256.17

mixed planted forest of *Castanopsis hystrix* × *Eucalyptus* (27%) was higher than that of all other scenarios managed by ECTF. The IRR of *Castanopsis hystrixh* × *Pinus massoniana* mixed forest (21%) was a little less than that of *Castanopsis hystrix* pure forest, but it was much higher than that of *Pinus massoniana* pure forest.

For the forest farmers, their *Eucalyptus* forest returns were greater than those for their *Cunninghamia lanceolata* forest and *Pinus massoniana* forest. Their IRR for *Eucalyptus* forest, *Cunninghamia lanceolata* forest and *Pinus massoniana* forest were 18%, 9%, and 9% respectively.

The LEVs of ten planted forest management scenarios

The LEV by the base data of all the scenarios was greater than zero. A positive LEV indicates that the investors could pay that amount for the land and still receive an 8% annual, real rate of return. Since the forestland in China was owned by state or collectivity, there was no forestland price anywhere. We collected estimates of forestland rents from the small business and forest farmers in research area, which ranged from $50 to $110 per year per ha. Considering that the small business always used the same rent to collect large areas of forestland from local forest farmers, we chose this rent ($75 per ha per year) in our analysis. The imputed land price would be $1012 per ha estimated by the formula for Present Value of a Perpetual Annuity at 8% (the forestland rent serves as the perpetual annuity).

The LEVs of *Pinus massoniana* forest, regardless of the management entities ECTF ($948) or forest farmers ($239 per ha), at the 8% discount rate, were lower than the estimated land price. It means the investment of *Pinus massoniana* forest could not earn an 8% annual rate of return with the payment of current land rent. While the *Cunninghamia lanceolata* forest managed by forest farmers had a lower LEV as well, other scenarios' LEVs were greater than the estimated price of land, but with huge gaps. The higher LEVs were *Castanopsis hystrix* × *Eucalyptus* ($14,158 per ha) and *Castanopsis hystrix* forest ($13,194 per ha) managed by ECTF, followed by *Eucalyptus* forests managed by the small business ($7555 per ha) and *Castanopsis hystrix* × *Pinus massoniana* forest managed by the ECTF ($8,547 per ha). The LEVs of *Eucalyptus* forests managed by the ECTF ($5321 per ha) and the forest farmer ($3,473 per ha) were less, but still quite attractive (Fig. 2). The same general rankings occurred among scenarios with LEVs as with IRRs.

Sensitivity analysis

Cost, timber price, and timber yield are important factors that determine both IRR and LEV. Table 5 shows that the IRRs and LEVs of *Eucalyptus* forest managed by ECTF were grouped by each factor's three levels (Table 4). The sensitivity coefficients in Table 6 were calculated by Eq. 4. The final sensitivity coefficients were generated from the Wilcoxon signed-rank test. The P value under a one-sided Wilcoxon signed-rank test of final sensitivity coefficients turned out to be less than the 0.05 significance level. We only listed five test sensitivity coefficients which were close to the final sensitivity coefficients for each variable's one-way change (Table 7). The last lines of Table 7 were the final sensitivity coefficients with their P value. Those numbers then represent the median sensitivity coefficient for the IRR and LEV for the entire series of changes in variables by management regime. The final sensitivity coefficients of other nine management regimes are showed in Figs. 3 and 4. The similar detailed calculations for each management regime are available as supplementary information by request from the authors.

Table 5 IRRs and LEVs of *Eucalyptus* forest managed by ECTF grouped according to the variables' 3 levels

Cost −20%[a]	Cost base	Cost +20%	Timber price −20%	Timber price base	Timber price +20%	Yield −20%	Yield base	Yield 20%
IRR								
18%	7%	−3%	18%	28%	36%	18%	24%	29%
24%	13%	2%	24%	35%	43%	28%	35%	40%
29%	18%	6%	29%	40%	49%	36%	43%	49%
28%	18%	9%	7%	18%	26%	7%	13%	18%
35%	24%	15%	13%	24%	33%	18%	24%	29%
40%	29%	20%	18%	29%	38%	26%	33%	38%
36%	26%	18%	−3%	9%	18%	−3%	2%	6%
43%	33%	24%	2%	15%	24%	9%	15%	20%
49%	38%	29%	6%	20%	29%	18%	24%	29%
LEV								
2343.05	−310.05	−2963.14	2343.05	5581.90	8820.75	2343.05	4256.91	6170.78
4256.91	1272.57	−1711.76	4256.91	8305.48	12,354.05	5581.90	8305.48	11,029.06
6170.78	2855.20	−460.39	6170.78	11,029.06	15,887.34	8820.75	12,354.05	15,887.34
5581.90	2928.81	275.71	−310.05	2928.81	6167.66	−310.05	1272.57	2855.20
8305.48	5321.14	2336.80	1272.57	5321.14	9369.71	2928.81	5321.14	7713.48
11,029.06	7713.48	4397.89	2855.20	7713.48	12,571.76	6167.66	9369.71	12,571.76
8820.75	6167.66	3514.57	−2963.14	275.71	3514.57	−2963.14	−1711.76	−460.39
12,354.05	9369.71	6385.37	−1711.76	2336.80	6385.37	275.71	2336.80	4397.89
15,887.34	12,571.76	9256.17	−460.39	4397.89	9256.17	3514.57	6385.37	9256.17

[a]IRRs generated when price and yield change in 3 levels (worst-, base- and best-case) while cost is constantly at the low level

Table 6 Sensitivity coefficients of *Eucalyptus* forest managed by ECTF

Cost −20%	Cost +20%	Timber price −20%	Timber price +20%	Yield −20%	Yield 20%
S (IRR)					
8.12	−7.55	−1.82	1.42	−1.31	1.12
4.56	−4.24	−1.53	1.20	−0.98	0.83
3.39	−3.16	−1.36	1.06	−0.83	0.71
2.85	−2.50	−3.09	2.34	−2.31	1.97
2.20	−1.93	−2.39	1.80	−1.31	1.12
1.86	−1.63	−2.02	1.53	−1.02	0.87
1.87	−1.59	−6.95	5.01	−14.05	11.95
1.55	−1.33	−4.36	3.14	−2.00	1.70
1.37	−1.17	−3.37	2.43	−1.31	1.12
S (LEV)					
−42.79	42.79	−2.90	2.90	−2.25	2.25
11.73	−11.73	−2.44	2.44	−1.64	1.64
5.81	−5.81	−2.20	2.20	−1.43	1.43
4.53	−4.53	−5.53	5.53	−6.22	6.22
2.80	−2.80	−3.80	3.80	−2.25	2.25
2.15	−2.15	−3.15	3.15	−1.71	1.71
2.15	−2.15	−58.74	58.74	3.66	−3.66
1.59	−1.59	−8.66	8.66	−4.41	4.41
1.32	−1.32	−5.52	5.52	−2.25	2.25

Figure 3 indicates that all the variables were important, but had different magnitudes. The decrease of cost led to remarkable IRR increases for *Eucalyptus* forest and *Castanopsis hystrix*×*Eucalyptus* forest. With 1% cost reduction, there were 2.7% (*Eucalyptus* forest managed by small business), 1.8% (*Eucalyptus* forest managed by ECTF), 1.4% (*Eucalyptus* forest managed by forest farmer) and 1.4% (*Castanopsis hystrix*×*Eucalyptus* forest managed by ECTF) increases in their IRRs. These changes are essentially price elasticities for responses of returns with respect to cost changes. The increase of cost could reduce the returns exactly the same amount of their IRRs as the decrease of cost increased returns. Both changes (decrease/increase of cost) had less effect on the *Cunninghamia lanceolata* forest (with final sensitivity (elasticity) coefficient 0.7/−0.5 for ECTF and 0.2/−0.2 for forest farmer), *Pinus massoniana* forest (0.8/−0.7 for ECTF and 0.3/−0.2 for forest farmer), *Castanopsis hystrix* forest (0.4/−0.3 for ECTF) and *Castanopsis hystrix*×*Pinus massoniana* forest (0.5/−0.4 for ECTF).

The increase of timber price was important as well. With 1% timber price rise, there were 2.1% (*Eucalyptus* forest managed by forest farmer), 1.8% (*Eucalyptus* forest managed by small business), 1.4% (*Eucalyptus* forest managed by ECTF) and 1.3% (*Castanopsis hystrix*×*Eucalyptus* forest managed by ECTF) increase of their IRRs. However, the decrease of timber price heavily influenced the IRRs of *Eucalyptus* forest managed by small business (1.4%) and forest farmer (1.7%).

Comparing with cost and timber price, timber yield had moderate effect on the IRRs. Except the IRRs of *Eucalyptus* forest managed by small business, the decline or rise of all the IRRs were less 1% with the 1% changes of timber yield.

Table 7 The TS_1's P value of Wilcoxon signed-rank test of *Eucalyptus* forest managed by ECTF

TS_{1Cost-}	P value	TS_{1Cost+}	P value	$TS_{1Price-}$	P value	$TS_{1Price+}$	P value	$TS_{1Yield-}$	P value	$TS_{1Yield+}$	P value
IRR											
2.2	0.2206	−1.9	0.1871	−2.2	0.1302	1.4	0.03316	−1.4	0.4290	1.3	0.5708
2.1	0.157	−1.8	0.157	−2.1	0.1068	1.3	0.01908	−1.3	0.1863	1.2	0.4292
2.0	0.1068	−1.7	0.1068	−2.0	0.08654	1.2	0.01044	−1.2	0.1863	1.1	0.1863
1.9	0.1068	−1.6	0.05487	−1.9	0.05487	1.1	0.00543	−1.1	0.05425	1	0.1863
1.8	0.04292	−1.5	0.03316	−1.8	0.03316	1	0.00384	−1	0.01874	0.9	0.0249
LEV											
2.5	0.157	−2.5	0.157	−3.4	0.1871	3.4	0.1871	−2.2	0.1863	2.2	0.1863
2.4	0.1068	−2.4	0.1068	−3.3	0.157	3.3	0.157	−2.1	0.1863	2.1	0.1863
2.3	0.1068	−2.3	0.1068	−3.2	0.1302	3.2	0.1302	−2.0	0.1863	2.0	0.1863
2.2	0.1068	−2.2	0.1068	−3.1	0.06932	3.1	0.06932	−1.9	0.05425	1.9	0.05425
2.1	0.04292	−2.1	0.04292	−3	0.04292	3	0.04292	−1.8	0.0249	1.8	0.0249
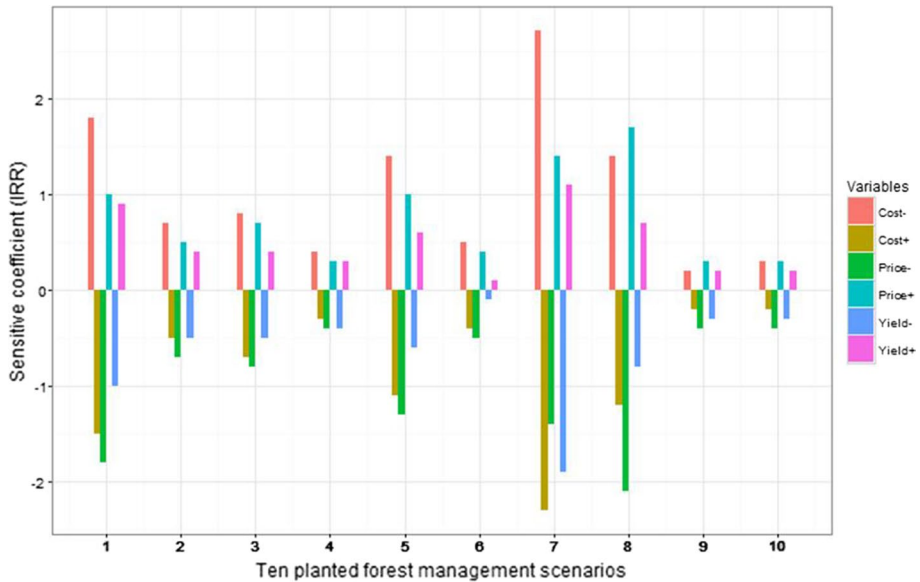
Fig. 3 Final sensitivity coefficient of IRRs. *Note*: Ten planted forest management scenarios in the horizontal axis were: (1) *Eucalyptus* forest, ECTF; (2) *Cunninghamia Lanceolata* forest, ECTF; (3) *Pinus massoniana* forest, ECTF; (4) *Castanopsis hystrix* forest, ECTF; (5) *Castanopsis hystrix×Eucalyptus* forest, ECTF; (6) *Castanopsis hystrixh×Pinus massoniana* forest, ECTF; (7) *Eucalyptus* forest, Small business; (8) *Eucalyptus* forest, Forest farmer; (9) *Cunninghamia Lanceolata* forest, Forest farmer; (10) *Pinus massoniana* forest, Forest farmer

Generally, the LEVs were more sensitive than IRRs (Fig. 4). Timber price was the strongest factor for the LEVs. For the *Eucalyptus* forest managed by Forest farmer, its LEV fluctuation ranged from 3.4 times that of the timber price. All the LEVs changed more than 1% with 1% changes of timber price.

Both the cost and timber yield greatly influenced the *Eucalyptus* forests managed by ECTF (2.1/−2.1 and −1.8/1.8 sensitivity coefficients) and small business (2.6/−2.6 and −3.3/3.3), and *Pinus massoniana* forest managed by ECTF (2.4/−2.4 and −1.7/1.7). Cost was still the key factor for the *Eucalyptus* forest managed by forest farmers with the final sensitivity coefficient 1.7/−1.7. Timber yield was the most influential factor for the LEVs of *Cunninghamia lanceolata* forest and *Pinus massoniana* forest managed by both ECTF and forest farmers.

Discussion

The efficiency of three management entities

It is useful to compare the efficiency or profits of the three ownership/land tenure groups by using the returns of *Eucalyptus* forest, because each of the management entities chose it as their main management models. The small business had the most
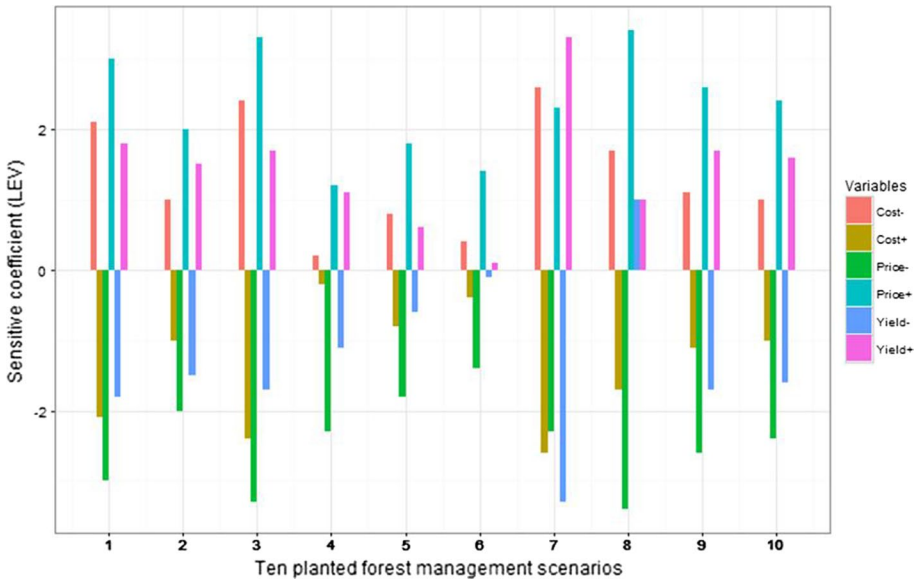
Fig. 4 Final sensitivity coefficients of LEVs. *Note*: Ten planted forest management scenarios in the horizontal axis were: (1) *Eucalyptus* forest, ECTF; (2) *Cunninghamia Lanceolata* forest, ECTF; (3) *Pinus massoniana* forest, ECTF; (4) *Castanopsis hystrix* forest, ECTF; (5) *Castanopsis hystrix × Eucalyptus* forest, ECTF; (6) *Castanopsis hystrixh × Pinus massoniana* forest, ECTF; (7) *Eucalyptus* forest, Small business; (8) *Eucalyptus* forest, Forest farmer; (9) *Cunninghamia Lanceolata* forest, Forest farmer; (10) *Pinus massoniana* forest, Forest farmer

management efficiency and profits, and ECTF was in the middle. The forest farmers had the least profits.

The small business

The higher calculated rates of return for small business came from their scale effect and long-term professional management experiences. Some of the small business owners had managed *Eucalyptus* forest in Fujian and Guangdong Provinces in South China on large scale for many years before this survey, which was helpful to reduce management cost and increase timber yield. The first 5 years' cost of small business for *Eucalyptus* forest were $5830 per ha which was lower than that of forest farmers ($6567 per ha) and ECTF ($7120 per ha) (Table 1). The total timber yield of a rotation of small business was the same as the yield of ECTF with 120 m^3 per ha, and higher than what the forest farmers harvested, at about 105 m^3 per ha.

Although the small businesses had the highest management level compared to the other two planted forest management entities, they were more sensitive to the internal or external factors (Figs. 3, 4). As measured by IRR, changes in returns were influenced mostly by the cost, where the initial costs reduced the IRR. When the fixed 8% discount rate was used, as indicated by LEV, timber yield was the most sensitive factor. The increase of the cost and decrease of yield may lead to a large loss. At present, their low cost will limit their further increase of income, but their timber yield still had potential to be improved. The MAI of

Eucalyptus forest can reach up to 25 m³ per ha per year in south China which was higher than that of Eucalyptus forest managed by small business (20 m³ per ha per year, Table 1).

The forest farmers

Comparing with the ECTF, the forest farmers had low efficiency and returns not only in the management of *Eucalyptus* forest, but also in *Cunninghamia lanceolata* forest and *Pinus massoniana* forest.

Forest farmers were less active with their *Cunninghamia lanceolata* forest and *Pinus massoniana* forest which was easy to see from the first 5 years' investment cost ($755 and $850 per ha respectively, Table 1). Their calculated rates of return were lower because of low yield (the MAI was 3.5 m³/ha/yr, Table 1). The main reasons leading to their low management returns were that they generally had both farmland and forestland. The return of forestland was uncertain and with long management period comparing with farmland, so that they did not rely on *Cunninghamia lanceolata* forest and *Pinus massoniana* forest for their livelihoods. Meanwhile, the area of forest farmers' forestland was small and location was remote. It was difficult for them to improve their forest roads and transport their timber out. The net timber price for the forest farmers was less than the market price.

Unlike the management of *Cunninghamia lanceolata* forest and *Pinus massoniana* forest, the forest farmers spent more money and paid more attention to the *Eucalyptus* forest management. Their first 5 years' cost was between the cost of small business and ECTF (Table 1) and their yield was almost the same as small business and ECTF (Table 1).

Based on IRR, the returns of forest farmers' *Cunninghamia lanceolata* forest and *Pinus massoniana* forest were stable under the fluctuation of the cost, timber price, and timber yield. This indicates that it is difficult for forest farmers to improve their low level of management without new incentives. Based on LEV at the fixed 8% discount rate, the returns of their *Cunninghamia lanceolata* forest, *Pinus massoniana* forest, and *Eucalyptus* forest changed most with the fluctuation of timber price. The forest farmer's timber price was lower than the market price, so there was plenty of opportunity for an increase. In addition, the timber price in China will still increase with fluctuations in a small range. This is easy to see from the timber price changes in the local timber market in research area (Fig. 5), and from the huge gap between timber supply and demand in China (Fig. 6).

Fig. 5 The timber price in Pingxiang, Guangxi Province, China. *Notes*: C: *Cunninghamia lanceolata* (size: 200–400 cm × 16 cm); E: *Eucalyptus* (size: 200–260 cm × 8–12 cm); P: *Pinusmassoniana* (size: 220–280 cm × 14–18 cm)
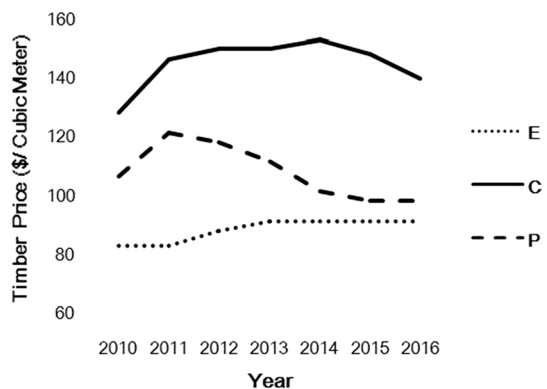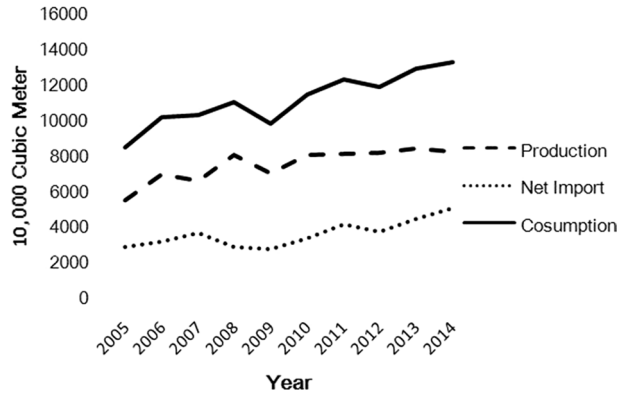
Fig. 6 Timber production, consumption, and net import in China (2005–2014)

The Experimental Center of Tropical Forestry

ECTF managed its planted forests not only for economic benefit, but also for experimental research. They managed more diverse planted forest models than any other entities, thus they gave us an opportunity to compare the management models in the same situation and assess which were better than others. The different economic returns and characteristics of ECTF's management models indirectly influence the management decision of small business and forest farmers.

The investment returns of four tree species

From the result of ECTF above, the *Castanopsis hystrix* forest had the highest economic returns among the four kinds of pure forest, closely followed by *Eucalyptus* forest. They had higher calculated rates of return due to high timber prices (the timber price of *Castanopsis hystrix* was \$334 per m^3) and fast growth rates (the MAI of Eucalyptus forest was 20 m^3/ha/yr). Although the *Cunninghamia lanceolata* forest's economic return was higher than *Pinus massoniana* forest because *Cunninghamia lanceolata*'s higher timber price (\$150/m^3), both of them were much lower than the other two pure forest management models.

The result of sensitivity analysis shows that the IRRs and LEVs of *Castanopsis hystrix* forest were more stable than those of the other three tree species, which were slightly influenced by cost, timber price and timber yield. It means that the investors who choose the *Castanopsis hystrix* forest will get high and stable revenue.

The *Eucalyptus* forest was most sensitive among the four tree species. The cost and timber price were dominant factors leading to the wide range of IRRs for *Eucalyptus* forest (Fig. 3). For LEV, the cost, timber price and timber yield were all key factors for the revenue. It means that the returns of *Eucalyptus* forest could be easily increase to a higher level. But it also means that the investment in *Eucalyptus* forest could be risky.

The IRRs of *Cunninghamia lanceolata* forest and *Pinus massoniana* forest were more stable than those of the *Eucalyptus* forest, but as *Eucalyptus* forests their LEVs were greatly influenced by three factors. The investments in *Cunninghamia lanceolata* forest and *Pinus massoniana* forest were not as good, due to not only the low revenues, but also the risk.

The economic benefit of two management modes

The mixed forest could improve the economic returns of pure forest. The economic return of *Castanopsis hystrix×Eucalyptus* forest was greater than that of *Castanopsis hystrix* forest and *Eucalyptus* forest managed by ECTF. The *Castanopsis hystrix×Pinus massoniana* forest improved the economic return of *Pinus massoniana* forest by a large scale. The mixed forests were more stable than the pure forest. *Castanopsis hystrix×Eucalyptus* forest was not as sensitive as *Eucalyptus* forest to the cost, timber price and timber yield. For the *Castanopsis hystrix×Pinus massoniana* forest, it reduced the change ranges of *Pinus massoniana* forest as well. Changing the pure forest to mixed forest is a way to further increase the economic returns and reduce the risk of *Eucalyptus* forest.It is also a way to improve the low efficiency of *Pinus massoniana* forest.

Domestic and abroad comparison

In China, many places manage planted forests. The economic returns of *Cunninghamia lanceolata* forest, *Pinus massoniana* forest and *Castanopsis hystrix* forest were not much different among regions (Song-Hai et al. 2016). The economic returns of *Eucalyptus* forest varied by location (Huang 2007). For example, In Fujian Province, which is also an important area for planted forest in Southeast China, the IRR of *Eucalyptus* forest planted by Yongan Forestry (Group) Co., Ltd, who had begun to manage the *Eucalyptus* planted forest on large scale since 1994, was 18.1%. This was lower than the IRR of *Eucalyptus* forest managed by its counterpart, small business (23%) in this research (Huang 2007). The IRRs of *Eucalyptus* forest ranged from 15.4 to 57.1% in Changtaiyanxi State-owned forest farm in Fujian Province (Wang et al. 2008).

Comparing the planted forest management in other countries, the returns for *Eucalyptus* forest managed by small business in south China were the same as the *Eucalyptus* IRR in Brazil (28%) and more than those in other countries (Argentina, Uruguay, Chile, Colombia, Venezuela, Mexico, Paraguay and Australia) (Cubbage et al. 2014). The intensively managed forest plantations in the southern hemisphere are much more profitable than those in the northern hemisphere (Sedjo 1999). The high economic returns of *Eucalyptus* forest managed by small business in south China stem from the high timber price (more than 90 $/m^3) in China, caused by the country's fiber supply shortage.

Pinus species returns excluding land costs in this research in South China (ECTF, 10%; forest farmer, 9%) were lower than those for Brazil (23%), Chile (15%), Uruguay (14%), Colombia (14%), Mexico (13%), Argentina (13%) and higher than those for Venezuela (8%), New Zealand (8%), USA (8%), and Australia (7%) (Cubbage et al. 2014).

Conclusion

This research shows the diversity and economic returns of planted forest management in China. These results indicate that small business in China was the most efficient forest managers by tenure type. The economic return of their *Eucalyptus* forest for small businesses was the same as that in Brazil, but had a high risk with fluctuations of cost, timber price, and timber yield. The Experimental Center of Tropical Forestry provided more forest management regimes for analysis, such as *Castanopsis hystrix* forest, *Castanopsis hystrix×Eucalyptus* forest and *Castanopsis hystrix×Pinus massoniana* forest, which had

the features of high profits and low risks. The results indicate that forest farmers had the lowest level of returns for the case of *Eucalyptus* forest management in South China, but it was still in the middle rank of global comparisons. The *Cunninghamia lanceolata* forest and *Pinus massoniana* forest management in China were less competitive, but they all had IRRs greater than 8% without land costs.

With land costs, the IRRs would be lower. We had information on land rent from small business and estimate the imputed land price $1012 per ha. Except *Pinus massoniana* forest and *Cunninghamia lanceolata* forest, all scenarios' LEVs were greater than the estimated price of land. Thus we could expect to make profits with forest plantation investments by renting forest land and growing timber at an 8% discount rate in most scenarios, but there were differences in profits.

The planted forest in China with higher derived stumpage prices (more than $90/m³) do have higher rates of return. The higher timber price in China was caused by its fiber supply shortage, and it will still increase with fluctuations in a small range in the future. For the *Eucalyptus* forest, the timber price was its most sensitive factor. Thus the returns of *Eucalyptus* forest could easily increase to a higher level with the rise of timber price. But it also means that the investment in *Eucalyptus* forest in China could be risky.

It was interesting that the sensitivity of the ranking of results did differ somewhat by capital budgeting criteria, as suggested by the forestry literature (e.g., Klemperer 1996; Wagner 2012), but not occurring that often. IRR changes were affected more by planting costs, which occured early in the rotation. Changes in LEV returns were affected more by the timber prices, which occurred at sale time. This is exactly why LEV is preferred if one knows their fixed discount rate—the preferred financial objective is to maximize real cash profits at a given discount rate, not the internal rate of return.

In order to achieve the highest rates of return at the stand level, for both small business and forest farmer in South China, it is good to introduce precious native tree species in their management, such as *Castanopsis hystrix* forest, or change their pure forest to mixed forest, such as *Castanopsis hystrix×Eucalyptus* forest and *Castanopsis hystrix×Pinus massoniana* forest. Those choices reduced the risk as well, as the precious native tree species and mixed forest were not sensitive under the most likely fluctuation of the cost, timber price and timber yield.

For the small business in China, there was still opportunity to improve their *Eucalyptus* forest's economic returns. They could further improve the IRR by reducing the cost and the LEV by increasing the timber yield. Both of these factors were sensitive factors for the small business' *Eucalyptus* forest management. In addition, most of the forest land contracts in China were less than 30 years, so that changing to long-cycle tree species was impossible for some small businesses. Small business in China depended more on the *Eucalyptus* forests, whose further management improvement through genetics, nurseries, and silviculture need more research development, and implementation.

Many forest farmers in South China with *Pinus massoniana* forest and *Cunninghamia lanceolata* forest had low economic returns. Besides changing to precious native tree species and mixed forest, renting out their forestland to the small business is a good choice as well, which was promoted by the central and local government after the Collective Forest Tenure Reform. It could solve the problem of low efficiency of forestland utility and the forestland fragmentation. What's more, improving the forest roads could increase forest farmers' derived timber stumpage price, making it closer to the market timber price, and then increasing their revenues.

In addition, cost was a considerable influence for the financial returns of planted forests investments. In the further research, we could calculate the planted forest investment

returns under the fluctuation of all part of cost, such as the cost of site preparation, planting, periodic stand treatments, harvest and management, so as to find out the details that influence the investment returns most. This will make the estimates of planted forest management returns in South China more robust. However, the base level returns we calculated were quite substantial, so our results should be reliable. They do provide detailed comparisons based on extensive empirical data sets among the three principal types of forest ownership in southern China.

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