Study on Payments for Environmental Services (PES) of Natural Production Forests (NPFs) in Hainan Province, China

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Technical Report of ITTO Project

ITTO RED-SPD 020/09 Rev. 1 (F)
Development and Demonstration on Scheme of Payment for Environmental Services (PES) Derived from Degraded and Secondary Tropical Production Forests in Hainan province, China

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Abbreviation

NPFs	Natural Production Forests
NCF	Non-commercial Forests
PES	Payments for Environmental Services
ES	Environmental Services
RCFTS	the Reform of Collective Forest Tenure System
NPV	Net Present Value
IRR	Internal Rate of Return
ROI	Return on Investment
PI	Profitability Index
DCF	Discounted Cash Flow
MCS	Monte Carlo Simulation
ROV	Real Option Valuation
OC	Opportunity Cost
NPV	Net Present Value

Summary

Conversion of Natural Production Forests (NPFs) to plantations by clear-cutting would bring risks to ecosystems' stability, resilience and environmental services. Now these risks could become real in southern collective forests area of China because NPFs' property rights were assigned to the forest-owners (collective organizations or villagers) after the Reform of Collective Forest Tenure System (RCFTS) in China. Theoretically, forest-owners (collective organizations or villagers) could convert their NPFs to plantations by clear-cutting based on economic considerations. So, scheme of Payments for Environmental Services (PES) of NPFs, could be an effective economic incentive to encourage forest-owners to maintain and sustainable manage their NPFs. Why to pay would be the primary question, and how much to pay (PES standard) would be the key issue of PES scheme of NPFs.

The investigation results showed that there were rich valuable native tree species and high biodiversity in NPFs (mainly degraded and secondary forests) in study areas. The soil hydrology-physical properties, soil chemical nutrient contents of the NPFs were significantly were better than plantations. NPFs were better than plantation in conservation of biodiversity and Maintenance of soil and water resources. It is necessary to implement the PES scheme of NPFs to prevent the conversion of NPFs to plantations.

There were 3 methods of calculating the PES standard. (1)To pay according to opportunity cost: A technical framework was developed with discounted cash flow (DCF), Monte Carlo simulation (MCS) and real option valuation method (ROV) which can be used to calculate the opportunity cost. Applying the framework in the study area, the results showed that the payments for environmental services (ES) of NPFs were 440 to 2,220 RMB/ha/a when to select the PES scheme with indefinite period, or 2,200-5,000 RMB/ha/a and the theoretical maximum was 10,670 RMB/ha/a in the limited period scenario. (2)To pay according to the willingness to accept the payments: With a logistic regression model, the investigation data of study area were analyzed based on contingent valuation method (CVM). Results showed that there existed the negative correlation between the probability that farmers' accepting the payments for ES according to the local PES standard of key non-commercial forests (NCF) and the proportion of planting income to total family income. The model prediction accuracy was 67.9%. Reducing farmers' dependence of planting would be helpful to implement the PES scheme. (3)To pay forestland rent to supply the ES for the public: the results showed that it was 300-1,500 RMB/ha/a for rents of different lands in different site qualities in study area.

Main contents of the PES scheme of NPFs in study area: The main objectives were to prevent the conversion from NPFs to plantations and to improve the quality of NPFs by sustainable management. The object of PES was the NPFs that were allocated to collective organizations or individuals. The local government was the main buyers and collective organizations or individual farmers who obtained the ownership certificate of NPFs were the sellers. A contract for PES of NPFs should be singed according to relevant laws and regulations to establish a mechanism of legal binding. The main obligations of the sellers are to insure that the ownership of the NPFs would not be changed, to insure the area of the NPFs would not be reduced and to insure the quality of the NPFs would not be declined.

Keywords: Natural production forests (NPFs); Payments for environmental services (PES); Opportunity cost; Discounted Cash Flow (DCF); Monte Carlo Simulation (MCS); Real Option Valuation (ROV); Contingent Valuation Method (CVM)

1 Introduction

1.1 The background and purpose

There were two purposes for the study and demonstration on implementation of the PES scheme of natural production forests (NPFs):

⑴ To promote the rational utilization of NPFs and to prevent the conversion of NPFs to pure plantations. It was a common focus of attention for the international community that to avoid a decrease of natural forest area (CBD, 2010). In order to promote sustainable management of NPFs, the primary task was to keep its natural attributes and preventing conversions occurred from NPFs into pure plantations.

⑵ To solve the conflicts between the protective utilization (selective logging) and a ruining utilization (clear-cuting and converting to plantations) on NPFs after reform of collective forest tenure (RCFTS), to protect the legitimate rights and interests of the owner of NPFs.

In accordance with law, owners of forest tenure enjoyed the contract and management right of forest land, proprietary of forest, usufruct, profit right and disposition right for all NPFs assigned to the owner.

As a rational man, their goal of management was to maximize the economic benefits, and their preference wass to convert NPFs into forest types with quick return, high economic efficiency and more cost-effective commercial way which means the pure plantation (including the economic forests and timber forests) and clear-cutting on the final logging (Stone, 2009). For the long-term and overall interests, NPFs were not allowed to adopt clear-cutting and convert to pure plantations according to rules made by the government and the forest resource management department. Obviously, there was a conflict between the different decision-makers. However, the PES scheme of NPFs was not yet supported by the current system. Therefore, the owners of NPFs could not manage their forest to pursue the economic benefits according to their own desire, they could not get any compensation as well as. This would lead to difficulties on implementation of property rights, to negative forest management and protection. Which might cause reduce in forest quality, degradation in function and increase in potential risk.

1.2 Progress of domestic and foreign research and practice

Study on forest PES started earlier and abundant theory and practice experience had been gained (Zbinden, 2005; Engel, 2008; Jiang and Su, 1997; Ke and Wen, 2004). Examples of application from a small river basin to the whole country of various scales were appeared for purposes of the forest environmental services, including protection of forest, development of forestry, conservation of biodiversity, maintenance of soil and water resources, carbon sequestration and so on (Landell-Mills and Porras, 2003; Li, 2007).

1.2.1 Domestic and foreign cases analysis

Items, including objective, buyers, sellers (providers of ES) and how much to pay et al. were the core contents of forest PES scheme. Table 1-1 shows some specific domestic and foreign examples.

1.2.1.1 Environmental objectives and trade objects

Generally, the forest PES aimed at one or a few ES including water conservation, purifying water quality, carbon sequestration, maintaining biodiversity, protecting forest landscape and so on, forest environmental services were the trade objects in forest PES.

Table 1-1 shows that multiple targets were included in the actions of forest PES launched and funded by the government generally. For example, the plan of biodiversity protection and prevent soil degradation (CRP) implemented by U.S. government the eco-compensation fund for non-commercial forests (NCF) was established by the Chinese government to protect the key protection forests. However, projects funded by the beneficiary (or users) tend to set fewer environmental targets. For example, Pimampiro project and ROFAFOR project on Ecuador had just been set up only one target. A case in Bolivia, the targets aimed at two services as water source protection and biodiversity. Some projects of PES funded by government had also a single target of environmental protection. For instance, the conversion of cropland to forest program focused on enhancing conservation function of soil and water through the vegetation restoration in China.

1.2.1.2 Buyer

Table 1-1 shows that buyers could be the beneficiary or their representatives of the forest ES (the government mostly), but did not exclude the participations of non-governmental organizations (NGO) and international organizations et al. In many cases, the buyer was a combination of different stakeholders. They jointly funded to buy the forest ES.

1.2.1.3 Seller

In the case of abroad, people who obtained PES were owners of the land or users who had land use right. When a long-term investment was required in forest PES (for example, reforestation), security of tenure and ownership became increasingly important (Wang, 2008).

Table 1-1 Cases of payments for environmental services of forests

Projects	Buyers	Paid for & Start year	How much to pay	Sellers	Scope /ha
Bird habitat and watershed protection in Los Negros, Bolivia (Asquith et al, 2008)	Pampagrande Municipality, US Fish and Wildlife Service	Bird habitat and watershed protection 2003	1.5-3.0 USD/ha/a	Santa Rosa farmers (46 landowners)	2,774ha, Upper Los Negros watershed
Pimampiro, Ecuador (Wunder and Alban, 2008)	Metered urban water users (20% fee)	Watershed protection 2000	6-12 USD/ha/a (per family 252USD a^{-1})	landholders	550ha, Palahurco watershed
PROFAFOR, Ecuador (Wunder and Alban, 2008)	FACE (Electricity consortium)	Carbon sequestration 1993	100-200 USD/ha/a	Communal & individual landholders	22,287ha, highlands and coastal regions
CRP, USA (Gill et al, 1999)	Government of USA	Water, biodiversity, soil and wildlife 1995	117.2 USD/ha/a	Landowners (farmers)	14,500,000ha
GAK, Germany	Federal government of Germany, European Union(EU)	Encouraging the private forest owners to implementing close-to nature forest management	70% of the management cost	private forest owners	Whole country
Payments for Environmental Services (PSA), Costa Rica (Zbinden and Lee, 2005)	FONAFIFO (autonomous state agency)	Water, biodiversity, carbon, scenic beauty 1997	45-163 USD/ha/a	Private landholders, indigenous communities	270,000ha, national, target areas
Payments for Hydrological Environmental Services (PSAH), Mexico (Munoz-Pina et al, 2008)	CONAFOR (state forest agency)	Watershed and aquifer protection 2003	27-36 USD/ha/a	Communal and individual landowners	600,000ha, national, priority areas,
The conversion of cropland to forest program (CCFP), China	Central government	Watershed protection 1999	609 RMB/ha/a	Farmers	12,120,000ha in 24 provinces
eco-compensation for non-commercial forests by central governments	Central governments	Protection and maintenance for national key protection forests 2004	75 RMB/ha/a, for state forests and 150 RMB/ha/a for collective and individual forests	The rangers and forest owners	69,930,000ha (national key protection forests)

1.2.1.4 PES standards (how much to pay)

Generally, the PES standard was made according to the opportunity cost which means sufficiently to compensate for losses by taking action to protect the environment instead of other uses (Wunder, 2005; Engel et al 2008; Tan, 2009; Li, 2009).

PES standard according to the opportunity cost was more reasonable. But in most existing cases, the PES standard was made obviously only according to the direct costs. For example, in the PSA project in Costa Rica, PES standard for forest protection was 45 USD/ha/a. If planting activity was involved, the PES standard would increase to 163 USD/ha/a. According to the rule of forest PES system supported by China's central government, state protection forest was compensated in 75RMB/ha, and collective and individual protection forest was compensated in 150 RMB/ha. More than 90% of the PES funds were directly used for maintenance expenses. It could be considered as a compensation for maintenance costs.

1.2.1.5 Ensuring mechanism

The law was the last resort to address environmental issues. Legal mandatory was a reliable guarantee for dealing with environmental issues by economic approaches. It was used to declare the rights and obligations of the parties involved on PES scheme.

1.2.2 Review of current research

Firstly, intercrossing and integration of economics with environment science and ecology had provided the theoretical support and analysis tools for research on PES and helped people to answer the questions, including why to pay, how much to pay, who was buyer and who was seller et al. in forest PES scheme.

Secondly, many cases of forest PES, not only played an important role to solve realistic problems between the environmental protection and economic development, but also played an important role to the further research of forest PES scheme. Useful experiences had been gained in the field of analyzing the respective roles of government and market, establishing a PES fund methods, participating and collaborating of different stakeholder etc.

Thirdly, a lot of theory and methods for a series of forest ES evaluation and its value accounting had been established, developed and improved. A lot of publications of research had a positive significance for providing technical support for decision-making. It had some positive significance to promote public understanding of the value of natural resources and strengthening the awareness of environmental protection.

Fourthly, while forest PES practices were different from poverty alleviation, but implement of PES had contributed to the solution of poverty in a certain extent in the poor area (Grieg-Gran et al., 2005).

2 Applied methodology

2.1 Basis of forest PES

2.1.1 Investigation methods of forest community

The investigation was conducted in June 2011 in Maohui community of Wuzhishan City of Hainan Province, 70 circular samples in radius of 3.26m were set in the natural production forest selected. The total area of 20 circular samples is 1/15 hectares. All trees which diameters greater than 5.0 cm were measured. The species name, DBH and tree height were recorded, richness, important values, and species diversity index were statistically calculated respectively.

Richness (*S*) was the total number of tree species.

Important value (*IV*) was the sum of all following three: relative frequency (*Fr*), relative abundance (*Dr*) and relative prominence (*Pr*) (Song, 2001). Important value for the sum of all tree species was 300%.

Diversity index calculated includes Shannon-Wiener diversity index (*H'*), Simpson diversity index (*P*) and Pielou homogeneity index (*E)*, the formulas (Fang, 2009) are as follows:

$$H' = -\sum_i^S P_i \ln P_i \tag{2.1}$$

$$P = 1 - \sum_i^S {P_i}^2 \tag{2.2}$$

$$E = {H'}/{\ln S} \tag{2.3}$$

In the formula above, P_i is relatively important value of a tree species which equal to the important value divides by 300.00%.

2.1.2 Soil investigation and analysis methods

A typical investigation method was used in the soil investigation in Dagan community of Lingshui County of Hainan Province; acquisition of soil sample is indicated in figure 2-1.

Ring skills determination was used to measure water-physical properties. Chemical properties of soil samples were measured according to the conventional method (People's Republic of China’s forestry industry standards, 1999). Among them, the determination of soil physical properties include 5 indicators: soil bulk density (SBD), maximal water holding (MWH), non-capillary porosity (NCP), capillary porosity (CP), total porosity percent (“TP”)；Determination of chemical properties of major projects includes 8 indicators: soil PH value, soil organic matter (SOM), total nitrogen (TN), total phosphorus (TP), total potassium (TK), hydrolyzable nitrogen (HN), available phosphorus (AP) and available potassium (AK).

Each indicator was repeated determined 3 times and the mean value was taken for analysis. The method of heteroscedasticity T-test for two independent samples was used to test the significance of the differences of the mean for results from determination on all NPFs and plantations. The same method was also used to test the significance of difference of the mean for soils of different vegetation types in the same group. Result is judged according to the p-value, where $p<0.05$ represents significant difference, $p<0.01$ means a more significant difference, and there is an extremely significant difference when $p<0.001$.

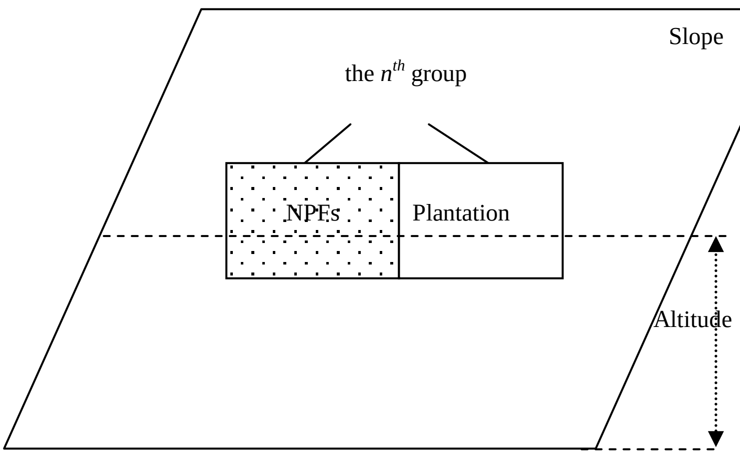

Fig. 2-1 Soil sampling schematic

2.1.3 Analysis method of management characteristics

⑴ Questionnaires

Questionnaire was implemented through personally interviews. The year 2011 was as the base year. The following data were recorded: location, the natural conditions, production conditions (convenience of transport etc.), tree species, investment costs (including labor, pesticides, chemical fertilizers, transportation, sales and taxes etc.by silviculture stages and yield phases), incomes from wood and non-wood products (including the production and price in different yield phases).

⑵ Data collection

Data collection aimed to check each other with questionnaires, ensured the reliability of the parameters. The data included technical specification for the production issued by the authorities, quotas of forests investment established by the forestry sectors, forest resource asset appraisal of the last two years, dealing cases and forest management contracts etc.

⑶ **Data analysis**

Referencing to forest resource asset appraisal method (Chen and Liu, 2001), the common economic indicators of the project were used to analysis. In the yield curve of 2012 of inter-bank fixed rate of national debt published by the Central Securities Depository Trust Clearing Corporation showed that the average interest rate of the debt repayment period of 30 years was 4.38%, it was onside as a risk-free interest rate in this report.

$$\mathrm{NPV} = \sum_{i=0}^{t} \frac{B_i - C_i}{(1+r)^i} \tag{2.4}$$

$$\text{return on investment} = \frac{\text{NPV}}{\text{Sum PV investment}} \tag{2.5}$$

$$\text{profitable index} = \frac{\text{Sum PV net benefit}}{\text{Sum PV investment}} \tag{2.6}$$

In Formula (2.4), B_i refer to sales revenue in year i, C_i is the cost in year i, r refer to discounted rate, t refer to project duration (year), the discount rate is the internal rate of return when the NPV is zero.

2.2 Study on PES standard of NPFs

PES standard of NPFs was analyzed by the following aspects: the opportunity cost analysis, willingness investigation and analysis, land rent analysis.

2.2.1 Study on PES standard based on opportunity cost analysis

2.2.1.1 Conceptual analysis

It can not be achieved to maximize value of forest products and forest ES in the same time. We shall have a choice. We may call the management model claimed by government as the model I and the management model sought by forest managers as the model II. Differences of net income per unit area of two management models can be shown as figure 2-2.

Height of the rectangle represents the relative size of net income in a unit area during a complete management cycle in figure 2-2. The right side represents the management model I, NPFs was preserved and operated on a low intensity of selective cutting. And the left side represented the management model II, NPFs were converted to pure plantations after clear cutting.

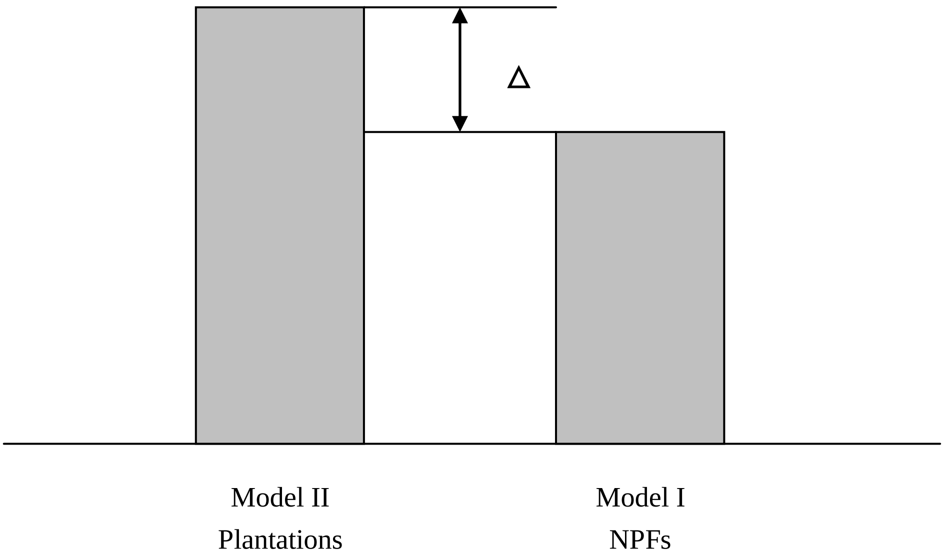

Fig. 2-2 Net benefits of forest management in one hectare

It is a prerequisite for selecting the management model I that forest PES of NPFs is provided. The rectangle on right indicates net benefits. On the same premise of maintaining natural attributes of NPFs unchanged, it supplies more ES to the public including conservation of biodiversity, maintenance of soil and water resources etc.

If you select the management model I mean you have abandoned the management model II, and the opportunity costs will be lost. Such loss is indicated as a "△ " in figure 2-2, instead of all the net benefit of the management model II (the high of the rectangle on the left in schematic figure 2-2). What needs to be done for the establishment of a standard of PES of NPFs is to calculate the values of △ shown in figure 2-2 base on opportunity analysis.

2.2.1.2 Technical framework

Base on the analysis of Discounted cash Flow (DCF), to introduce Monte Carlo Simulation (MCS) and Real Option Valuation (ROV), to analyze the opportunity costs of preserving NPFs from the different perspective, then the PES standard will be determined. The technical framework is shown in figure 2-3.

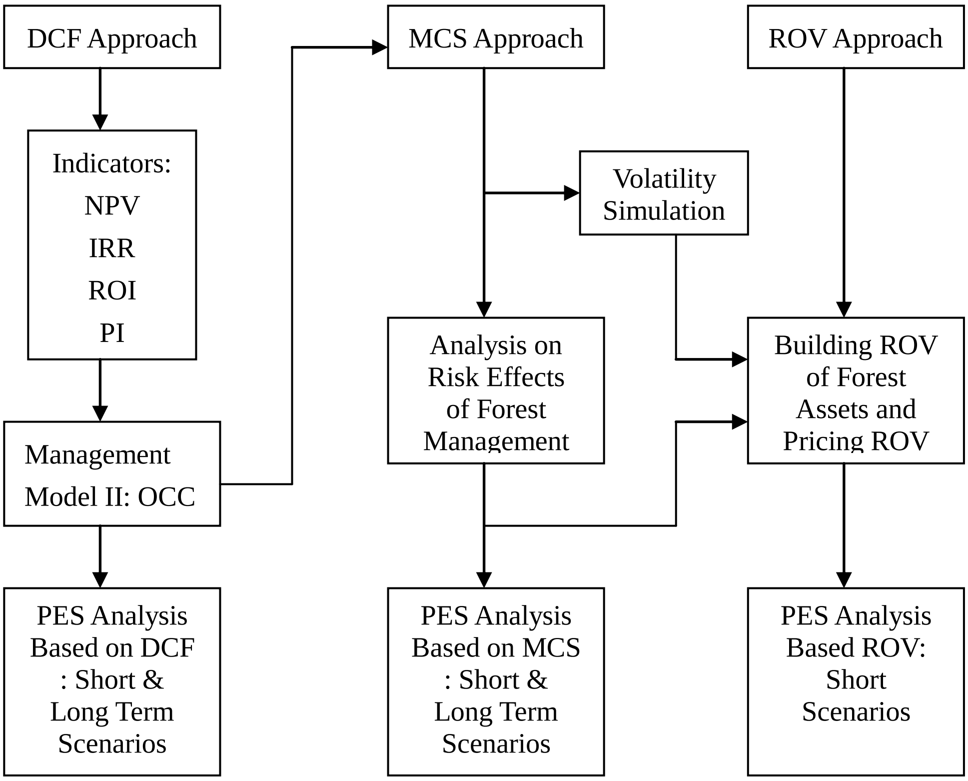

Fig. 2-3 Frame for the PES standard analysis based on opportunity cost

Ⅰ Discounted Cash Flow (DCF) Analysis

⑴ To determine the "opportunity cost carrier"

That objects of forest cultivation of the management model II is the carrier of opportunity cost. In a prepared area to implement PES of NPFs, opportunity cost carriers may be timber trees, may also be economic forest trees. These species shall be filtered using the DCF analysis based on production practice.

The greater of the net present value mean stronger of profitability in normal circumstances. Therefore, the basic principles of species filter should base on maximum NPV method, in order to ensure the reliability of the result. The internal rate of return, return on investment and profitability index should be analyzed simultaneous for comprehensive measuring the effect of investment and management of candidate tree species. These indicators can be calculated as the formula (2.4) ~ (2.6).

In forestry economic analysis, formulas for calculating the NPV fall into two categories: time limit ($NPV_{Limited}$) and time indefinite ($NPV_{Infinite}$) (Dieter, 2001). For example, formulas to calculate $NPV_{Limited}$ and $NPV_{Infinite}$ for timber are as follows:

$$\mathrm{NPV}_{Limited} = \sum_{t=0}^{T}(p_t \cdot v_t - c_t) \cdot e^{-i \cdot t} \qquad (2.7)$$

$$\mathrm{NPV}_{Infinite} = \frac{\sum_{t=0}^{T}(p_t \cdot v_t - c_t) \cdot e^{i \cdot (T-t)}}{e^{i \cdot T} - 1} \qquad (2.8)$$

In formula (2.7) and (2.8), p_t is the price per cubic wood in *t* year , v_t is volume per hectare in *t* year, c_t indicates the costs per hectare in *t* year, $e^{-i\,t}$ is the discount factor (where *e* is a natural base, *t* is ages of the forest stands，*i* is a discount rate) and *T* for forest harvesting time. Whether present of *e* is the most obvious sign of distinction between the discrete and continuous NPV formulas. Both formula (2.7) and (2.8) belong to the continuous calculation formula because of appearing in the *e*. There are studies (Dieter, 2001) to prove that difference of results of two formulas is negligible if time scale is long enough.

⑵ **Accounting PES standards for reference**

After filtering out the target tree species，the △ values indicated in figure 2-2 can be gotten by accounting NPV of "management model I" and "management model II":

$$\Delta = Payment = NPV_a/n_a - NPV_b/n_b \qquad (2.9)$$

In formula (2.9), *Payment* represents the reference standard of PES. The n_a represents a complete cycle time (year) needed for the opportunity cost carriers, NPV_a represents net present value of management model II. The n_b is a rotation of selective cutting of NPFs(year), NPV_b represents net present value of the management model I.

Payment is calculated in formula (2.9) based on a complete management cycle in unit of RMB/ha/a. This treatment can avoid the one-sidedness from calculation on an incomplete management cycle. Meanwhile, it can guarantee the comparability between "meiosis” and "minuend". In practice, granting of PES often follows the form of matching and year by year. Obviously, Payment in unit of RMB/ha/a can meets the actual needs.

In formula (2.9), n_a or n_b usually up to represent the time scale of decades, this is a "short time scale" relative to unlimited demand of the people in ES, payment calculated in a team for a management period belong to a "Payments of Short-term Scenario" in this sense.

Discussion on relatively longer time scale of PES has more practical significance. It is necessary to analyze multiple rounds of management scenarios, to calculate the Payments of long-term Scenario. Meanwhile, in order to avoid one-sidedness in an incomplete business cycle, a common multiple of the n_a and n_b are used to analyze. It can be set as the least common multiple for simplicity. As described earlier, when time scale is long enough (for example, hundreds of years), the differences of the deadline NPV calculation formula (2.7) and indefinite NPV formula (2.8) can be ignored, or two formulas are interchangeable, but it should be noted to discount using the low interest rate. Some scholars (Orice 1997; Weitzman 1998) have discussed how to calculate net present value for the long-term future using a lower discount rate.

Ⅱ Monte Carlo Simulation (MCS) Analysis

MCS is a method to simulate and to analyze random events using a computer to generate random numbers and to reflect the effect of random processes. MCS can be used to measure uncertainty of an investment-income (the risk).

Base on analysis of "opportunity cost carrier" filtered out by the DCF, the discounted cash flow of the plantation and NPFs can be simulated and analyzed by MCS technology for management objective. In order to account for PES standards, the mean of net present value (NPVm) is regarded as output of the model. parameters of probability distribution of *NPVm* can be obtained by simulation. There are four classes usually:

(1) The center value of distribution, it is used to describe the expected value of average return, and it is usually characterized by statistics such as an average, the median and so on.

(2) Scope of a distribution, it is the possibilities of variable falls in the distribution to different regions. Common statistics are standard deviation, variance, coefficient of variation etc. One of the standard deviation reflects a departure from a center (mean value), is often regarded as a measurement of the degree of uncertainty or risk size. The larger of the standard deviation mean the greater the risk of the investment.

(3) Skewness (*SK*) is used to measure the asymmetry of the probability distribution of random variables, to describe the direction and amplitude of distribution skew. Negative skew (skew to the left) said the tail of left side is longer, and the distribution is concentrated upon the right side of the case. Skewness with the sample of N values is as following:

$$\mathrm{SK} = \frac{m_3}{m_2^{3/2}} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2\right)^{3/2}} \qquad (2.10)$$

In formula (2.10), where $\bar{x}$ is the mean of sample, m_3 is the third central moment of sample, and m_2 is the sample variance. When skewness<0 means that the vast majority of values (including the median) are located on the right side of the mean value, the larger value has been more likely appears, that skewness>0 represents the opposite of meaning. So to select the project with left – skewed when you expect the mean of return equal to variance. When the difference between mean and the median is large, the median could avoid the extreme value, to be better to represent the expected return value.

⑷ Kurtosis means that the change mainly caused by tiny extreme deviations but minimal frequency of occurrence. So Kurtosis can be used to describe the probability of unexpected events. The size of Kurtosis is relative to the size of a normal distribution, so sometimes also it is referred to as Excess kurtosis (*EK*). Excess kurtosis with a sample of N values as following:

$$EK = \frac{m_4}{m_2^2} - 3 = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^2} - 3 \quad (2.11)$$

In formula (2.11), where m_4 is the fourth sample moment about the mean, m_2 is the second sample moment about the mean (that is, the sample variance), x_i is the i^{th} value, and $\bar{x}$ is the sample mean, minus "3" is in order for the kurtosis of the normal distribution equal to 0. Super positive kurtosis is known as the "leptokurtic distributions" and negative kurtosis is called “platykurtic distributions”. If distribution of the expected return of the project in peak form, usually tail of the distribution looks "fat ", that means the extreme emergencies more likely to occur (a big losses or gains), or projects have a significant value at risk (VAR).

As the expected return may not strictly follow the normal distribution, therefore, in comparing the net present value of the project, sometimes an analysis for the above several aspects is needed to make more accurate estimates and decisions.

Ⅲ Real Option Valuation (ROV) Analysis

As a value analysis tool, ROV is mainly used for appraisement of investment projects with flexible options, the value of such projects mainly from future growth rather than the initial investment. By ROV, that how uncertainty impact on the value of projects can be understood by policymakers. Research of ROV has been widely concerned, and has been extended to valuation of natural resources, evaluation of the research and development projects, evaluation on intangible assets, investment in real estate, high-tech enterprise's value assessment, and many other areas (Miller et al, 2002; Smit et al, 2006; Bernardo and Chowdry, 2002； Adner and Levintha, 2004； Liu, 2009; Yan, 2011; Peng, 2011).

Method about combination of a Binary Tree Example and Monte Carlo Simulation was used for analysis on forest ROV in this report mainly. Comparing with the results of sblack-scholes option pricing model is done to verify the reliability of the result, following these steps:

The first step is to simulate solution of parameters. ROV analysis requires 5 parameters, including the price of the asset of targets, (*S*, discounted value of future cash flows), exercise price (*K*, Discounted value of their management costs), Risk-free interest rate (*r*), maturities (*T*) and fluctuation ratio (*σ*).

⑴ **Monte Carlo simulation for fluctuation ratio (σ)**

The logarithm of the income approach of present value is used for getting σ in this report，this method has advantages of adjusting the negative cash flow, it can provide more accurate and conservative estimators of fluctuation ratio for real options analysis.

Firstly, to calculate the intermediate values of X, the formula as following:

$$X = \ln\left(\frac{\sum_{i=1}^{n} PVCF_i}{\sum_{i=0}^{n} PVCF_i}\right) = \ln\left[\frac{\frac{CF_1}{(1+r)^0}+\frac{CF_2}{(1+r)^1}+\cdots+\frac{CF_n}{(1+r)^{n-1}}}{\frac{CF_0}{(1+r)^0}+\frac{CF_1}{(1+r)^1}+\cdots+\frac{CF_n}{(1+r)^n}}\right] \tag{2.12}$$

In formula (2.12), $PVCF_i$ is the present value of future cash flows of the Phase i, CF_i is the cash flow in Phase i, r is the discount rate. In order to ensure consistency of analysis on option pricing, the discount rate r here equal to the risk-free interest rate. Intermediate values *X* is equivalent to the relative yield of logarithm of cash income approach. It is the natural logarithms of relative earnings of price at the present stage and future earnings, with future earnings as numerator in the formula. Calculating the cash flow discounted to the No. 0 (base year) first in calculations, and than, to calculate the cash flow discounted to the Phase 1th (base year +1 year), the cash flow of Phase 0 is ignored.

Secondly, simulating the formula 2.12 aims to capture the uncertainty in the project. The denominator set for the baseline represents the net present value of the project, or asset return. And assuming it is the best estimate of the proceeds, so its value is constant. All future cash flows of DCF is included in calculation of the numerator. Because of uncertain, full of volatility in future, so simulated object is regard as numerator in a fraction. It is assumed that the price factor is following logarithmic normal distribution in running a simulation because the market prices cannot be less than 0. Under this assumption, if intermediate values X obey normal distribution, the standard deviation is volatility (Mun, 2005). Z value calculation formula of standard normal distribution is as following:

$$Z = \frac{x-\mu}{\sigma} \tag{2.13}$$

Previous type can be turn to:

$$\sigma = \frac{x-\mu}{Z} \tag{2.14}$$

⑵ **Simulation of cash flow of S and K**

In ROV analysis the discount rate is expressed as risk-free interest rate, *S* is discounted value of cash flows, *K* is discounted value of the investment cost, *T* is time required for a complete business cycle time for management target. According to the MCS method above described, to simulate on cash flow, parameters *S* and *K* are gotten. Simulating results of Skewness (Formula 2.1) and kurtosis (Formula 2.11) are examined, the median is regards as inputs for obtaining the option price when the mean and median do not coincide and there is a large deviation, in order to obtain more conservative results.

The second step, calculating and to test the option price

Above parameters σ、S、K as inputs, value of the objects for a monument period T is estimated by binary tree method. The target species for management can be obtained from the analysis of analysis of discounted cash flow, management period t is expressed as times (years) needed by a complete management cycle time (year) for the management object.

Finally, after comparing the result gotten from a binary tree method with black-scholes option pricing model, to test how many steps are needed for running binary tree and reliability.

2.2.2 Study on PES standard based on Contingent Valuation Method (CVM)

2.2.2.1 Survey content and procedures

According to general principle of CVM, contents and steps of survey for developing a PES standard of NPFs in this report are as follows:

Step 1: To introduce the interviewees about main ecological functions of natural production forests, the consequences of conversion of natural production forests to plantations and the idea of implementing PES of NPFs, according to the characteristics of the local natural environment.

Step 2: To survey the basic situation of interviewees including their family members, age, income level, education level, income sources, planning of the household development of plant and so on.

Step 3: To survey awareness of the forest ES of interviewees, as well as understanding of forest PES and related policies in Hainan Province and China.

Step 4: To describe the current national policies on forest PES, and related documents of forest PES for non-commercial forests in Hainan..

Step 5: To survey whether interviewees can promise not to convert natural production forests to plantations on the premise of accept a certain PES to continuously supply the ES from natural production forests. If interviewees agree with this idea, whether interviewees agree with the PES standard for protection forests (Non-commercial forests) prescribed in the government documents, or to present a personal thought and reasonable PES standards. If interviewees do not agree with this idea, you should to ask the reasons of disagreement.

2.2.2.2 Data processing method

Because of both numeric variables such as age, income and categorical variables such as education, eco-consciousness of environmental protection are existing in CVM survey data, the generalized logistic regression model (LRM) can be used for correlation analysis referencing to the relevant literature (Johnson, 2005; Miao, 2008), an overview of the LRM is as follows:

For the dichotomous nominal variables, 0 and 1 can be used to represent for different states respectively, for example, urban and rural areas, men and women. A logistic regression analysis can be made under certain data support. E(y/x) is used to represent the conditional mean of variables in the condition of the argument. If dependent variable is numeric variables with the 0 and 1 instead of continuous numeric variables, the mean of will fall in between 0~1, 0≤E(y/x)≤1, for Multiple Linear Regression functions for the mean, than :

$$\hat{y} = E(y/x) = a + \sum_{j=1}^{m} b_j x_j \quad (2.15)$$

The mean of condition of dichotomous nominal variables belongs to the generalized logistic function, than:

$$f(x) = \frac{1}{1+e^{-(a+\sum_{j=1}^{m} b_j x_j)}} \quad (2.16)$$

Since the function values are between 0~1, it is at least equal to the cumulative distribution of distribution in the form, so the formula (2.16) can be regarded as conditional probability distribution of a dependent variable, marked as p(y), it is:

$$p(y) = \frac{1}{1+e^{-(a+\sum_{j=1}^{m} b_j x_j)}} \quad (2.17)$$

If the ratio of probability of success and failure probability is defined as odds, that the probability of an event occurs corresponding to a multiple of the probability that disappears, and defining " than taking the logarithm for the odds, that is the Logic transform " (Johnson, 2005), than:

$$odds = \frac{p(y)}{1-p(y)} = e^{a+\sum_{j=1}^{m} b_j x_j} \quad (2.18)$$

Taking the natural logarithm for both sides, than:

$$g(x) = \ln odds = a + \sum_{j=1}^{m} b_j x_j \quad (2.19)$$

By the formula (2.19) a nonlinear relationship between the variables and probability can be established, it is a relationship of logistic, regression analysis based on the relationship is a logistic regression analysis.

The R software (version 2.13.0) was used to complete the logistic model, test, and predictive analysis. glm ( ), step ( ), Wald.Test ( ) etc. functions were used. 70% survey data are random selected for modeling, residuals are used to test effects of prediction.

The prognosticate accuracy rate (CR) is used to check the forecast results, the following formula:

$$CR = \frac{A+D}{A+B+C+D} \times 100\% \quad (2.20)$$

After selecting a threshold (generally it takes 0.5), all the predicted value greater than the threshold value can be represented as 1, others are counted as 0, the forecast results can be divided into 0 or 1.

Relationships between predict ed and observed values can be divided into 4 classes, represented A, B, C, D in the formula (2.1) representatively, of which: A for observation=1 and approximate prediction value to 1; B represents observations = 1 and predicted value similar to 0; C on behalf of the observation Value = 0 and predicted value similar to 1; D on behalf of the observation Value = 0 and predicted value is approximate to 0.

2.2.3 Study on PES standard based on rented land

Supply of forest ES based on rented land can meet the interests of both sides in forest PES. The government as representative of the overall long-term interests can supply ES by renting forest land from owners of NPFs. In rural area of China, collective or individual benefit from rental of woodland is also widespread, so mode of supply ES by rented land have operability furthermore. When using this approach, PES standards is regard as rental of land. The rental for land generally is accounted using the method of land expectation value, formula (Liu, 2006) is as follows:

$$\mathrm{Bu} = \frac{A_u + D_a(1+P)^{u-a} + D_b(1+P)^{u-b} + \ldots - \sum_{i=1}^{u} C_i(1+P)^{u-i+1}}{(1+P)^u - 1} - \frac{V}{P} \tag{2.21}$$

In formula (2.21), B_u is the expectation value of the forest land, C_i is the forest production costs in the year i (clean up the land, land preparation, planting, and so on). A_u is the net income from the forest harvest in year of u (that A_u is calculated as the income from sales of the harvest to deduct all costs on including harvesting, processing, marketing, management, tax, and so on). D_a and D_b are revenues from year a to year b from forest thinning in forest. For non-timber forest, the time points are regarded as in early perinatal period and in rich period. The u is period of forest management, V is yearly cost of forest maintenance, P is the rate of discount.

If simply marking the cost of renting forest land as "*B*", than $B=B_u \times P$. In the specific application, in addition to account the land rents of NPFs, the land rents of substitute plantation of NPFs should be accounted at the same time. In the study area the actual rents should be surveyed. More options of result should be provided according to the results of the calculation and the situation of survey.

3 Presentation of the data

3.1 Basic information of NPFs in Maohui community

The forest distribution map of the Maohui community is shown in figure 3-1, 25 subcompartments of them are relate to NPFs, their basic information is shown in table 3-1.

Table 3-1 Main mensuration factors of natural production forests in Maohui Community

Sub compartment	Dominant tree species	Mean DBH /cm	Mean height /m	Mean Volume /m³/ha	Density /N/ha	Area /ha	Volume /m³
1	*Macaranga denticulata*	8.8	7.0	47.9	2247	0.4573	21.89
2	*Litchi chinensis*	10.4	6.9	69.5	2397	0.2087	14.51
3	*Liquidambar formosana*	14.8	11.8	375.9	4001	6.0200	2262.85
4	*Liquidambar formosana*	16.9	9.6	363.1	3686	2.3867	866.59
5	*Liquidambar formosana*	12.8	10.5	182.9	2797	0.4940	90.36
9	*Mallotus paniculatus*	22.6	8.4	382.5	2497	0.9027	345.28
13	*Ficus auriculata*	10.4	6.4	116.0	4395	0.2413	27.99
14	*Broussonetia papyrifera*	17.0	7.9	152.7	1798	0.1973	30.13
21	*Ficus auriculata*	10.6	7.6	94.7	2847	0.2360	22.34
27	*Liquidambar formosana*	12.9	11.0	239.6	3446	0.9153	219.34
31	*Liquidambar formosana*	14.6	11.9	343.0	3648	35.3353	12119.78
39	*Macaranga denticulata*	13.4	7.2	169.6	3476	2.7840	472.05
49	*Macaranga denticulata*	13.2	5.9	133.8	3446	1.1127	148.89
75	*Broussonetia papyrifera*	17.0	7.9	207.0	2697	0.0900	18.63
81	*Liquidambar formosana*	16.8	13.4	282.2	2098	2.0573	580.67
90	*Broussonetia papyrifera*	21.2	10.6	183.5	1079	0.8687	159.40
105	*Broussonetia papyrifera*	18.1	8.3	239.5	2435	1.7640	422.51
108	*Broussonetia papyrifera*	11.1	5.9	29.5	1049	0.3347	9.88
112	*Broussonetia papyrifera*	5.0	3.0	0.9	300	0.1827	0.17
123	*Ficus microcarpa*	15.8	9.6	194.2	2198	0.4520	87.79
133	*Helicia obovatifolia*	10.6	7.6	94.7	2847	0.5767	54.60
138	*Ficus auriculata*	8.3	6.0	26.7	1648	0.4973	13.29
157	*Broussonetia papyrifera*	13.9	8.1	93.2	1598	0.2800	26.10
159	*Markhamia stipulata* var. *kerrii*	16.2	8.5	105.2	1299	0.9840	103.56
168	*Macaranga denticulata*	14.6	7.3	141.5	2397	0.5793	82.00

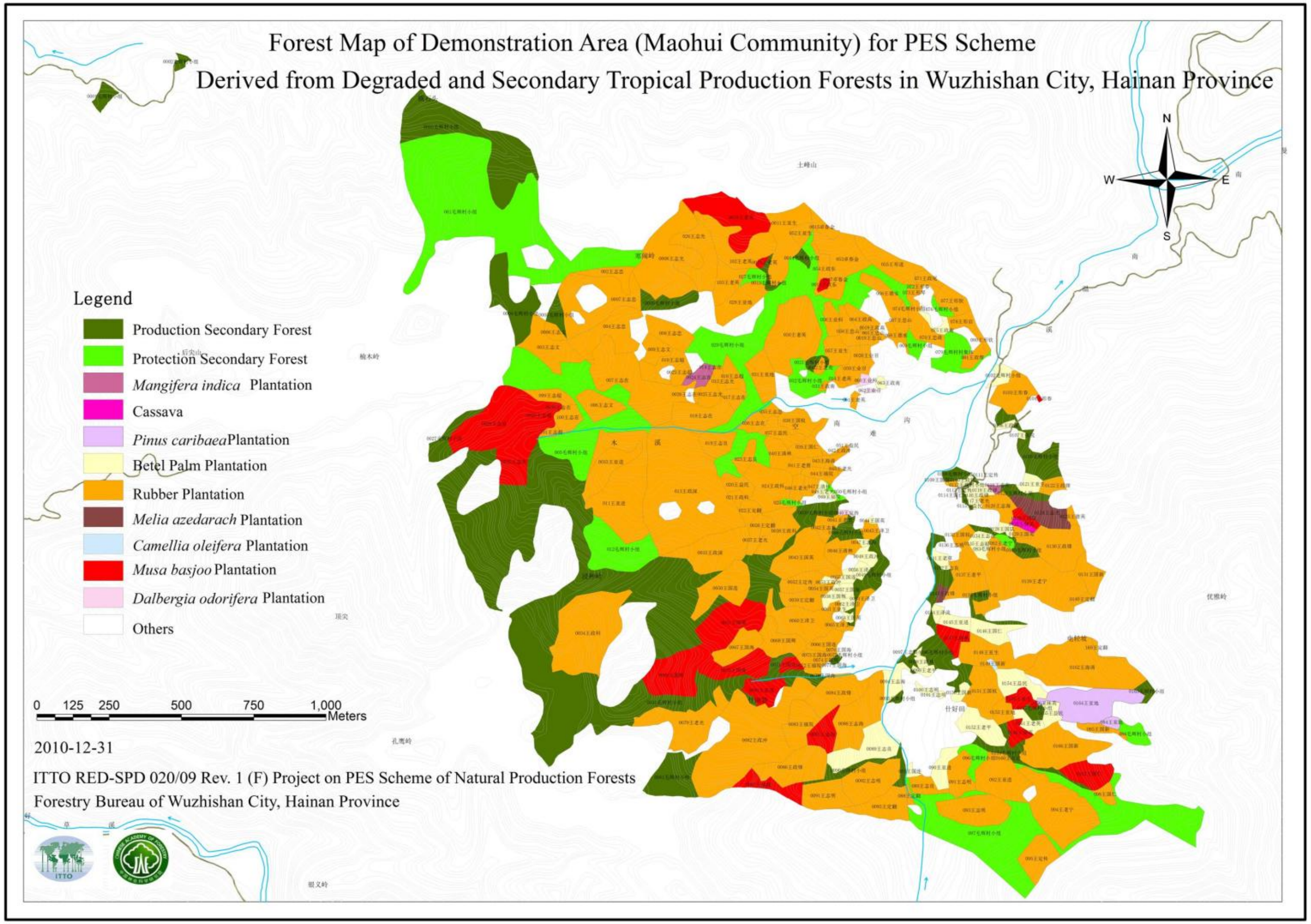

Fig. 3-1 Forests distribution in Maohui community (2010)

3.2 Basic information on typical community of NPFs

Secondary forest dominated by *Liquidambar formosana* which developed about 30 years represents the principal parts of NPFs in the study area. According to the aforementioned community survey methods, tree species of community composition and their important values is indicated in table 3-2. Secondary forest dominated by *Liquidambar formosana* has a total of 64 tree species, categorized in 27 families and 47 geniuses. The species which important value listed on the top 10 are *Liquidambar formosana*, *Lithocarpus silvicolarum*, *Macaranga denticulata*, *Cratoxylum cochinchinense*, *Glochidion lanceolarium*, *Lannea coromandelica*, *Phyllanthus emblica*, *Syzygium hainanense*, *Pithecellobium clypearia*, accounted for 73.3% of total, they are the main tree species in community. In which, the important value of *Liquidambar formosana* as the dominant tree species is accounted for 37.7% of total, greater than the sum of the important value of rest species listed in of the top 10, equal to 5.5 times of value of *Macaranga denticulate*, which in the second place level.

The tree layer has two sub-layers. Trees in sub-layer I are higher than 10m and in sub-layer II are less than 10m. There are 27 tree species in sub-layer I, and account for 44.96% of total trees; important value of *Liquidambar formosana* is 197.5%, important values of tree species greater than 10 is only *Macaranga denticulate* for other tree species. Important value of *Liquidambar formosana* is 12.3 times larger than *Macaranga denticulate's,* which are dominant in numbers. There are 58 tree species in sub-layer II, and account for 67.00% of total trees. Species with bigger important value include *Liquidambar formosana* (52.58%), *Lithocarpus silvicolarum* (33.06%), *Macaranga denticulate* (26.55%) *and Cratoxylum cochinchinense* (25.28%).

Biodiversity indices of secondary forests of *Liquidambar formosana* is shown in table 3-3.

Table 3-2 Important value of tree species in secondary forest of *Liquidambar formosana*

Tree species	*Fr*(%)	*Dr*(%)	*Pr*(%)	*IV*(%)
Liquidambar formosana	18.03	34.96	60.24	113.24
Lithocarpus silvicolarum	7.92	8.65	3.89	20.46
Macaranga denticulata	7.38	7.64	5.09	20.11
Cratoxylum cochinchinense	7.10	6.64	2.29	16.03
Glochidion lanceolarium	4.37	4.01	2.34	10.73
Lannea coromandelica	4.64	2.63	2.63	9.91
Phyllanthus emblica	4.37	2.51	0.88	7.76
Syzygium cumini	3.55	2.01	2.03	7.58
Pithecellobium clypearia	3.55	2.63	1.05	7.24
Ficus auriculata	1.64	2.63	2.52	6.79
Machilus nanmu	3.28	2.63	0.68	6.60
Chunia bucklandioides	2.19	3.01	1.28	6.47
Mallotus paniculatus	2.46	1.63	1.47	5.56
Evodia lepta	2.19	1.50	1.26	4.95
Ormosia pinnata	1.64	1.00	0.88	3.52
Dillenia pentagyna	1.64	0.75	0.96	3.35
Aporusa dioica	1.64	0.88	0.31	2.83
Sterculia lanceolata	1.64	0.75	0.38	2.77
Dimocarpus longan	0.82	0.75	1.14	2.71
L. corneus	1.09	1.00	0.45	2.54
Sapindus saponaria	1.09	0.63	0.66	2.38
Aporusa villosa	1.09	0.50	0.37	1.96
Engelhardtia roxburghiana	0.82	0.50	0.46	1.78
Reevesia thasoidea	1.09	0.50	0.14	1.73
F. hispida	0.82	0.38	0.45	1.64
Walsura robusta	0.27	0.50	0.84	1.61
Albizia procera	0.55	0.38	0.64	1.57
Sarcosperma laurinum	0.82	0.38	0.12	1.32
Glycosmis parviflora	0.55	0.38	0.24	1.16
Albizia attopeuensis	0.55	0.25	0.35	1.15
Castanopsis jianfenglingsis	0.27	0.38	0.49	1.14
Cinnamomum camphora	0.55	0.25	0.28	1.08
Croton chunianus	0.55	0.25	0.25	1.05
F. microcarpa	0.27	0.38	0.40	1.05
Flacourtia rukam	0.27	0.50	0.25	1.02
Elaeocarpus sylvestris	0.55	0.38	0.09	1.01
the sum IV of tree species was 283.78 which *IV* ≥1, and the percent was 94.59%				

Notes: the tree species whose IV<1 were not listed in the table, including: *M. pomifera*，*C. porrectum*，*Artocarpus nitidus subsp. Lingnanensis*，*Peltophorum dasarhachis var. tonkinensis*，*Sindora glabra*，*Cycas revoluta*，*Radermachera frondosa*，*G. wrightii*，*Amesiodendron chinense*，*Symplocos cochinchinensis*，*Albizia chinensis*，*Randia cochinchinensis*，*R. hainanensis*，*Vatica mangachapoi*，*Memecylon ligustrifolium*，*D. turbinata*，*Canarium album*，*Beilschmiedia intermedia*，*Bridelia balansae*，*L. glaber*，*E. petiolatus*，*M. apelta*，*Alphonsea monogyna*，*Phoebe hungmoensis*，*M. chinensis*，*R. spinosa*，*M. cicatricosa*，*Schefflera heptaphylla*

Table 3-3 Biodiversity indices of secondary forests of *Liquidambar formosana*

Layer	Altitude /m	*IV* of the dominant species /%	Forest age /year	*S*	*H'*	*P*	*E*
Total	490	113.24	30	64	2.80	0.83	0.67
Layer I	-	197.50	-	27	1.65	0.56	0.50
Layer II	-	52.58	-	58	3.18	0.93	0.78

Growth of stand is shown in table 3-4. The average diameter of stand is 13.5cm, the average tree height is 8.7m, stand density is 3 416 N/ha strains and stand volume is 271.1m^3/ha. Trees in sub-layer I has a low density (33.0%), but a greater stock volume (78.3%). There is a certain amount of species with high value for protection and utilization in the stand, the first class timbers include *Vatica mangachapoi*, *Sarcosperma laurinum*, second-class timbers include *Syzygium hainanense*, third class timbers include *Cinnamomum porrectum*, *Machilus chinensis*, *Memecylon ligustrifolium*. Stem density of three class timbers is 1 041 N/ha (30.5%) and stock volume is 62.3 m^3/ha (23.0%).

Table 3-4 Main mensuration factors of secondary forest of *Liquidambar formosana*

Items	Mean DBH /cm	Mean height /m	Density /N/ha	Volume /m^3/ha
Total tree layer	13.5	8.7	3 416	271.1
Layer I	19.3	13.7	1 126	212.4
Layer II	9.4	7.3	2 290	58.7
3rd～1st class timber	12.7	10.3	1 041	62.3

3.3 Analysis of the physical and chemical properties of the soil

A total of 6 groups and 14 samples were investigated, among them, there are 6 NPFs, 4 plantations and 2 cassavas. A total of 30 soil profiles were dug, the results of analysis of the physical and chemical properties of the soil are shown in table 3-5 and 3-6 respectively.

3.4 Investment and income situation of typical commercial forest

In local area, the NPFs are dominated by secondary forest of *Liquidambar formosana*. The management target for potential alternative species of *Liquidambar formosana* including rubber, betel nuts, eucalyptus and the Caribbean pine, investment and income for different forests are shown in the table 3-7~3-11.

Table 3-5 Soil water-physical properties of different vegetations in Dagan community

Layers	Vegetation	SBD g/cm^3	MWH g/kg	NCP %	CP %	TP %
0-20cm	NPFs	1.45	348.33	18.33	25.65	43.39
	Plantations	1.43	337.20	17.42	26.22	44.87
	p-value	0.244	0.287	0.272	0.356	0.090
	DPF	1.46	353.53	17.26	26.89	44.16
	Rubber	1.40	312.66	16.37	25.33	41.70
	p-value	0.181	0.090	0.256	0.228	0.235
	SF	1.44	366.18	19.04	23.88	42.91
	Areca	1.42	331.10	18.46	27.69	44.52
	p-value	0.366	0.172	0.424	0.176	0.217
	NPFs	1.43	335.27	19.25	26.87	43.23
	Cassava	1.48	313.05	18.22	26.54	44.24
	p-value	0.139	0.223	0.418	0.456	0.305
20-40cm	NPFs	1.60	**280.38***	**16.43****	24.14	39.62
	Plantations	1.63	**257.19***	**13.02****	23.57	37.60
	p-value	0.154	0.048	0.004	0.375	0.094
	DPF	1.60	267.10	15.22	24.20	39.42
	Rubber	1.63	239.93	13.43	21.31	34.74
	p-value	0.338	0.120	0.127	0.142	0.272
	SF	**1.57***	**303.40***	**17.73***	24.13	**41.85***
	Areca	**1.70***	**250.02***	**12.29***	25.18	**37.46***
	p-value	0.047	0.027	0.042	0.390	0.024
	NPFs	1.56	275.76	16.12	23.78	37.70
	Cassava	1.59	278.76	13.23	25.15	39.70
	p-value	0.404	0.454	0.130	0.136	0.250
40-60cm	NPFs	**1.69***	249.92	12.09	24.27	36.81
	Plantations	**1.74***	239.28	11.15	26.08	36.69
	p-value	0.033	0.143	0.210	0.066	0.457
	DPF	1.70	247.11	12.29	23.75	36.04
	Rubber	1.75	229.93	11.98	25.09	37.08
	p-value	0.158	0.097	0.420	0.193	0.249
	SF	**1.66***	248.06	12.29	24.18	36.46
	Areca	**1.78***	234.22	8.62	27.20	35.83
	p-value	0.036	0.283	0.092	0.113	0.396
	NPFs	1.66	245.84	10.35	26.13	36.48
	Cassava	1.70	258.35	12.01	26.95	38.96
	p-value	0.174	0.275	0.231	0.338	0.104

Notes: *—$p<0.05$; **—$p<0.01$; DPF-degraded primary forest; SF-secondary forest

Table 3-6 Soil chemical properties of different vegetations in Dagan community

layer	Vegetation	pH	SOM g/kg	TN g/kg	TP g/kg	TK g/kg	HN mg/kg	AP mg/kg	AK mg/kg
0-20 cm	NPFs	4.40	**36.35***	1.16	**0.39***	37.32	61.41	**2.17***	30.78
	Plantations	4.43	**28.48***	1.12	**0.37***	34.76	59.90	**1.47***	30.46
	p-value	0.279	0.016	0.223	0.036	0.101	0.180	0.033	0.430
	DPF	4.37	33.48	1.16	0.38	**40.24***	**61.84***	2.00	30.58
	Rubber	4.43	26.98	1.04	0.35	**33.54***	**57.83***	2.09	26.08
	p-value	0.208	0.059	0.065	0.070	0.015	0.044	0.405	0.138
	SF	4.47	36.19	1.14	0.40	**32.42***	59.41	2.13	30.58
	Areca	4.45	33.48	1.09	0.39	**37.76***	63.87	2.34	34.25
	p-value	0.447	0.349	0.256	0.279	0.024	0.123	0.341	0.059
	NPFs	4.35	**36.53***	1.22	0.41	43.02	63.04	1.38	31.00
	Cassava	4.36	**25.23***	1.23	0.37	34.68	59.02	1.77	27.67
	p-value	0.465	0.027	0.471	0.095	0.063	0.080	0.367	0.262
20-40 cm	NPFs	4.27	20.79	**0.94***	0.28	**26.88***	**31.51*****	1.02	**19.06***
	Plantations	4.30	17.94	**0.81***	0.27	**23.59***	**28.39*****	0.94	**17.19***
	p-value	0.217	0.051	0.015	0.065	0.018	0.000	0.212	0.049
	DPF	4.24	**21.65***	0.94	0.27	**28.33***	**31.36****	1.22	18.81
	Rubber	4.30	**17.09***	0.76	0.26	**23.83***	**27.43****	0.99	16.20
	p-value	0.162	0.040	0.053	0.401	0.024	0.006	0.064	0.157
	SF	4.33	18.99	0.92	0.29	22.93	31.77	0.92	18.67
	Areca	4.30	18.07	0.91	0.28	24.75	29.98	0.95	18.83
	p-value	0.378	0.374	0.434	0.145	0.183	0.127	0.402	0.456
	NPFs	4.24	**24.06***	0.92	**0.31***	30.00	**30.20***	0.78	18.67
	Cassava	4.25	**17.73***	0.81	**0.27***	24.64	**28.09***	0.72	17.00
	p-value	0.437	0.013	0.283	0.036	0.083	0.030	0.427	0.134
40-60 cm	NPFs	4.21	11.57	**0.65***	0.23	**21.13***	**25.37***	**0.57***	9.97
	Plantations	4.21	10.15	**0.56***	0.21	**17.73***	**22.85***	**0.51***	9.64
	p-value	0.498	0.160	0.039	0.129	0.033	0.042	0.046	0.253
	DPF	4.20	13.98	0.64	0.24	**23.01***	27.44	0.59	10.00
	Rubber	4.20	10.65	0.54	0.21	**17.39***	24.99	0.53	9.43
	p-value	0.464	0.122	0.080	0.128	0.029	0.091	0.144	0.235
	SF	4.23	9.21	0.59	**0.21***	18.21	22.54	0.56	**9.58***
	Areca	4.22	10.01	0.57	**0.22***	17.96	23.08	0.50	**10.67***
	p-value	0.430	0.342	0.273	0.040	0.453	0.373	0.179	0.034
	NPFs	4.18	12.50	0.75	0.23	20.08	**25.59***	0.50	**10.67****
	Cassava	4.21	8.87	0.58	0.21	18.45	**19.41***	0.48	**8.00****
	p-value	0.218	0.069	0.119	0.059	0.192	0.025	0.363	0.007

Note: *—$p<0.05$; **—$p<0.01$; ***—$p<0.001$; DPF-degraded primary forest; SF-secondary forest

Table 3-7 Cash flow of management of Eucalypt in Maohui community (RMB/ha)

Year	1	2	3	4	5	6	Sum
Gross Income	0	0	0	0	0	36000	36000
Investments	6030	1530	630	630	630	19710	29160
Net cash flow	-6030	-1530	-630	-630	-630	16290	6840
NPV	-6030	-1466	-578	-554	-531	13147	3989

Note: (1) Base year 2011, Start year 2011; Discounted rate (risk-free interest) 4.38%; (2) Cost: Land rent 450 RMB/ha/a, Cultivation 180 RMB/ha/a, Clear the forest land 750 RMB/ha, Soil preparation 1500 RMB/ha, Seedling 900 RMB/ha, Planting (planting density 1655 N/ha), Base fertilizer 600 RMB/ha, Tending (in the 2nd year) 450 RMB/ha, topdressing (in the 2nd year) 450 RMB/ha, Tax 32 RMB/m^3, felling and skidding 180 RMB/m^3, cost of sales and management is 10% of the Gross Income; (3)Yield: Volume at final felling 90 m^3/ha; (4) Price: standing volume 126 RMB/m^3.

Table 3-8 Cash flow of management of Caribbean pine in Maohui community (RMB/ha)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum
Gross Income	0	0	0	0	0	0	0	0	0	0	0	16875	16875	16875	16875	16875	16875	112800	214050
Investments	12450	630	630	630	1830	630	630	630	630	630	630	1155	1155	1155	1155	1155	1155	30522	57402
Net cash flow	-12450	-630	-630	-630	-1830	-630	-630	-630	-630	-630	-630	15720	15720	15720	15720	15720	15720	82278	156648
NPV	-12450	-604	-578	-554	-1542	-508	-487	-467	-447	-428	-410	9810	9398	9004	8626	8264	7917	39700	74244

Note: (1) Base year 2011, Start year 2011; Discounted rate (risk-free interest) 4.38%; (2) Cost: Land rent 450 RMB/ha/a, Cultivation 180 RMB/ha/a, Clear the forest land 825 RMB/ha, Seedling 7500 RMB/ha, Planting (planting density 1650 N/ha, retain after thinning 1050～1200 N/ha), Base fertilizer 600 RMB/ha, Tending 900 RMB/ha, Drawing resins (Since 12th year) 525 RMB/ha/a, Tax 32 RMB/m^3, felling and skidding 180 RMB/m^3, cost of sales and management is 10% of the Gross Income; (3) Yield: Volume at final felling 217.5 m^3/ha, out-turn rate 65%; (4) Price: standing volume 361 RMB/m^3.

Table 3-9 Cash flow of management of Areca in Maohui community (RMB/ha)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Gross Income	0	0	0	0	0	0	16500	16500	16500	16500	49500	49500	49500	49500	49500
Investments	30000	20050	20050	20050	20050	20050	25810	25810	25810	25810	25810	25810	25810	25810	25810

Net cash flow	-30000	-20050	-20050	-20050	-20050	-20050	-9310	-9310	-9310	-9310	23690	23690	23690	23690	23690
NPV	-30000	-19208	-18402	-17630	-16890	-16182	-7198	-6896	-6607	-6330	15431	14784	14163	13569	13000

Year	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
Gross Income	49500	49500	49500	49500	49500	49500	49500	49500	49500	49500	49500	49500	49500	49500	0
Investments	25810	25810	25810	25810	25810	25810	25810	25810	25810	25810	25810	25810	25810	25810	1200
Net cash flow	23690	23690	23690	23690	23690	23690	23690	23690	23690	23690	23690	23690	23690	23690	-1200
NPV	11931	11431	10951	10492	10051	9630	9225	8838	8467	8112	7772	7446	7133	6834	-332

Note: (1) Base year 2011, Start year 2011; Discounted rate (risk-free interest) 4.38%; (2) Cost of afforestation 30000 RMB/ha; Cost before fruiting: fertilizer 19329.75 RMB/ha/a, Weeding 720 RMB/ha/a; Cost begin to fruit: fertilizer 19329.75 RMB/ha/a, Weeding 480 RMB/ha/a, picking the fruit 6000 RMB/ha; Final clear-cutting 1200 RMB/ha; (3) Yield: from 7 to 10 years old 550 kg/ha; from 11 to 30 years old 15kg a tree; (4) In site price of fruit is 0.5 RMB/kg.

Table 3-10 Cash flow of management of Rubber tree in Maohui community (RMB/ha)

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Gross Income	0	0	0	0	0	0	0	0	15746	15746	15746	15746	60361	60361
Investments	14130	13658	13658	13658	13658	13658	13658	13658	23196	23196	23196	23196	25837	25837
Net cash flow	-14130	-13658	-13658	-13658	-13658	-13658	-13658	-13658	-7450	-7450	-7450	-7450	34524	34524
NPV	-14130	-13084	-12535	-12009	-11505	-11023	-10560	-10117	-5287	-5065	-4853	-4649	20640	19774

Year	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Gross Income	60361	60361	60361	60361	60361	60361	36887	36887	36887	36887	36887	36887	36887	36887
Investments	25837	25837	25837	25837	25837	25837	16030	16030	16030	16030	16030	16030	16030	16030
Net cash flow	34524	34524	34524	34524	34524	34524	20858	20858	20858	20858	20858	20858	20858	20858
NPV	18945	18150	17388	16658	15959	15290	8850	8478	8122	7782	7455	7142	6843	6555

Year	29	30	31	32	33	34	35	36	37	38	39	40	41	
Gross Income	36887	36887	36887	36887	36887	36887	36887	36887	36887	36887	36887	36887	108000	
Investments	16030	16030	16030	16030	16030	16030	16030	16030	16030	16030	16030	16030	0	
Net cash flow	20858	20858	20858	20858	20858	20858	20858	20858	20858	20858	20858	20858	108000	
NPV	6280	6017	5764	5522	5291	5069	4856	4652	4457	4270	4091	3919	19442	

Note: (1) Base year 2011, Start year 2011; Discounted rate (risk-free interest) 4.38%; (2) Cost in afforestation: one seedling 8 RMB (density 540 N/ha), planting one seedling 12 RMB, Cultivation 800 RMB/ha/month; Cost before production of rubber (from 2nd to 8th year): Cultivation 800RMB/ha/month, fertilizer 9990 RMB/ha/a, farm chemicals 337.5 RMB/ha/a; Cost before full fruiting period (from 9th to 12th year): rubber tapping 10.95 RMB/stem/a, fertilizer 15984 RMB/ha/a, farm chemicals 654.75 RMB/ha/a, transport 600 RMB/t; Cost in full fruiting period (from 13th to 40th year): rubber tapping 10.95 RMB/stem/a, fertilizer 15984 RMB/ha/a, farm chemicals 2193.75 RMB/ha/a, transport 600 RMB/t; Cost at final felling：Tax 32 RMB/m^3, felling and skidding180 RMB/m^3, cost of sales and management is 10% of the Gross Income; (3) Profit: mean yield 1.2 kg/stem/a before full fruiting, mean yield 4.6 kg/stem/a in full fruiting period; price of rubber 24.3RMB/kg; volume in 41th year 270 m^3/ha, standing volume 170 RMB/m^3

Table 3-11 Investment and profit of management of *Liquidambar formosana* forest in Maohui community

Item	Parameter	Notes
maturation	60 year	natural regeneration
selective cutting cycle	30 year	
land rent	450 RMB/ha/a	
Cultivation	180 RMB/ha/a	
felling and skidding	200 RMB/m^3	
tax	32 RMB/m^3	
sales and management	10% of the Gross Income	
mean growth rate	4.32%	
yield in one rotation	84.7 m^3/ha	Equal to or above 3rd timber class
out-turn rate	65%	
price stand volume	411 RMB/m^3	

4 Analysis and interpretation of the data and results

4.1 Basis for PES of NPFs

It can be seen from Tables 3-1 to 3-4, the typical NPFs in Maohui communitya, secondary forest of *Liquidambar formosana*, had the function of maintaining habitats for local native species. There were in total 64 tree species in the sample plots, belonging to 27 families and 47 genera. They could be divided into 2 sub-layers. The values of Shannon-Wiener diversity index, Simpson diversity index and Pielou evenness index were 2.80, 0.84 and 0.67 respectively. The average diameter of the stand was 13.5cm, the average height was 8.7m, the stocking density was 3,426 trees/ha and the standing volume was 271.1m^3/ha. There was typical Dipterocarp species (*Vatica mangachapoi).* There were other valuable native timber species such as *Sindora glabra, Sarcosperma laurinum*, *Syzygium jambos*, *Engelhardia roxburghiana*, *Photinia davidsoniae*, *Cycas revolute*, *Heritiera parvifoloia.*.

When the NPFs converted to plantations by clear cutting, the surface soil would be severely eroded, erosion ditches would appear at some site, and soil (physical and chemical properties) degradation became evident.

Based on the basic data from tables 3-7 to 3-11, the investment-return of the secondary forest of *Liquidambar formosana* in Maohui and other typical commercial forests was analyzed and shown in table 4-1. Results indicated: the rotation of secondary forest of *Liquidambar formosana* was relatively long, internal rate of return was at the 4th rank, but not evidently different from the 3rd rank, Rubber tree, the investment/return ratio and the Profitability index were at the 2nd rank.

Among the plantation forests, the rotation of Eucalypts was short, the internal rate of return was at the 2nd rank, and the investment/return ratio and the Profitability index were respectively at 4th and 5th ranks. The overall performance was in the middle and lower level. The rotation of betel nut was relatively long, and the internal rate of return was the lowest, other indices were also ranked lower. And the overall performance was poorer than other species. Rubber had the longest rotation, the internal rate of return, investment/return ratio and profitability index were all at the 3rd rank, and the overall performance was at intermediate level. Caribbean pine had a moderate rotation, the internal rate of return, investment/return ratio and Profitability index were all at the 1st rank, and its overall performance was better than other species.

Table 4-1 Main economic indicators of production forests (discounted rate 4.38%)

Forest types	Sum PV investments /RMB	Sum PV benefits /RMB	NPV /RMB	IRR /%	Return on investment /%	Profitability index /%	Rotation /year
Liquidambar formosana	19644.1	34362.2	14718.1	9.4%	80.7%	180.7%	30*
Eucalypt	21661.2	29054.7	7393.7	13.4 %	15.9%	115.9%	6
Areca	424240.2	490278.5	66038.2	7.1%	15.8%	116.0%	30
Rubber tree	525805.6	356962.1	168843.5	10.2 %	47.3%	147.3%	40
Caribbean pine	37098.1	111341.8	74243.7	17.7 %	200.1%	300.1%	18

Note: "*" means selective cutting cycle.

Overall, NPFs had high species diversity and stronger resistance to soil erosion and conservation of soil nutrients. However, selective thinning of NPFs had a long operation cycle and a slow economic return, influencing farmers' livelihood in mountain areas. Influenced by economic considerations, the risk of being converted to pure plantations was high. Therefore, it was necessary to take PES of NPFs as an economic policy tool to encourage and guide the farmers to maintain and sustainable manage the NPFs with low intensity of selective thinning, in order to achieve the harmonization of economy and environment development. It was recommended that the PES fund be paid to forest-owners on a yearly basis in order to supplement the drawback of no short and medium term profits during the management of NPFs.

4.2 Standards for PES of NPFs

The typical secondary forest of *Liquidambar formosana* in Maohui community was taken as a case study. All calculations related to value represented an area of 1ha. The annual average of NPV in 1ha was recorded as "NPV_m". The PES standard for a single cycle scenario was set as "short term PES standard", and that for multiple cycles was set "long term PES standard". The baseline year was set to 2011. According to the treasury yield curve of 2011 inter-bank fixed interest rate published by the China Government Securities Depository Trust & Clearing Co. Ltd., the average interest rate for the 30 year debt was 4.38%, and the non-risk interest rate was set to 4.38%. Eucalypt, Areca, Rubber and Caribbean pine were taken as the candidate species, and the rotations were respectively set to 6, 30, 40 and 18 years. The cycle of selective thinning of NPFs was set to 30 years, and the intensity of selective thinning was 30%. The costs for tree planting and harvesting and the prices of forest products were given in tables 3-5 to 3-9.

4.2.1 PES standard based on opportunity cost

4.2.1.1 Carriers of opportunity cost

Based on cash flow, the NPV_m of candidate species were calculated (table 4-2), the discount rate was set in turn to 1%, 2%, ……, until 15% in the calculation, and the non-risk interest rate of 4.38% was used. Results indicated that:

(1) With the same discount rate, when it was smaller than or equal to 4.38%, the NPV_m of Rubber trees was the largest, for example, when the discount rate was 3.00%, the NPV_m was 6,585 RMB/ha/a for Rubber trees, 5,236 RMB/ha/a for Caribbean pines, 3,930 RMB/ha/a for Areca, 850 RMB/ha/a for the NPFs, and 800 RMB/ha/a for Eucalypt trees.

When the discount rate was larger than 4.38%, the NPV_m of Caribbean pine was the largest, for example, when the discount rate was 6.00%, the NPV_m was 3,090 RMB/ha/a for Caribbean pine, about 2,370 RMB/ha/a for Rubber trees, 735 RMB/ha/a for Areca trees, 520 RMB/ha/a for Eucalypt trees, and the lowest (about 230 RMB/ha/a) for the NPFs. Therefore, to obtain maximum net earnings, the species for operation should be selected from Rubber or Caribbean pine according to interest rates.

(2) With the increase of discount rate, all the values of NPV_m for the candidate species were decreased. The NPV_m for Eucalypt became negative when the discount rate was 14%, and that for Areca became negative when the discount rate was 8%, for the NPFs when 9% and Rubber when 11%. However, even when the discount rate was the maximum value 15%, the NPV_m of Caribbean pine was still positive. This implies that Caribbean pine was not sensitive to the changes of interest rate, if the market fluctuation of interest rate is large, Caribbean pine should be selected for operation.

Due to the long cycle and high risk of forest operation, China had developed and implemented a number of favorable measures, and commonly used measures include reduction of taxes, fees and debt interests. For example, the State Forestry Administration document (Lin Cai No. [2008]8) and the Ministry of Finance notice (MOF notice on adjusting re-lending requirements for the World Bank loan "National afforestation program" 2000-9-1) clearly specified the adjustment on interest rate for forestry loan projects. Therefore, the relatively conservative and non-risk interest rate was used as the discount rate to conduct the financial analysis for the candidate species (table 4-3).

Results indicated that: the investment/return ratios were from large to small in turn: Caribbean pine>NPFs>Rubber>Eucalypt>Areca, the Profitability indices were from large to small in turn: Caribbean pine>Eucalypt>Rubber>NPFs> Areca. It could be seen that the calculations of financial indicators supported the selection of Caribbean pine as the target species for operation. It should be noted that the technical and economic indicators of the NPFs, the secondary forest of *Liquidambar formosana*, were not lag behind: although the internal rate of return was ranked at the 4th, it was not significantly different from that of Rubber which was considered to have better profit, 8% lower; the investment/return ratio was ranked at the 2nd, 71% higher than that of Rubber, also higher than that of Eucalypt and Areca; the Profitability index was ranked at the 2nd, 23% higher than that of Rubber, also higher than those of Eucalypt and Areca.

Table 4-2 The mean NPV in one rotation

Discounted rate /%	Eucalyptus /RMB/ha/a	Areca /RMB/ha/a	Rubber /RMB/ha/a	Caribbean pine /RMB/ha/a	NPFs /RMB/ha/a
0.00%	1140.00	10170.58	16545.43	8702.67	2455.60
1.00%	1020.01	7603.99	12193.46	7354.43	1741.90
2.00%	907.19	5562.00	8980.24	6209.87	1223.74
3.00%	801.06	3931.91	6585.42	5236.39	847.27
4.00%	701.16	2626.67	4784.43	4406.92	573.69
4.38%	664.75	2201.27	4221.09	4124.65	490.60
5.00%	607.09	1578.72	3418.47	3698.87	374.98
6.00%	518.46	735.40	2374.23	3093.44	230.83
7.00%	434.91	55.49	1570.15	2574.86	126.52
8.00%	356.12	-493.43	946.97	2129.94	51.31
9.00%	281.78	-936.95	461.28	1747.60	-2.60
10.00%	211.60	-	80.95	1418.54	-40.93
11.00%	145.33	-	-217.98	1134.89	-
12.00%	82.71	-	-453.55	890.03	-
13.00%	23.53	-	-	678.36	-
14.00%	-32.43	-	-	495.13	-
15.00%	-85.37	-	-	336.30	-

Table 4-3 The basic financial analysis in one ration

Objects	Internal rate of return /%	Return on investment /%	Profitability index /%
Eucalyptus	13.4%	15.9%	115.9%
Areca	7.1%	15.8%	116.0%
Rubber	10.2%	47.3%	147.3%
Caribbean pine	17.7%	200.1%	300.1%
NPFs	9.4%	80.7%	180.7%

With low interest rate (lower than the non-risk interest rate), the NPV_m of unit area was higher of Rubber trees than Caribbean pine. For example, when the discount rate was 4%, the NPV_m was 7.9% higher of Rubber trees than Caribbean pine. When the discount rate was 2%, the NPV_m was 30.8% higher of Rubber trees than Caribbean pine. As mentioned above, high discount rate and low interest rate exist in practice. Therefore, it is necessary to compare the threshold values of discount rate that reflects the relation between discount rate and interest rate. According to table 4-2, the threshold discount rate that determines the NPV_m of Rubber and Caribbean pine was between 4.00% and 5.00%, and within the range the relation between annual average net present values (y) and discount rate (x) was in linear correlation (Figure 4-1).

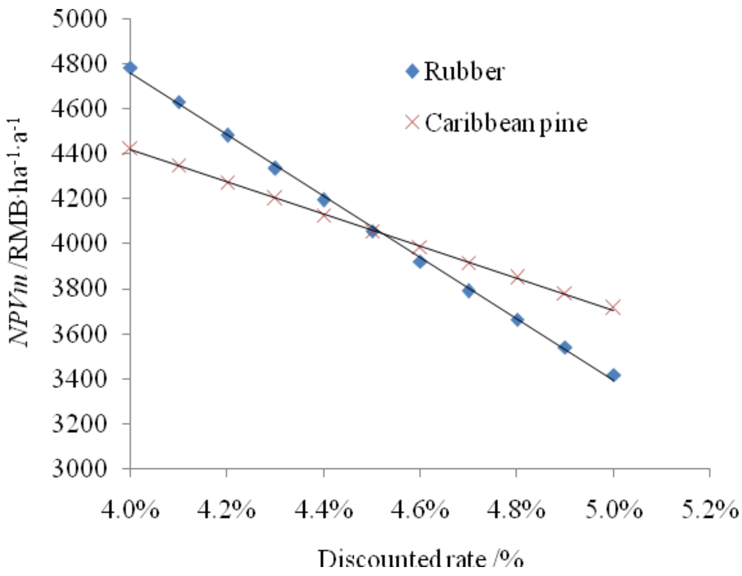

Fig. 4-1 Effect of the shift of discounted rate on the results of mean NPV

With *x* values of 4.1%, 4.2%… 5.0%, the fitted linear equation was as below:

y = -136462x + 10214 (R^2= 0.9986)……Rubber;
y = -71051x + 7258.4 (R^2= 0.9995)……Caribbean pine

According to the above equations, when the annual average net present values of Rubber trees and Caribbean pine were equal, the discount rate was4.52%. It can be seen from table 4-1 that when the discount rate larger than 4.52%, Caribbean pine should be selected for operation, otherwise Rubber should be selected.

4.2.1.2 Discounted cash flow analysis

(1) Standards for short term PES

Based on the above analyses, when developing the standards for PES for NPFs based on opportunity cost, the carriers of opportunity cost would differ with the changes of discount rates: when the discount rate was larger than 4.52%, the PES standard would be $Payment= NPV_{m\ \mathrm{Caribbean\ pine}}- NPV_{m\ NPFs}$, otherwise $Payment= NPV_{m\ \mathrm{Rubber}}- NPV_{m\mathrm{NPFs}}$. According to table 4-2, the standards of PES with the discount rate between 0-10% were obtained (Table 4-4).

Table 4-4 Payments of short-term PES scheme for NPFs

Discounted rate /%	agent of OC: rubber Payments /RMB/ha/a	Discounted rate /%	agent of OC: CP Payments /RMB/ha/a
0.00%	14089.83	4.52%	3565.43
1.00%	10451.56	5.00%	3323.90
2.00%	7756.51	6.00%	2862.61
3.00%	5738.15	7.00%	2448.34
4.00%	4210.74	8.00%	2078.62
4.38%	3730.48	9.00%	1750.20
		10.00%	1459.47

Note: “OC”-opportunity cost; “CP”-Caribbean pine.

It was clear that the higher the discount rate the estimated PES standards were more favorable to ecosystem service buyers, the lower the discounted value the more favorable to owners of the forest. With different discounted rates, the carriers for calculating the standards of PES were also changed, therefore the determination of an appropriate discounted value was of critical importance. Compared to other sectors, forest had long operation cycle and low economic benefit, and it had been given the mandate of ecological benefit, in general, counties would implement some favorable forestry policies, such as interest subsidy and interest free. In Hainan province, the loan interest for the World Bank loan afforestation projects was 6%, and adjusted to 4% by the favorable policy support. When using net present value of earnings for asset evaluation of forest resources, the interest rate was usually not higher than 6% (Teeter and Caulfield, 1991; Chen and Liu, 2001; Huang et al., 2007). Therefore, for the calculation of the standards for PES, the discount rate of 4-6% was more realistic, and reasonable. It could be known from table 4-4, when the discount rate was between 6% and 4%, the PES standard was 2,860-4,210 RMB/ha/a. If calculated on the non-risk interest rate 4.38%, the standard was 3,730 RMB/ha/a.

(2) Long term PES standard

DCF analysis showed that the “carrier of opportunity cost” in the study area was not the only one. The “operation model II” might select Rubber or Caribbean pine as target species for operation. A complete cycle of Rubber operation needed 40 years, Caribbean pine needed 18 years, selective thinning cycle for NPFs was 30 years. Suppose the duration of operation was 360 years, Rubber could have 9 cycles of operation, Caribbean pine 20 cycles and NPFs 12 cycles. As described earlier in this report, with long term scale, the calculation of *NPV* should use lower discount rates, here 0%, 1.0%, ….., 4.0% and non-risk interest rate 4.38% were used (table 4-5).

It could be known from Table 4-5 that: (1) when using lower interest rates, the NPV of long term Rubber operation was larger than those of Caribbean pine and NPFs, therefore the Rubber should be selected as the “carrier of opportunity cost”. (2) With the increase of discount rate from zero to the non-risk interest rate, the standards for long term PES was reduced from 14,000 RMB/ha/a to 490 RMB/ha/a. Since the change was too large, the discount rate should be carefully selected. Referring to the lowest loan interests for World-bank loan afforestation project in China (Lin Cai No. [2008] 8), the discount rate was suggested be 2%, and corresponding PES standard was 1,570 RMB/ha/a.

Table 4-5 Payments of long-term PES scheme for NPFs

Discount rate /%	Rubber		Caribbean pine		NPFs		Payments /RMB/ha/a
	NPV /RMB	NPVm /RMB•a^{-1}	NPV /RMB	NPVm /RMB•a^{-1}	NPV /RMB	NPVm /RMB•a^{-1}	
0.00%	5956353.9	16545.4	3415560.0	8737.7	891576.2	2476.6	14068.8
1.00%	1438952.7	3997.1	784136.5	2178.2	200127.4	555.9	3441.2
2.00%	639583.3	1804.4	369673.7	1026.8	83774.7	232.7	1571.7
3.00%	373020.3	1036.2	225043.8	625.1	44478.7	123.6	912.7
4.00%	234630.7	651.6	153013.5	425.0	25741.8	71.5	580.1
4.38%	198745.4	552.1	134370.9	373.3	21083.7	58.6	493.5

With a discount rate of 2%, the PES standard for multiple operation cycles was 1,570 RMB/ha/a. As described in chapter 3, the equations (2.7), (2.8) were respectively the calculation equation for *NPV* with limit and without limit of time. With use of these 2 equations, the NPV_m were respectively 1,804.40 RMB/ha/a and 1,805.75 RMB/ha/a for Rubber trees with 360 years of operation, indicating a difference of less than 2 RMB/ha/a. The NPV_m were respectively 232.70 RMB/ha/a and 232.88 RMB/ha/a for the NPFs, with a difference of less than 1 RMB/ha/a. Therefore, 1,570 RMB/ha/a could be taken as the standard for PES with no limit of time (no limit on duration) and being paid on a yearly basis. This was applicable to the scenario of selective thinning of NPFs without time limit, and also conformed to the internal requirement by PES.

4.2.1.3 Monte Carlo simulation

The Monte Carlo simulation was carried out by the Crystal Ball software package (Oracle 11.1). Rubber and Caribbean pine were used according to the carrier analysis of opportunity cost in section 4.2.1.1. In order to calculate the PES standard equally paid on yearly basis, the output was set to NPV_m, same as the previous section, and the input includes price and production. Price referred to commodity (timber and rubber) prices and investment cost (labor, fertilizer, pesticide and transportation), and production referred to forest products (timber and rubber) at the mature period. In the simulation, the confidence level was set to 95%, and mean, standard deviation and percentage were used to control the precision of the estimates of output. The limit of error was set to 5%. The simulation was run for 20,000 repetitions when all set requirements were met, otherwise, the number of repetitions was increased until all set requirements were met.

Assumptions for the simulation include: (1) the prices were random variables that conform to normal distribution; because the market price was impossible to be negative; (2) the production in 1 ha area was a random variable that conformed to normal distribution, and the minimum value was set to zero, representing the maximum loss due to emergency event (Typhoon, disease and pest).

The initial settings for simulation were: (1) the initial price was set to the average of 2011 in the study area; (2) the initial production was set to the multiple-year average under average management level in the study area and average site conditions. The Crystalk Ball software requires settings of standard deviation of the set initial values. The product of the initial value of input by a percentage (default 10%) was taken as the standard deviation. Referring to the methods by Knoke (2005), the percentage was set to 20%, intending to obtain relatively conservative results of simulation.

(1) Short term PES standard

The results of Monte Carlo simulation of cash flow were given in table 4-6. The static values in table 4-6 were not simulated, equaled to the results of DCF analysis. The discount rate was set to the risk-free interest rate (the value of projects or assets mainly depended on cash flow, not the discount rate) in the simulation. When the simulation was run for 20,000 repetitions, all the simulation results of the 3 target species for operation met the requirements by set precision.

The results of the simulation revealed that the average probability distribution of NPV_m did not evidently differ from their respective static values. For instance, Rubber had the largest difference, and its static value was 12.04 RMB/ha/a less than the simulated value. No matter static value or simulated value, it was always $NPV_{m\ Rubber}$>$NPV_{m\ Caribbean}$ pine, but the difference between them was no large than 20 RMB/ha/a. Moreover, the simulation indicated that Rubber had the largest standard deviation, with an absolute value of 2,590.35 RMB/ha/a, 2.2 times of Caribbean pine and 10.7 times of the NPFs, implying that the impact of risk was the largest for Rubber. "Risk aversion" and expectation of high return made the operators select Caribbean pine as the target species for the "operation model II". Therefore, when considering risk, the standard of PES for the NPFs in the study area was 3,600±1400 (rounding to integer), i.e., 2,200-5,000 RMB/ha/a.

Table 4-6 the static and simulated results of mean NPV in one rotation

Results	Rubber /RMB/ha/a	Caribbean pine /RMB/ha/a	NPFs /RMB/ha/a
Static value	4221.09	4141.54	534.01
Simulated value±S.D.	4233.13 ±2590.35	4148.18 ±1194.07	536.68 ±241.19
Precision /%	0.85% 1.08%	0.40% 1.08%	0.62 1.16%

(2) Long term PES standard

The duration of operation and the discount rate were respectively set to 360 years and 2%, other settings were the same as those for single operation cycle. Simulation was carried out to get NPV_m (Table 4-7) for the scenario of long term operation. Result indicated that: the simulated NPV_m for Rubber was 1,670 RMB/ha/a, lower than the static value, the uncertainty had an impact on NPV_m of ±890 RMB/ha/a; the simulated NPV_m for Caribbean pine was slightly higher than the static value, and the uncertainty had an impact of ±280 RMB/ha/a on NPV_m; the simulated NPV_m for the NPFs was slightly higher than the static value, and the impact of uncertainty was ±85 RMB/ha/a on NPV_m.

Table 4-7 The static and simulated results of mean NPV in long period

Results	Rubber /RMB/ha/a	Caribbean pine /RMB/ha/a	NPFs /RMB/ha/a
Static value	1804.40	1026.87	232.71
Simulated value ±S.D.	1760.30 ±894.66	1028.37 ±278.11	233.70 ±85.13
Precision /%	0.70% 1.08%	0.37% 1.08%	0.50% 1.17%

The NPV_m of Rubber was higher than that of Caribbean pine (Table 4-7), but its standard deviation was 3.2 times of that of Caribbean pine and 10.5 times of that of the NPFs, therefore, Rubber was not selected as target species for operation. The risk of Caribbean pine was higher than the NPFs, but influenced by the uncertainty the lowest NPV_m of Caribbean pine was 750 RMB/ha/a, while the largest NPV_m of the NPFs was 320 RMB/ha/a, and the former was 2.3 times of the later. Therefore, in order to avoid risks and obtain a certain investment return, Caribbean pine should be selected as the target species for operation. The standard of PES for NPFs in the study area was about 800±360 RMB/ha/a, i.e., 440-1,160 RMB/ha/a.

4.2.1.4 Real options pricing

(1) Simulations of input parameters

Simulation of volatility σ

The confidence level was set to 95% and the error limit was set to ±5%, when all set requirements are met, the simulation was run for 5,000 repetitions, otherwise, the number of repetitions was increased until all the set requirements were met. Results indicated that 5,000 repetitions of running can meet the precision requirement. For a complete operation cycle, the standard deviation was 0.29 for Rubber, 0.13 for Caribbean pine, and 0.25 for the NPFs. The standard deviation is the volatility σ if recorded in percentage. In comparison, the largest volatility was for Rubber, followed by NPFs and Caribbean pine in turn.

S, K and T for different target species for operation

Parameters and simulation settings were same as in section 4.1.2.3. The values of S, K and T were set to the duration (year) of a single operation cycle of the target species. But the NPFs was calculated on the cycle of selective thinning. The results of simulation were given in table 4-8.

The distributions of S values of the 3 target species were all in right-skewed (skewness>0), i.e. the right tail was relatively long, and most S values (including the median) were in the left side. The distribution kurtosis of the K values the 3 target species were all larger than 3 (super Kurtosis>0), belonging to cute kurtosis, the tails of the distribution was “relatively fat”. Considering skewness and kurtosis, the S value should take the median, the S value was 513,464.79 RMB/ha for Rubber, 109,555.27 RMB/ha, and 35,194.41 RMB/ha for the NPFs. The simulated K values were similar to S, all were in right-skewed distribution, all kutosis were larger than 3, therefore, the median was taken as the estimate of K. The K value was 351,175.58 RMB/ha for Rubber, 36,512.28 RMB/ha for Caribbean pine and 19,745.78 RMB/ha for the NPFs.

Table 4-8 Simulated results of parameters *S* and *K*

Parameter	Objects	Time /year	Mean /RMB•hm^{-2}	Median /RMB•hm^{-2}	S.D.	Skewness	Kurtosis
S	Rubber	40	520867.46	513463.79	101111.09	0.45	3.47
	Caribbean pine	18	111454.23	109555.27	22620.48	0.47	3.39
	NPFs	30	35998.76	35194.41	7884.04	0.67	3.83
K	Rubber	40	351542.12	351175.58	23043.08	0.14	3.01
	Caribbean pine	18	36787.05	36512.28	3663.44	0.49	3.59
	NPFs	30	19898.43	19745.78	2343.56	0.39	3.27

(2) Real option price estimation

The price estimates of Rubber, Caribbean pine and the NPFs under the scenario of a complete operation cycle based on binary-tree method and Black-Scholes model were shown in figures 4-2a, 4-2 b and 4-2c. With increase of the steps, the option price estimate obtained by binary-tree method tended to get stable with the number of steps. After 1000 steps, the estimates for Rubber, Caribbean pine and NPFs reached the stable state, closing to the estimates by Black-Scholes model. Therefore, the estimates by binary-tree method could be taken as the option price.

The option price by binary-tree method was rounded 467,460 RMB/ha for Rubber, 92,960 RMB/ha for Caribbean pine and 30,490 RMB/ha for the NPFs. In comparison, the option value of Rubber was the largest, in addition to the relation with long operational cycle, it was also related to the features of cash flow: except investment in afforestation, there would be large amount of inputs of labors, pesticides and fertilizers. For Caribbean pine, the main investment expenditures were in tree planting and harvesting and sales at the end of rotation, even though thinning and resin collection were also conducted within the rotation period. For the NPFs, harvesting and sales accounted for a major part of the expenditures, basically with no investment in tree planting because it mainly relied on natural regeneration. Therefore, amount the three target species, Rubber had the most uncertain factors that affect the expected return, and this was also shown by the volatility rates of the 3 target species.

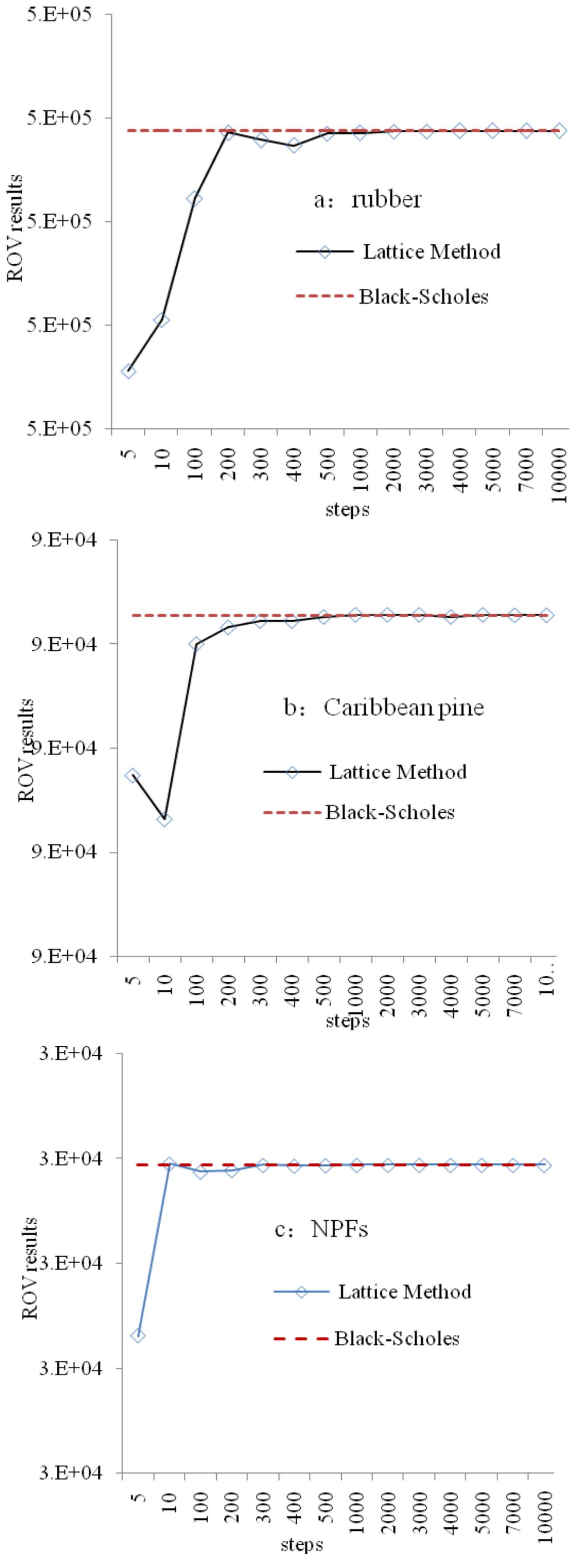

Fig. 4-2 Results calculated with Lattice Method and Black-Scholes Model

According to the definition of the methods of net present value, NPV=S-K. Based on the simulated S and K (similarly the median was taken) values in Table 4-8, the NPV could be calculated. It was 162,290 RMB/ha for Rubber, 73,040 RMB/ha for Caribbean pine and 15,450 RMB/ha for the NPFs. In comparison, all the 3 option values were higher than the net present values, and the option value was 2.8 times of its net present value for Rubber, 1.3 times for Caribbean pine and 1.9 times for the NPFs. The option value expected to rise was higher than the net present value, because it considered not only the net present value, but also the value of flexible management strategy.

(3) Short term PES standard

The above analyses showed that with medium risk, Rubber would bring a high value, so that the Rubber should be selected as target species for operation. Considering the yearly based equal payment of PES, the PES standard was $Payment = NPV_{m\ \mathrm{Rubber}} - NPV_{m\ \mathrm{NPFs}}$, and rounded to 10 670 RMB/ha/a. This was the short term PES standard.

4.2.2 PES standard based on recipient's willing

Whether the PES system for NPFs could be accepted by the ES sellers, and to what level of the standard of PES they could accept? In order to answer these 2 questions, Dagan Community was selected as the study area for a survey. Before the survey there were already some researchers who had conducted studies on restoration of forest landscapes in the study area using participatory method for surveys. The local people have already had ideas about participatory forest management, and preliminary ideas about PES for non-commercial forests (NCF).

4.2.2.1 Socio-economic analysis

In the study area, a part of the residents were working outside the area for business or other jobs for long time. There were 106 households that can be interviewed, of which 8 households clearly refused to interviews, and 98 households were interviewed, accounting for 70.0% of the total number of local households (90.7% of the total number of households that could be interviewed). During the interviews, information on family members was collected covering 488 persons, accounting for 81.3% of the total population of the community. Based on the data collected in the interviews, social economic analysis was give below:

(1) Income level and PES

In 2010, the average family income in Dagan Community was 26,338 RMB (ranging from 1,280 to 85,000 RMB). The income from crop cultivation accounted for 32.3% on average of the family income, and other incomes were mainly from working or doing business (mainly sales of agriculture products, daily consumables and self-produced rice wines) in other places.

(2) Willingness of growing the target species

Rubber and Areca had the largest cultivation area among the economic crops, but more than 60% of them were plated in recent 10 years and still at young age, few of them reached the initial production period. Stipulated by the price hiking and the tradition of chewing Areca of the Li minority people, about 90% of the interviewed people adjusted the cropping structure by reducing fruit trees and agriculture crops (mainly cassava) and growing more Rubber and Areca. 75% of the households indicated that if the policy allowed converting the NPFs to plantations they would chose to plant Rubber and Areca.

(3) Family labor resources

According to the data from interviews with households, the average family size was 5 persons, of which 2.2 persons were farming labors (18-50 years old), 1.0 person was working in other places, and 1.8 persons were for other jobs. The farming labors above 18 years of age accounted for 60.1% of the total population.

(4) Level of education and awareness of forest ecosystem service

Excluding schooling students and pre-schooling children, the average number of education years of family members was 8.4 years (ranging from 4.5-11.0 years). Among the 98 interviewed families, 265 adults had 9 years or more compulsory education, accounting for 54.3%. 2 adults had university education, accounting for 0.4%. Among the 98 household heads, 8 persons had a high school education, and the rest had an elementary school education. With the main family members (mainly spouses and parents) presented, 14 out of the 98 household heads could tell more than 3 types of forest ecological functions, 43 household heads could tell 1-3 types of the ecological functions and 41 household heads could tell 0 ecological function. This indicated that about 58.2% of the households knew at least 1 ES, and 41.8% of the households had no understanding of ES.

The above survey results indicated that: the income difference was large among local families, farmers had strong willingness to develop economy, increase income and reduce the income gaps; local farmers were poorly educated, labors were mainly distributed in crop cultivation, and this situation was difficult to change in short time; local farmers had strong willingness to expand the scale of plantations. These factors coupled with the priority for expanding Rubber plantations in local township plan and the rapid rise of Rubber price in recent years, and with limited land resources the possibility of converting NPFs to plantations was large.

4.2.2.2 Modeling and prediction

(1) Selection of variables

Based on the analyses in previous sections, the selected independent and dependent variables were given in table 4-9. The dependent variables included the proportion of income from crop cultivation to the total family income, age of interviewees, annual total family income, number of persons working on farming, and they were used for integrated analysis of the impacts of socioeconomic factors. 94.9% of the interviewed families expressed agreement not to shift their natural forests to plantations under the condition of receiving a certain amount of PES, hence ensuring sustainable supply of ES of natural forests and quality improvement. Since the proportions of these families were high, the dependent variable was set to "whether agree the same PES standard for NPFs as for non-commercial forests (NCF)".

Table 4-9 Variable range and description

Variables	Description	Range
Age (*a*)	independent variable	0～100
farmers in family (*l*)	independent variable	0～10
income percent of crop farming (*i*)	independent variable	0.0%～100.0%
level of education (*ed*)	independent variable	0: ≤9 years education；1: >9 years education
know how many ecological function (ec)	independent variable	0: 0 type；1: 1～3 types；2: >3types
whether accept 300RMB/ha/a as PES standard of NPFs (wta)	dependent variable	1: agree，0: oppose

(2) Regression model

Stepwise regression was used in the modeling. For easy comparison, the all variables mode logit01 and the stepwise model steplogit01 were given at the same time, estimates of the parameters and results of tests were presented in table 4-10 and 4-11, and the abbreviations are the same as in table 4-9.

It could be seen from table 4-10 that when all the variables of table 4-9 were used in the model, only the "number of persons per family working on crop farming (*l*)" and "income proportion of crop cultivation to the total income (*i*) were significant, indicating that the 2 variables had significant impact on *wta* of the interviewed households, but no significant impact on age (*a*), level of education (*ed*) and ecological awareness (*ec*).

Table 4-10 Fitted results of all variables

Variables	Coefficient	Std.	*z*-statistics	*p*-value
intercept	-1.11624	1.22870	-0.908	0.3636
a	0.03113	0.02279	1.366	0.1719
l	0.38378	0.23098	1.662	0.0966*
i	-1.51101	0.68749	-2.198	0.0280**
as.factor(ed)1	-0.25412	0.80314	-0.316	0.7517
as.factor(ec)1	0.14375	0.48484	0.296	0.7669
as.factor(ec)2	-0.60607	0.70301	-0.862	0.3886

Notes: *—*a* = 0.1，**—*a* = 0.05，as. factor ( ) is a R function

The stepwise regression was further used to screen variables, and model steplogit01 was obtained. The fitted values of the regression model showed that only regression of *i* was significant (a = 0.05) while those of *l* and the intercept were not significant (Table 4-11). Therefore, the variables need to be further screened. Taking account of the possible linear relation between *l* and *i*, or the possibility of containing information of *l* in the *i*, the *l* was removed from the model steplogit01 obtained from stepwise regression and the fitted values were presented in Table 4-12. Results indicated that the *i* and the intercept were all significant, and that the *p* value of the intercept was 0.00217, reaching 0.01 significance level. The *p* value of the *i* was 0.01548, reaching 0.05 significance level. The results in Table 4-12 proved that the removal of l was in consistence with the above inference.

Table 4-11 Fitted results of stepwise regression

Variables	Coefficient	Std.	*z*-statistics	*p*-value
intercept	0.3701	0.5618	0.659	0.510
l	0.3296	0.2118	1.557	0.120
i	-1.6642	0.6546	-2.542	0.011 **

Notes: **—*a* = 0.05

Table 4-12 Fitted results after excluding the variable *l*

Variables	Coefficient	Std.	*z*-statistics	*p*-value
intercept	1.0733	0.3501	3.066	0.00217***
i	-1.5519	0.6411	-2.421	0.01548**

Notes: **—*a* = 0.05，***—*a* = 0.01

By comparing the coefficients of variable *i* (Table 4-10, 4-11, 4-12), they were all negative values and differed little, indicating the explanation of the dependent variable *wta* by the independent variable *i* was relatively reliable and the appropriateness of removing l in the model. Furthermore, χ^2 test of including *i* in the model (logit02) and only keeping the intercept in the model (Null model) obtained a probability value *p* of 0.01334976, lower than the 0.05 significance level, indicating that the model logit02 was significantly advantageous over the Null model, or inclusion of *i* in the model was of practical implications. The model logit02 can be written as below:

$$\text{logit02} = \ln(odds) = \ln\left(\frac{p}{1-p}\right) = 1.0733 - 1.5519i \qquad (4.1)$$

(3) Prediction

According to the equation (2.20) and model 4.1 and the 28 observation values for test of prediction, the rate of correct prediction was calculated, obtaining a value of 57.9%, specific observation values (*wta*) and corresponding predicted values (*wta**) were presented in Table 4-13. Based on the grouping methods described in previous sections of this report and according to the predicted values in Table 4-13, the proportion of Class A samples to the total number of tested samples was 53.6%

(Results of incorrect predictions of Class B and C were removed), implying that the proportion of those accepting the PES standard for public welfare (300 RMB/ha/a for NPFs) was larger than half. This suggested the feasibility of protecting local natural forests through PES for the NPFs.

Commonly, very few examples were available on using the rate of correct prediction to test the results of prediction. Miao (2008) used more than 1,000 samples to establish a model, with 1 and 0.5 as the criteria, to analyze the prediction errors. It was found that the prediction errors smaller than 0.5 accounted for 54%. Referring this example, the predictions of this study were acceptable.

Table 4-13 Observed and predicted values

observed value *wta*	predictive value *wta**	observed value *wta*	predictive value *wta**	observed value *wta*	predictive value *wta**	observed value *wta*	predictive value *wta**
1	0.682	1	0.665	1	0.427	1	0.637
1	0.466	0	0.383	1	0.745	1	0.675
1	0.647	1	0.589	1	0.593	0	0.559
0	0.692	0	0.705	1	0.574	0	0.383
1	0.383	0	0.383	1	0.383	1	0.447
1	0.682	1	0.685	1	0.619	0	0.383
1	0.658	1	0.633	1	0.589	0	0.689

4.2.2.3 Brief sum-up

The logit model used for predicting the willingness of forest owners to accept PES included only an intercept and an independent variable *i*, the equation was simple and the rate of correct prediction reached 67.9%. More than half of the households were predicted to accept the PES standard, 300 RMB/ha/a, suggesting the feasibility of using the local standard for public welfare forest for NPFs. From decision maker's point of view, PES for NPFs based on current policies needed a low cost, easy to be accepted by other groups of people, useful for rapidly entering decision-making process and solve currently prominent conflicts.

The proportion (i) of crop cultivation to the total family income was negatively correlated with the willingness of villagers to accept a set PES standard. It was suggested mitigate the pressure of shifting NPFs to plantation forests through improving education, providing more training on job skills, expanding income generation channels and reducing reliance on crop cultivation.

After the reform of forest ownership, the property right of NPFs in rural areas belonged to the village collectives or individual farmers, implementation of PES for the NPFs no doubtedly needed the recognition from the forest owners. However, the use of common CVM approach to obtain survey data and establish models to analyze the probability of acceptance by stakeholders for the assumed policy was a new attempt and to what extent the idea could provide evidence for decision-making still needed further test in practice.

4.2.3 PES standard by land rent

The loan interest of 6% of Hainan World Bank loan afforestation program was taken as the discount rate (the interest rate before the implementation of favorable policy) for evaluating land rent of the major part of the NPFs, the secondary liquidambar forest, in Maohui (Table 4-14). The basic parameters such as related prices, yields and taxes used for the evaluation were same as those used in the cash flow analysis. For comparison, same method was used to calculate the land rent for Eucalypt forest (representing fast growing broad-leaved forest), Caribbean pine forest (representing tropical conifer forest) and Rubber forest (representing tropical raw material forest) with average level of yield in the study area, investigation was conducted on land rent of commercial forests in the study area and surrounding communities with similar production and management conditions.

In comparison, the rent for Rubber forest and Caribbean pine forest was relatively high, and those of the secondary Liquidambar forest and the Eucalypt forest were similar. Compared to the calculated values, the trade prices were at a lower level. For the scenario of ES supply from rented forestland, the approach of market trading can be used. The ultimate transaction price was determined by negotiation between the two sides. Based on the calculation and survey results, the land rent are in the range of 300～1 500 RMB/ha/a。

Table 4-14 The reference PES standard by land rent

Items	NPFs /RMB/ha/a	Eucalyptus /RMB/ha/ year	Caribbean Pine /RMB/ha/ year	Rubber /RMB/ha/ year
Method of Forestland Evaluation Value	998.85	974.87	1352.77	1466.62
Cases in practice	300[a]	450[b]	1050[c]	2000[d]

Notes: a-Maohui community, b-Wuzhishan city, c-Changhao county, d-rubber plantation

4.2.4 Summary of PES standards

(1) PES standard based on opportunity cost. The standard of short term PES for the NPFs in study area was 2,200-5,000 RMB/ha/a, the theoretical upper limit was 10,670 RMB/ha/a. In order to make the decision making more flexible, the results from discount cash flow method and Monte Carlo simulation method were combined, obtaining a range of long term PES standard as 440-1,570 RMB/ha/a.

(2) PES standard based on willingness to accept PES. The PES standard for the NPFs in study area was 300 RMB/ha/a.

(3) PES standard based on land rent. The PES standard equaled to the land rent, the standard in the study area was 330-1,500 RMB/ha/a for different site qualities.

4.3 PES Scheme of NPFs in Maohui community

Further studies were conducted on the scheme of PES for NPFs, particularly the objective, object, standards, buyers, sellers and legal binding et al.

4.3.1 Objective of PES scheme

The main objectives of PES scheme were to prevent the conversion from NPFs to plantations and to improve the quality of NPFs by sustainable management.

4.3.2 Object of PES scheme

The object of PES was the NPFs that were allocated to collective organizations or individuals after the reform of collective forest tenure system. During the implementation, on-site investigation can be conducted in combination with maps and descriptions recorded in the forest tenure certificate to determine the forest types (or dominant species), area, location, ownership, vegetation etc. It would provide a basis of PES scheme of NPFs for dynamic monitoring and management.

4.3.3 Standard for PES

Firstly, the time scale should be set to long term PES model, in order to achieve the fundamental objective of stable and continual supply of ES.

Secondly, different results from different calculating methods for PES standard, such as DCF, MCS, ROV and CVM et al., could be as references for consulting among sellers, buyers and other stakeholders.

Thirdly, no matter which PES standard was to be used, the final PES standard in practice should be decided by mutual agreement. This is because, on one hand the ES buyers are fully aware of their purchase power, and on the other hand the PES standards usually related to the livelihood of the forest owners. Therefore, in order to protect the interest of sellers, the implemented PES standard at the lowest should be no less than the lower limit of the calculated range.

The standard of the PES of NPFs in Maohui community was 300 RMB/hm2 in 2012. 70% of the fund should be paid to the individuals (villagers) and 30% of the fund kept in the villagers group (community) when the owner of NPFs was the villagers group. If the owner of NPFs was the villagers (individuals), 100% of the fund should be paid to the villagers (individuals). The standard of the PES of natural production forests should be gradually increased with the development of regional economy and the quality improvement of the natural production forests.

4.3.4 The ES buyers

The users and interested parties of the ES of NPFs concentrated in small areas, and the buyers are mainly local residents. However, at present there is no scheme and willingness of purchasing ES by the public, the current buyers should be set as the representative of local public interests, local government, correspondingly, the financial sources should be from local governmental finance. The interested parties of the ES of NPFs may come from outside, such as international environment protection organizations, non-governmental organizations, public welfare institutions, they pay great attention to environmental services and are potential buyers.

4.3.5 The ES sellers

The sellers of ES of NPFs should be the owners of NPFs which may be the individuals (villagers) or the collective organizations (e. g. villagers groups, villages etc.)

4.3.6 Legal binding

A contract for PES of NPFs should be singed according to relevant laws and regulations to establish a mechanism of legal binding. The rights and obligations of the buyers include: (1) Examination of property rights; (2) Providing funds; (3) monitoring and examination. The rights and obligations of the sellers include: (1) To insure that the ownership of the NPFs would not be changed; (2) To insure the area of the NPFs would not be reduced; (3) To insure the quality of the NPFs would not be declined; (4) Other rights and obligations specified by laws and regulations; (5) Other necessary provisions: liability for breach of contract, schemes of entry and quit, conditions for termination etc.

5 Conclusions

Based on an analysis of current status of PES studies, the NPFs in Maohui community, Wuzhishan City and Dagan community of Lingshui County of Hainan Province was taken as cases to analyze the basis of the PES of NPFs and study on the PES standards of NPFs. In combination with theoretical and the case studies, key points of PES scheme of NPFs were discussed.

5.1 Basis of PES of NPFs

Cases study showed that it was necessary to carry out PES scheme of NPFs in conservation of biodiversity, maintenance of soil and water resource maintaining etc.

(1) Conservation of tree species diversity

The secondary forest of *liquidambar formosana* in the study area was the main component of NPFs. Investigation on typical sample plots showed that there were 64 species in total, belonging to 27 families, 47 genera. Shannon's diversity index, Simpson's diversity index and Pielou’s evenness index were 2.80, 0.84 and 0.67 respectively. The tree layer had two sub-layers, and the tree species diversity was lower in sub-layer I than in sub-layer II. *Liquidambar formosana* was predominant in sub-layer I. In sub-layer II, the dominance of *Liquidambar formosana* was less obvious than in sub-layer I. In addition to *liquidambar formosana,* other tree species with a higher importance value include *Lithocarpus silvicolarum, Macaranga deheiculata* and *Cratoxylon ligustrinum.*

(2) Conservation and Maintenance of soil and water resources

The soil investigation in the study area showed that the NPFs was 9% higher than the plantations in soil water storage capacity, superior in soil chemical properties, and 15% higher in the contents of soil nutrients on average. The NPFs was less eroded of surface soil, and with a lower content of stones. Among the NPFs, the degraded primary forests had a litter layer on ground surface, the secondary forests had few litter, and the secondary forests which were seriously disturbed and nearby residential areas were subjected to desertification in ground surface. The ground surface of plantations was subjected to serious desertification due to the high content of stones and severe soil erosion caused by flooding. More severely, erosion ditches were formed in some specific localities.

5.2 PES standard of NPFs

There were three ways of PES of NPFs and corresponding techniques, methods, and case studies of each way were given as follows:

(1) Based on opportunity cost

Corresponding methods included discount cash flow (DCF) model, Monte-Carlo simulation (MCS) model and real options pricing (ROV) model. Among them, the Monte-Carlo simulation (MCS) model could reflect market risk, and the obtained standard was a range, which gave a space for more flexible choices compared to the “point” estimation by discount cash flow (DCF) analysis. Real options pricing (ROV) model was not frequently used in forest valuation, but the valuation contained the value of managerial decision-making (right), and it represented a new idea. According to the opportunity cost analysis on the PES standard of NPFs in the study area, short-term PES standard was 2,200-5,000 RMB/ha/a, the theoretical upper bound was 10,670 RMB/ha/a. The results of discount cash flow (DCF) model and Monte-Carlo simulation (MCS) model were combined to obtain a long-term standard of 440-1 570 RMB/ha/a.

(2) Contingent Valuation Method (CVM)

To avoid deviations of contingent valuation, the traditional questionnaire design and handling were modified, and a model was developed to analyze and predict residents’ willingness (probability) of accepting preset PES scheme and standard, providing new ideas for decision-making studies and practices. According to this approach, PES standard of NPFs in the study area was 300 RMB/ha/a.

(3) Based on land rent

The ES could be supplied by renting NPFs from the forest owners, and the PES standard was the rent of the forestland. PES standard could be obtained by the method of expected price of forestland in combination with a survey of rent cases in practice. The land rent for different site qualities in the study area was 300-1 500 RMB/ha/a.

5.3 Key points of PES scheme of NPFs

(1) Long-term (unlimited duration) PES model were consistent with the inherent requirement and fundamental objective of PES of NPFs, which should be clarified in policy development of PES of the NPFs.

(2) PES standard of NPFs needed to comply with the development level of local economy. Providing a range for the PES standard based on studies would give more flexibility in decision making. It should be noted that in order to ensure the property interests of the forest owners, no matter which kind of PES approach are used, the actual PES standards implemented should be no less than the lower bound of the range.

(3) The main objectives of PES scheme of NPFs were to prevent the conversion from NPFs to plantations and to improve the quality of NPFs by sustainable management. The object of PES was the NPFs that were allocated to collective organizations or individuals. The local government was the main buyers and collective organizations or individual farmers who obtained the ownership

certificate of NPFs were the sellers. A contract for PES of NPFs should be singed according to relevant laws and regulations to establish a mechanism of legal binding. The main obligations of the sellers were to insure that the ownership of the NPFs would not be changed, to insure the area of the NPFs would not be reduced and to insure the quality of the NPFs would not be declined.

6 Recommendations

The results from discount cash flow analysis are largely influenced by the discount rate. In this report the discount rate was chosen according to relevant policies and trading cases and obtained reasonable results. For example, the range of long-term PES standard of 490-1,570 RMB/ha/a was based on the most favorable interest rate 2% the of the World Bank loan afforestation program and the risk-free rate of 4.8%.

Relatively, Monte-Carlo simulation (MCS) has some advantages. For example, using discount rate 2%, the range of long-term PES standard was 440-1,160 RMB/ha/a by Monte-Carlo simulation (MCS), close to the result of the traditional discount cash flow (DCF) model, and Monte-Carlo simulation (MCS) can reflect the degree of influence by the management risk. Monte-Carlo simulation (MCS) can reflect the market risks, and standard obtained is a range, providing more flexible choices of the PES standard compared to the “point” value of PES standard by the discount cash flow (DCF) analysis.

The results obtained from real options pricing method (ROV) contain the net present value of management and the value of flexible disposition right (i.e. investment and business strategy), the PES standard was therefore bigger than that of the discount cash flow (DCF) method, although both methods took the Rubber trees as the carrier of opportunity cost and used the same discount rate (refers to the risk-free rate) in calculation.

The results from real option analysis (ROV) was also beyond the range of long-term PES standard obtained by Monte-Carlo simulation (MCS), because Monte-Carlo simulation (MCS) only considered the influence degree of uncertainty factors, but overlooked the value of investment and management strategy corresponding to these uncertainties. The PES standard obtained by real options method (ROV) is for short-term PES, because the pricing theory and method of real option are from the field of finance, and it is appropriate to set the mature period as a complete management cycle, if the mature period is set too long, it will be beyond the scope that the theory and method can cover.

A complete PES scheme of NPFs includes objective, object, buyers, sellers, standard, constrain, inspection and supervision etc. The emphasis of this report was put on the basis for PES and the PES standard. The NPFs is a natural ecosystem at a state of dynamic succession. And the level of social and economic development is also in continuously changing. How to make the PES standard in consistence with the dynamics of nature and society, further studies need to be carried out from the viewpoint of both ecology and socioeconomics.

The ES provided by NPFs differs in quality and quantity among different site conditions, more studies on PES standard for different site conditions should be conducted further.

7 Implications for practice

As an important component of forest resources, the NPFs play a significant and irreplaceable role in balancing ecological environment and promoting the sustainable economic and social development. In order to encourage the owners of collective forests to effectively protect and sustainable manage (utilize) the NPFs, and to avoid them converting to plantations, study on the PES of NPFs as an economic incentive has important theoretical and practical significance.

This report provided an innovative approach on PES of NPFs. It took the NPFs in Maohui and Dagan communities in Hainan province as case study, methods including cash flow model, Monte-Carlo simulation model and real options pricing model that are based on opportunity cost and contingent valuation method were used through combination of theories and actual examples to develop the PES scheme of NPFs including the basis, standards and objects et al of PES.

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