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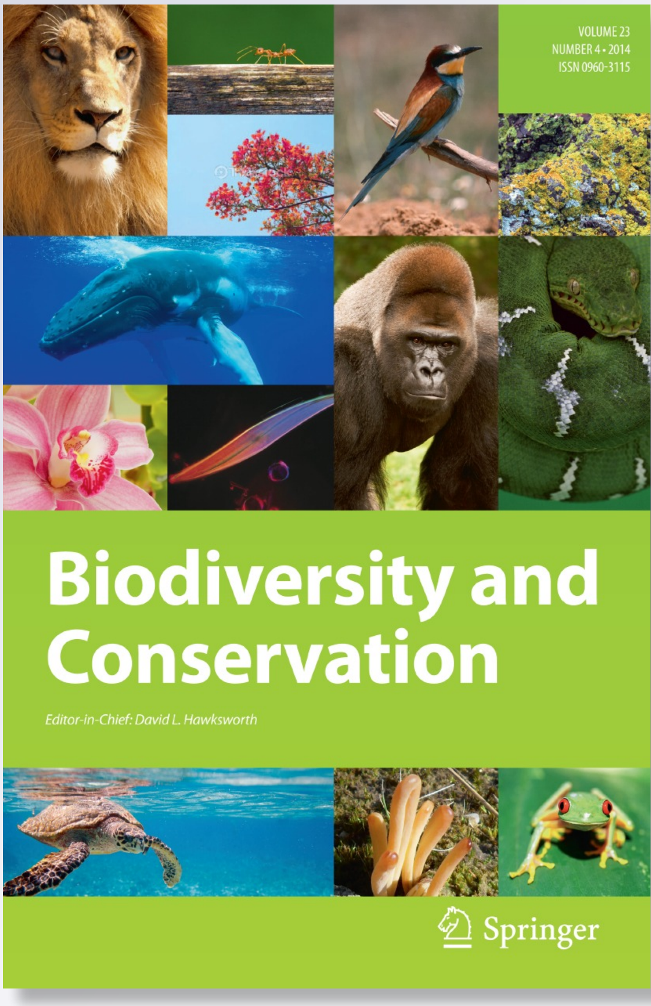

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ORIGINAL PAPER

An economic analysis of reforestation with a native tree species: the case of Vietnamese farmers

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Abstract The area of degraded forests in Vietnam is substantial, currently about 3.1 million ha of which about 1.7 million ha (55 %) were granted to individual farms for reforestation. However, the result of farmers' reforestation efforts is limited. We aimed to examine the financial return, technical efficiency, and factors determining reforestation with a native tree species (*Canarium album*) by farms. Our results showed that reforestation with *C. album* is less financially profitable than that with an exotic tree species (*Acacia mangium*) as the alternative land use option. The subsidy from the government is found insufficient to compensate for the income losses of farmers participating in reforestation with the native tree species. Reforestation with *C. album* could be more successful if participating farmers were equipped to be more technically efficient. Finally, our findings clearly showed that the security of forest land property rights and the provision of

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forest extension services are among the determinants of participation in, and the subsequent success of reforestation with *C. album*.

Keywords Cost benefit analysis · Technical efficiency · Determinants

Introduction

Tropical forests continue to degrade globally, with negative consequences for environmental sustainability and forest-dependent human communities (Nagendra 2007). Despite signs of forest recovery in a few countries (Meyfroidt and Lambin 2011), the rate of tropical deforestation remains alarmingly high (FAO 2010). Furthermore, the area of degraded tropical forests is substantial and thus reforestation is important to support people and reduce pressures for additional deforestation. Large reforestation programs have been implemented in a number of countries to deal with the challenges of energy shortage, biodiversity loss, and global climate change (Nguyen and Tenhunen 2013). However, little attention has been given to the crucial problem of sustaining economic activity of people who participate in such programs (Chazdon 2008) and finding out the determinants of successful reforestation. It is believed that reforestation provides one of the solutions to the current problem of forest loss and its consequences (Angelsen 2010).

Vietnam has experienced critical changes in forest resources and management over the last few decades (Castella et al. 2006; Lambini and Nguyen 2014; Vu et al. 2014). Nearly three quarters of its land territory (331,123 km^2) are mountains and hilly terrains. Approximately one-third of the highland population depends for their subsistence on forests (Nguyen 2008). A large part of degraded forest land has been allocated to farmers for reforestation, but the success of farmers' reforestation is limited (Tran 2010). In some localities, slash and burn cultivation reappears, even though it is forbidden. Some farmers have done nothing, leaving their lands to be further degraded (MARD 2010).

Reforestation of these degraded areas with native tree species (NTS) is difficult, because many of the soils are very infertile and very few NTS are able to tolerate such sites. Thus, early plantation development in Vietnam focused only on monoculture of fast-growing exotic tree species (ETS) of *Eucalyptus*, *Acacia,* and *Pinus* (McNamara et al. 2006). As noted by Knoke et al. (2008), the advantages of NTS are justified by their ecological benefits. Therefore, NTS are now increasingly preferred in reforestation programs in Vietnam. Our research was, thus, motivated by the following questions: (1) What is the economic advantage of farmers' reforestation with NTS? (2) How is the comparative performance of farmers in their reforestation with NTS? (3) Which are the factors explaining the participation in and success of their reforestation with NTS?

Even though there are different actors, ranging from individual farms to private and state enterprises, participating in reforestation in Vietnam, we purposely focused on farmers' efforts. This is because about 51 % of degraded forest land area were granted to individual farms. Moreover, many reforestation schemes are coordinated by state or private enterprises but actual reforestation activities have been done by farmers in practices (via medium or long-term contracts). Economic incentives for farmers' investments are crucial for successful reforestation (Demurger and Yang 2006; Le et al, 2012). Unfortunately, understanding of factors constraining or supporting farmers' reforestation with NTS has been in the dark. The knowledge gap is not only in Vietnam (Nguyen et al. 2010), but also

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in many areas in the humid tropics (Olschewski and Benítez 2005). Whereas the driving forces associated with reforestation have been well documented in developed countries, drivers of reforestation in tropical developing countries are less studied (Nagendra 2007). We thus believe that our findings will shed some light for future policy interventions aimed at reforestation with NTS.

Forest transition and reforestation in Vietnam

Vietnam has undergone a transition from net deforestation to net reforestation. In 1943, under the French colonial administration, the national forest cover was 43 %. After a couple of decades of separation, the country was unified in 1975, but the forest cover decreased to 33.8 % in 1976 (Lambini and Nguyen 2014). This trend had continued until 1990 when the forest cover reached its lowest level of 27.8 % (Wil et al. 2006). During the period 1980–1995, Vietnam lost approximately 110,000 ha of natural forests annually (Nguyen et al. 2010). In addition to the loss in forest areas (i.e., deforestation), forest quality also decreased (i.e., forest degradation). The forest area with rich and medium timber stock had declined while the area with poor stock (timber volume less than 80 m^3 ha) had rapidly increased and reached the number of 7 million ha in 1990. Due to the steep terrain in most forest areas and concentration of rainfall in summer, poor forest sites were further degraded because of water and soil erosion (FAO 2010; Vu et al. 2014).

The causes of Vietnam's deforestation and forest degradation at that time were complicated and diverse, including forest conversion to farm land, forest devastation by wars, over-exploitation by state forest enterprises (SFE), illegal logging, and a deficient institutional and legal framework (Wil et al. 2006; Sikor 2001; Koninck 1999). However, one of the main reasons was the nationalization of all lands and forests, which started shortly after the victory over the French for the independence in 1954. Such a practice was very popular in the former socialist countries (Nguyen 2008). All forests and forest land were put under the management of a system of SFE established in the early 1960s and other governmental entities (Nguyen 2002; Koninck 1999). While SFE were granted with huge areas of forests, they did not have sufficient manpower for effective management. In contrast, people who lived in or near forests for much of their livelihood had no legal access to forests. As a consequence, they simply exploited forest products for survival, in contravention of prevailing forest regulations (Bui 2001; Le et al. 2010). Past policy-makers perceived forest management as a process to protect forests from local dwellers. This resulted in conflicts in resource use between local people and SFE. Consequently, forests were destroyed regardless of many efforts made by the state in terms of administrative punishment and law enforcement (Ayanu et al. 2011; Nguyen 2001).

Since the beginning of the 1990s, part of forest land has been granted to farmers and forests have been gradually recovered. Several internal political, socioeconomic, and land use processes contributed to this increase (Meyfroidt and Lambin 2008). Forest management changes in Vietnam over the last few decades can be described with two ongoing trends: (1) the shift from a top-down to bottom-up, participatory approach in forest management; and (2) the transformation from the only state to multi-stakeholder management schemes (Nguyen et al. 2010; Nguyen and Uibrig 2007). Forests and forest land are currently managed by different forest user groups: state forest management boards (SMB) which are non-profit institutions, SFE, farm households (HH), not-yet-allocated (under the management of People's Committees—PC), and other entities (OT) (Fig. 1). Farm households are now the second largest forest user group, sharing about 25 % of forest

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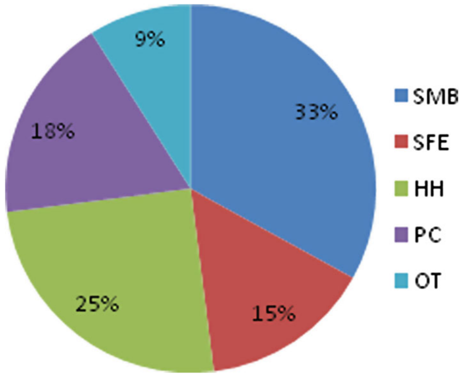
Fig. 1 Proportion of forest areas managed by different forest user groups in 2010 (*Source* Nguyen and Tran 2011)



lands in 2010. This share will increase during the upcoming years, since the allocation of forest land to farm households is not yet completed. It is noted that in Vietnam land use is purposely regulated and thus degraded forest land allocated to farmers can only be used for reforestation purposes (Nguyen 2008).

These changes finally lead to an increase in the national forest cover, which was 39.5 % in 2010 (GSO 2011). Vietnam's forests, thus, have experienced a transition from net deforestation to net reforestation (Table 1). The positive trend in forest resources does not mean that forest clearing behaviors have disappeared; it nonetheless indicates that tree planting has more than compensated for the overall deforestation. In parallel with the allocation of forest lands, some reforestation programs have been implemented. There have been critical debates on the efficiency and effectiveness of many reforestation activities (Meyfroidt and Lambin 2008). Most of planted forest areas are with ETS (McNamara et al. 2006) while the forest losses in the past decades were diverse natural forests (Koninck 1999). From 1975 to 2011, more than 6 million ha of forest plantations were established, an area larger than the bare lands designated for forest establishment. This indicates that reforestation should be considered a complementary approach to improve forest resources.

During the period 1990–2010, about 1.2 million ha of degraded forest lands were successfully reforested. However, the area of degraded forests is still relatively large (3.1 million ha or 19 % of the total forestry land area), indicating the need to further promote reforestation. This paper contributes to this need by examining reforestation efforts with a NTS at the farm level, because nearly 55 % (1.7 of 3.1 million ha) of these degraded forests were granted to farmers (DOF 2010).

Conceptual framework

Consider a farm that has been granted a parcel of degraded forest land. In principle, the farmer will choose the land use option that maximizes the land rent, given his/her constraints and prevailing input and output markets. In other words, the decision to select a specific land use option is based on the maximization of an underlying profit function, which is assumed to be consistent with individual farm behavior. Thus, it is reasonable to examine which land use option will bring the highest (expected) net benefit. In the economic literature, there are a large sheer of models describing competing land use options, i.e., agricultural crops and forest trees (see Nguyen et al. 2010 for a review). Most of these models are based on the assumption that, due to population pressure, the expansion of

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Table 1 Forest change in Vietnam (1943–2010)

Year	Forest area (1,000 ha)			Forest cover (%)	Forest area per capita (ha)	Average annual change	
	Natural forest	Plantation	Total			Area (1,000 ha)	%
1943	14,300	0	14,300	43.0	0.70		
1976	11,077	92	11,169	33.8	0.22	−94.88	−0.66
1980	10,186	422	10,608	32.1	0.19	−140.25	−1.26
1985	9,038	584	9,892	30.1	0.16	−143.20	−1.35
1990	8,430	745	9,175	27.8	0.14	−143.40	−1.45
1995	8,252	1,050	9,302	28.2	0.12	25.40	0.28
2000	9,444	1,471	10,915	33.2	0.14	322.60	3.47
2005	10,283	2,334	12,617	36.4	0.15	340.40	3.12
2010	10,305	3,083	13,388	39.5	0.15	154.20	1.22

Source Lambini and Nguyen (2014) and GSO (2011)

agricultural land will lead to deforestation. These models have been used to explain the reduction of forest areas in many countries. However, considering our specific case where granted forest land is regulated only for reforestation purpose, the competition between agricultural crops and forest trees is not relevant any more. In reality, farmers are allowed to mix crops with forest trees (for supporting the trees in their initial life stage and additional income) but they are not allowed to use the land solely for agricultural crops (Le et al. 2012; Villamor et al. 2011). Furthermore, degraded forest land is so infertile that it is not appropriate for agricultural crops (Nguyen et al. 2013; Nguyen 2012). Thus, the issue of competing land use options is only relevant to the decision of which forest tree species (i.e., NTS or ETS) or which reforestation practices are selected. Therefore, the farmer will either (1) reforest with NTS, or (2) reforest with ETS. This is actually what has been observed in Vietnam. Another cultivation option is to mix both NTS and ETS during the whole forest rotation. However, this has not been found in the study areas at the farm level, because (1) the silvilcultural procedure is complicated, and (2) there is no evidence on the economic advantage of this option that would facilitate farmers to adopt it.

If reforestation is mandatory, it could be considered an investment and farmers will treat it just as any other investment. A farmer will compare the net present value of the expected benefits with the net present value of the expected costs. If the benefits outweigh the costs, then the investment will be made, assuming no internal or external credit rationing. The expected net present value (*NPV*) of an investment can be formulated as:

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \quad (1)$$

where B_t, C_t are the benefits and costs at time t, respectively, r is the discount rate, and n is the time horizon. It should be noted that the supports or subsidies of the government (if any) are included in the benefits. This is similar in the case of taxes that are included in the costs. Since reforestation is a long-term process that may last for several years, and its success depends on many factors that are beyond the management of farmers, i.e., timber price change, farmers are assumed to be cautious and will reforest without or with minimal outside assistance. Finally, other factors may affect the choice of reforestation. These may

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include the requirements of the government, technological constraints such as soil quality, information diffusion (i.e., extension services), and characteristics of the farm.

If the farmer decides to reforest with NTS, then the expected net benefit should be higher than that of the competing land use option, in this case reforestation with ETS. In other words, the net benefit of reforestation with ETS should be considered as the opportunity cost of reforestation with NTS. The decision to reforest with NTS is economically justified only when its net benefit is higher than that of reforestation with ETS. Even though both reforestation with NTS and ETS are long-term investments, their durations differ significantly. ETS are normally much faster-growing than NTS and thus, the comparison of *NPV* over different time scales is difficult. Therefore, in addition to *NPV*, we used the equivalent annual annuity (*EAA*) to compare the financial returns of reforestation with NTS and ETS. *EAA* is calculated as:

$$EAA = \frac{r \times NPV}{1 - (1 + r)^{-n}} \tag{2}$$

where r is the discount rate and n is the length of the investment.

Now consider a number of farms that have performed reforestation with NTS. If we are to compare their performance, the efficiency of reforestation with NTS should be examined so that the scope for improvement of the performance can be figured out. To our understanding, this kind of exercise has been given little attention in reforestation. The concept of the technical efficiency is illustrated in Fig. 2, describing the production process of one input x into output y of a farm. The production frontier y represents the maximum output attainable from each input level. Farms operate either on that frontier, if they are technically efficient, or beneath the frontier, if they are technically inefficient (Nguyen et al. 2012). Point A represents an inefficient point, whereas points *B* and *C* represent efficient points. A farm operating at point *A* is inefficient, because technically it could increase its output to the level associated with the point *B* without requiring more input; or alternatively, it could produce the same level of output using less input, at point *C* on the frontier (Hoang and Nguyen 2013).

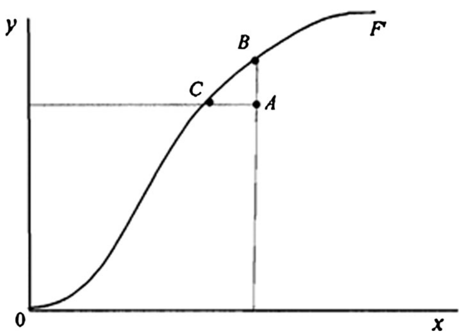

Fig. 2 Production frontier and technical efficiency (TE)

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Input-orientated technical efficiency (*TE*) addresses the question of the proportional reduction of input quantities while producing a given level of output quantities. *TE* is defined as:

$$TE = xTE/x \tag{3}$$

where *xTE* is the input vector at the technically efficient point and *x* is the currently used input vector.

Once the decision to reforest with NTS is made by farmers, it is needed to examine the determinants of the participation and success. This is because there has been evidence that the levels of the participation in and success of reforestation in Vietnam are different among farms (see Nguyen et al. 2010). It is expected that the differences in terms of (1) land property rights, (2) farm characteristics, and (3) other factors such as the diffusion of related information can influence the participation in and success of reforestation with NTS. The specification of the variables representing these groups is described in the next section.

Study design

Study sites

We focused on the Northern Uplands because this region has the largest degraded forest land of the country (FAO 2010). The total land area of the region is about 102,000 km^2, a little less than one-third of the total area of the country. About 82 % of the region consists of hills and mountains with the minimum elevation of 500 m above the sea level (Nguyen et al. 2013). The ethnic diversity is represented by 31 of 54 officially recognized ethnic groups (Khong 1995).[1] In terms of land use, only 15 % of the land area are under agricultural cultivation; 47 % are classified as "unused land"; and 37 % are classified as land for forestry or forestry land. The category of forestry land includes actual forested land and non-forested areas that are designated for either afforestation or reforestation. Although Vietnam has become a major rice exporter, the Northern Uplands still faces food insecurity problems (Nguyen 2008, 2009). We selected two provinces in the Northern Uplands (i.e., Son La and Bac Kan) as our study sites (Fig. 3). These provinces were chosen because they have large areas of degraded forest land and the allocation of such degraded forest land to farmers has not been completed (Nguyen 2012). A few decades ago in these provinces, there were natural forests with native tree species with the tree height of up to 30 m, belonging to *Dipterocarpaceae*, *Meliaceae*, *Sapindaceae*, *Burseraceae*, *Leguminosae*, *Magnoliaceae*, *Theaceae* and *Fagaceae* families. It is hard to find such native tree species in the areas nowadays.

Reforestation in the study sites

Various tree species have been selected by farmers in the Northern Uplands for reforestation, including both NTS and ETS. It should be noted that many NTS cannot survive if they are not covered by a certain level of shade in their initial life stage. Therefore, if the degraded forests are able to provide such a level of shade, NTS can be planted directly. If not, farmers need to establish the shade first by planting some agricultural crops or fast-

[1] Kinh is the majority ethnic group of Vietnam with about 85 % share of the population (Khong, 1995).

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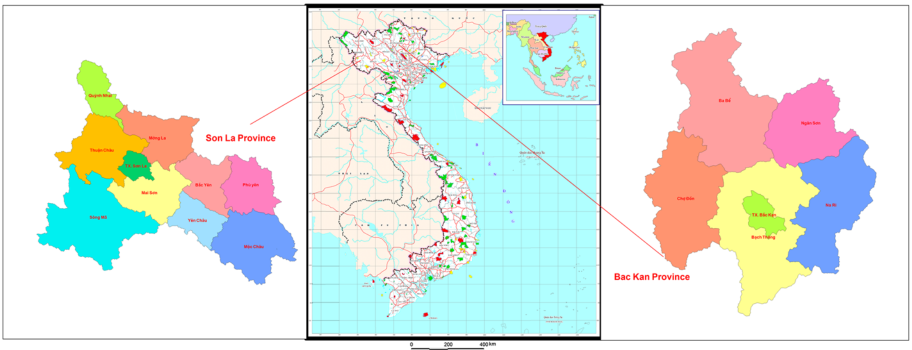

Fig. 3 Location of the study sites: Son La (*left*) and Bac Kan (*right*) provinces in Vietnam (*middle*)

growing tree species. This makes reforestation with NTS more silviculturally complicated for farmers.

In the study sites of Son La and Bac Kan provinces, *Canarium album* and *Acacia mangium* (see Fig. 4) are among the species preferred for reforestation. This is because *C. album* is one of native species that has been familiar to farmers for years. *A. mangium* has been introduced recently and its timber is easy to sell locally as the Bai Bang Paper Mill, one of the biggest paper producing companies in Vietnam, is located in the Northern Uplands. Farmers also prefer monoculture (with a single tree species) due to its ease in silvicultural procedures. For these two species, farmers buy seedlings when planting and sell standing trees when harvesting. In other words, the timber buyers are responsible for harvesting.

For reforestation with *A. mangium*, the seeds were normally imported to make seedlings by the local tree seed companies and then sold to farmers when the seedlings grow to a plantable size of about 25–40 cm height. Even though various efforts have been devoted to establishing *A. mangium* stands for seeds in Vietnam, the growth of trees from domestic seeds is slower compared to those from imported seeds (Vu et al. 2005). The most common planting density is 2,000 seedlings/ha (2 m × 2.5 m). The average survival rate is 80 %. A minimum of weeding once a year during the first 2 years is required. Fertilizer application is not common as most farmers are poor. Thinning is carried out twice during the rotation to achieve a final density of 600–700 tree stems/ha. These stems are clearly felled after 8–9 years to provide about 80–100 m^3 of timber/ha.

For reforestation with *C. album*, this species cannot survive when planted on open and degraded land, needing a certain level of shade in its initial lifetime, normally during the first 3–5 years. Thus, farmers in the study sites first planted *A. mangium* to improve site conditions as the tree canopy of *A. mangium* forms a protective shelter for *C. album*. The procedures are as follows. About 800 seedlings per ha of *A. mangium* are planted; and 2 years later, about 1,000 seedlings of *C. album* (20–25 cm height) are planted. In these first 2 years, weeding is conducted for *A. mangium* once a year. After two more years, all *A. mangium* are removed to leave the living space for *C. album*. Normally, one more time of weeding is required in the next year after planting *C. album*. After 6–8 years, the forest cover of *C. album* can be closed and then two times of thinning are required (year 9 or 10, and year 14 or 15) with the thinning intensity of about 300 stems/ha/time. The final standing stock is normally 300 stems/ha with a final timber volume of about 150–180 m^3/ha (years 27–30) (Vu and Pham 2005). Obviously, reforestation with

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Fig. 4 *C. album* (*higher left* seedling in a nursery, *lower left* fruits) and *A. mangium* (*higher right* a 2-year plantation, *lower right* flowers)

C. album has an initial phase with *A. mangium* which is completely removed when *C. album* does not require any more shade. It would be interesting to continue keeping *A. mangium* and examine the possible effects of this practice in order to identify the optimal level of mixture and optimal rotation age from both ecological and economic points of view (see Nghiem 2014).

Data collection

Our data were collected from 2006 to 2010. The whole data collection procedure can be briefly described as follows. First, from the Provincial People's Committees we obtained the list of all farms who had been granted degraded forest land for reforestation in 2004 and 2005. We randomly selected 200 farm households to investigate their reforestation efforts with *C. album*. Second, we conducted our farm survey in the winter of 2006 to collect data on farm household characteristics that include household income and housing assets, employment status, area of allocated degraded forest land, the status of forest land property

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rights (forest land title), and areas of reforestations. Each farm was given a book with designated tables to record all of their costs and benefits of reforestation and their number of visits to extension services. This book is called "the Farm Forest Management Book". In addition, we established a system of permanent sample plots on their degraded forest land. 10 % of degraded forest land areas were sampled with the area of each sample plot of 500 m^2 (20 m × 25 m). This was done in cooperation with the Forestry University, Vietnam (FUV) in order to study the biological and environmental dynamics of newly reforested stands. Third, the success of reforestation was evaluated in 2010 by forest technicians from FUV, following the indicators issued by the Ministry of Agriculture and Rural Development (MARD 2007). Reforestation with *C. album* was successful if at least 500 trees/ha were alive with a minimum height of 2 m. All Farm Forest Management Books were collected. In the end, we had the following data: (1) farm household characteristics; (2) the level of the participation and success of reforestation with *C. album* (in 2006 and 2010, respectively); (3) all costs and benefits of their reforestation from 2006 to 2010.[2] The government paid via a pilot project of FUV 2 million VND/ha[3] for successful reforestation with *C. album* (Pham and Tran 2011). This subsidy was given only once during the entire forest rotation to support farmers who succeed in reforestation with *C. album*, regardless of the income or forest rotation length.

Data analysis

Reforestation with *C. album* was started in 2006 with the planting of *A. mangium*. Then *C. album* was planted in 2008. *A. mangium* was removed in 2011 and *C. album* is assumed to be harvested in 2035. Obviously, the rotation of *C. album* can also be longer (see Nghiem 2013). Our assumption of a 30 year rotation length in this case is based on the fact that the trees can reach the timber size in local markets when they are about 27–30 years old (Vu and Pham 2005). The competing land use option, in this case reforestation with *A. mangium* only, the rotation is much shorter, *A. mangium* was planted in 2006 and is assumed to be harvested in 2014. From the Farm Forest Management Books, we calculated all the costs and benefits that farmers have had during the period 2006–2010. Regarding the benefits, as our data was not sufficient to reliably estimate the final timber volumes of *A. mangium* and *C. album* at the end of the forest rotations, we took these figures from Vu and Pham (2005) and Vu et al. (2005). For our cost-benefit analysis with *NPV* and *EAA*, We performed sensitivity analyses with different discount rates, labor wages, and timber prices. Even though the average economic growth rate in Vietnam was 7 % over the past few decades, it seems to be decreasing. It was only 6 % in 2011 and 5 % in 2012 (GSO 2013). Thus, we used the real discount rate of 5 %. However, since farmers reported that it was difficult for them to get loans from commercial banks with the interest rate of 5 %. In some cases, the interest rates were much higher than 5 %. In other cases, some farmers were eligible to borrow loans from a government-subsidized bank with the interest rate of 3–5 %. Therefore, real interest rates of 3 and 7 % were also taken into account. Regarding labor wages, it is expected that with the economic growth, opportunities for non-farm income are becoming more available, thereby increasing labor demand. The increase in labor wage has been observed in the study area (Nguyen et al. 2010). Similarly, timber prices are expected to increase. However, it has been observed that timber prices have

[2] Other data on forest dynamics from the measurement of the sample plots are not described herein as this is beyond the scope of this paper.

[3] VND is the currency unit of Vietnam; in 2010 1 US$ equalled 19,500 VND.

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fallen (FAO 2010). Thus, in our analysis, timber prices may remain unchanged, increase by 20 or 50 %, or decrease by 20 %. There is no tax levied on reforestation yet.

In short, we performed the financial analysis with 3 real discount rates (3, 5, and 7 %) and 5 different scenarios:

- BAU (Business As Usual) scenario: labor wage and timber price are unchanged,
- Scenario 1: labor wage increases annually by 5 % and timber price remains unchanged,
- Scenario 2: labor wage increases annually by 5 % and timber price increases by 20 %,
- Scenario 3: labor wage increases annually by 5 % and timber price decreases by 20 %, and
- Scenario 4: labor wage increases annually by 10 % and timber price increases by 50 %.

The decrease of timber price, as in Scenario 3, might force farmers to delay their harvesting. However, timber price is beyond the control of farmers and its variations are very difficult to forecast. Thus, waiting for a better price might be an option, but it is not a very good choice due to following reasons. The forest rotation will be longer and will affect the net revenue that farmers receive. Farmers do not know until when they should wait. The growth of individual trees and the whole stand would be different if the rotation is too prolonged. Finally, farmers often need annual income to survive. They can wait for better timber prices if the credit markets are functioning well and they can borrow money for annual needs. Unfortunately, credit markets for forest production are very limited in tropical countries in general and in Vietnam in particular (Boscolo et al. 2010).

For the evaluation of farm performance in the reforestation with *C. album*, we categorized the inputs during the first years (2006–2010) into three groups: (1) land, (2) family labor, and (3) capital. We chose the successfully reforested area of *C. album* as the output. It was obvious that the soil quality would be different among farms. However, all degraded forest soils were classified in the same soil fertility category by the government (Class 7), making our assumption reasonable. We used data envelopment analysis (DEA, see Nguyen et al. 2012) to calculate the technical efficiency of farmers' reforestation. Thus, our DEA model had one output and three inputs. We used an input-oriented approach with the assumption of constant return to scale (CRS)[4], as it is reasonable to assume that farmers minimize their inputs (initial investment) to reach the same level of outputs (successfully reforested land).

For the determinants of the participation and success of the reforestation with *C. album*, given the censored nature of the dependent variables, econometric models that account for limited distribution dependent variables are necessary. As we would also like to examine the intensity of the participation and success of reforestation, which were represented by the land shares (the share of planted area over granted land area, and the share of successful area over planted area), the shares were not discrete, but continuous, positive and censored at 0 and 100. These characteristics were suitable to apply the Tobit model (Nguyen et al. 2010). The explanatory variables of the Tobit model included those representing the characteristics of farm households, the diffusion of related information, and the status of land property rights that farmers hold over granted forest lands. Thus, we conducted two models. Model 1 was used to identify the determinants of the participation. The dependent variable was the share of the reforested area over the degraded forest land area of the farm (%). Model 2 was used to identify the determinants of the success. The dependent variable was the share of the successfully reforested area over the reforested area (%). The independent variables included: education, age, ethnic group (dummy), and gender (dummy) of

[4] Test statistics $= 0.786 <$ critical values at 5 % LOS $= 3.84$.

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Table 2 Basic characteristics of the interviewed farms (2006)

	Participants (146)	Nonparticipants (48)	All farms (194)
Education of farm heads (year)	6.49 (2.05)	3.21 (2.13)	5.64 (2.49)
Age of farm heads (year)	47.15 (12.40)	41.92 (11.16)	45.85 (12.28)
Share of farm heads of Kinh group (%)	30.82	4.17	24.23
Share of male farm heads (%)	91.10	87.5	90.20
Household size (person)	5.02 (1.47)	4.90 (1.52)	4.99 (1.48)
Household labor	3.17 (1.09)	2.40 (1.13)	2.92 (1.89)
Household asset value (1,000 VND)	14,377 (8,942)	7,047 (5,093)	12,564 (8,744)
Share of non-farm income (%)	26.06 (19.16)	15.78 (14.60)	23.51 (18.28)
Share of permanent non-farm income (%)	11.64	2.08	9.28
Loan (1,000 VND)	835.20 (1,305)	433.32 (889.26)	735.80 (1,226)
Allocated forest land area (ha)	4.38 (1.53)	4.04 (1.69)	4.29 (1.57)
Share of farms with forest land titles	73.28	8.33	57.21
Rehabilitated forest land area (ha)	3.17 (1.30)	0.00	2.39 (1.78)
Successfully rehabilitated forest area[a] (ha)	2.15 (1.43)	0.00	1.62 (1.55)
Number of extension visits	1.34 (1.15)	0.23 (0.43)	1.06 (1.13)

Standard deviations in parentheses

[a] Successfully reforested area of *C. album* and number of extension visits were collected in 2010

the farm heads, labor share of the households (percentage of laborers over household size), household wealth status, non-farm income share (%), permanent non-farm income (dummy), forest land title (dummy), total loan (1,000 VND in 2010 price), and the number of visits to extension services to get consultations on reforestation with NTS. As the household wealth status was difficult to measure, we replaced it with the household asset value (in 1,000 VND in 2010 price). However, some independent variables might be statistically insignificant. Thus, each model was run with two versions. The full version included all the variables described above; and the significant factor version included only the significant variables from the full version.

Findings and discussion

We interviewed 200 farm households. However, after checking the data, we excluded 6 households (3 % of the sample) because they lacked important data. In the end, our data set included 194 farm households, of which 146 households (75 %) conducted reforestation with *C. album* in 2006. We divided our sample into two groups: participants and non-participants (Table 2).

Table 2 shows that the participants had a higher education level and were older than the non-participants, even though in general the education level of farm heads was low. This is understandable because in these mountainous regions, low living standards and limited access to education institutions constrain schooling. In general, primary schools (from grade 1 to grade 5) are, in most cases, available in villages, but secondary or high schools are only available in towns where it takes hours on foot to get there. Most of the farm heads were middle-aged. The share of the Kinh ethnic group was higher in the participating group, but the majority of the interviewed farmers belonged to minority ethnic groups. This

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is because the study sites are home of different minority ethnic groups. Regarding the gender of farm heads, most farms were male-headed. This is generally the case in Vietnam. Only when the male farm heads have either passed away or are away from home due to some reasons (i.e., for off-farm jobs), then the women can take over this role. Farm labor was higher in the participating group. This is reasonable since reforestation is very labor intensive. The participants seem to be better off than the non-participants in terms of the household asset value. On average, a farmer was granted 4.3 ha of degraded lands for reforestation. This figure was not very different between the two groups. In the participating groups, 68 % of the granted land were reforested and the mean success was about 64 %. About 57 % of the farmers already received forest land titles, but this figure was much higher in the participating group. This was also similar in terms of the extension visits. The intensity of the contacts with extension services was 6 times higher in the participating group than in the non participating group.

Costs and benefits of reforestation

Table 3 shows the timeline of reforestation with *C. album* and *A. mangium*. In the case of *A. mangium* 2,000 seedlings were planted with a survival rate of 80 %. Weeding was conducted during the next 2 years. During the third year, the density of the stand was adjusted with the first thinning, which focused more on the removal of disqualified stems (either disease affected or slowly growing trees) and, thus, there was no marketable product. The second thinning was in 2011 and provided 20 m^3 of fuelwood. Final harvesting would be conducted in 2014 with the average timber volume of 90 m^3/ha.

In the case of *C. album*, 800 seedlings of *A. mangium* were planted in 2006 and were removed completely in 2011. 1,000 seedlings of *C. album* were planted in 2008. Weeding was conducted in 2007, 2009, and 2010. The pruning would be conducted in 2012 and 2017 and thinning in 2015 and 2020. The final density of 300 stems would be harvested in 2035, providing an average timber volume of 170 m^3/ha.

All costs and benefits of reforestation recorded in the Farm Management Books during the first years (2006–2010) were analyzed (Table 4). The costs were termed as the initial reforestation costs, which were about 14 million VND. This figure is not considerably

Table 3 Timeline of reforestation with NTS and ETS

Year	ETS (*A. mangium*)	NTS (*A. mangium* and *C. album*)
2006	2,000 seedlings planted; 1,600 survived	800 seedlings planted; 600 survived
2007	1st weeding	1st weeding before raining reason
2008	2nd weeding	1,000 seedlings planted; 800 survived
2009	3rd weeding, 1st thinning, 500 trees cut	2nd weeding
2010		3rd weeding
2011	2nd thinning, 400 trees cut (20 m^3 fuelwood)	600 trees removed (30 m^3 fuelwood)
2012		1st pruning
2014	Harvesting, 700 trees cut (90 m^3 timber)	
2015		1st thinning, 300 trees cut (20 m^3)
2017		2nd pruning
2020		2nd thinning, 300 trees cut (45 m^3 fuelwood)
2035		Harvesting, 300 trees cut (170 m^3 timber)

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Table 4 Average costs and benefits of reforestation in the first 5 years (2006–2010) in 2010 price (1,000 VND/ha)

Category	ETS (*A. mangium*)		NTS (*A. mangium* and *C. album*)	
	Cost	Benefit	Cost	Benefit
Seedlings	1,400	0	3,040	0
Labor	8,420	0	8,210	0
Other costs	4,000	0	3,000	0
Subsidy	0	0	0	2,000
Thinning	0	0	0	0
Total	13,820	0	14,250	2,000

Table 5 NPV of reforestation under different interest rates and scenarios in 2010 price (1,000 VND/ha)

Scenarios	ETS (*A. mangium*)			NTS (*A. mangium* and *C. album*)		
	3 %	5 %	7 %	3 %	5 %	7 %
BAU	47,858	42,639	37,784	91,959	51,252	25,821
Scenario 1	47,078	41,855	36,993	84,736	45,409	21,313
Scenario 2	59,073	52,962	47,292	106,191	58,698	29,604
Scenario 3	35,084	30,749	26,694	63,207	32,120	13,493
Scenario 4	57,962	51,848	46,174	137,219	77,575	49,091

different between the two species. Most of the costs were labor cost (about 60 %), including both family and hired labor. If family labor cost was excluded, the total cost reduced significantly. This is understandable, because farmers wanted to reduce the initial capital investment. They tried to use their own labor. This strategy is common in developing countries due to the imperfect operation of labor and credit markets. The differences between these two approaches in terms of the initial reforestation costs include (1) seedling cost: the seedling price of *C. album* was three times more expensive than that of *A. mangium*, (2) pesticide and insecticide costs were higher in reforestation with *A. mangium.* As an ETS, *A. mangium* is susceptible to a variety of diseases. Damping-off caused by different fungi is one of the most serious diseases. This includes, for example, heart rot (or white rot). This disease invades the trees through branch wounds and makes the affected wood whitish, spongy or fibrous, with dark stains. Heart rot can dramatically decrease timber volume and quality (Sein and Mitlöhner 2011).

Table 5 describes *NPV* under different scenarios, indicating that both reforestation approaches are profitable as the values of NPV are positive. This would be considered an economic incentive for farmers to reforest instead of leaving the land abandoned. This finding is consistent with Nguyen et al. (2010). Due to its higher timber volume per ha and price, NPV is higher for reforestation with *C. album* than with *A. mangium.*

The point to show here is that in all scenarios, the variation of *NPV* is much larger with *C. album* than with *A. mangium*. Farmers performing reforestation with *C. album* face a higher level of income risks due to the changes of labor wages, timber prices, and interest rates. As the farmers are poor, this is even more disadvantageous to them because the rotation of *C. album* is much longer than that of *A. mangium*. Obviously, the longer the

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Table 6 EAA of reforestation under different interest rates and scenarios in 2010 price (1,000 VND/ha/year)

Scenarios	ETS (*A. mangium*)			NTS (*A. mangium* and *C. album*)		
	3 %	5 %	7 %	3 %	5 %	7 %
BAU	6,146	5,998	5,799	4,691	3,334	2,080
Scenario 1	6,046	5,888	5,677	4,323	2,953	1,717
Scenario 2	7,586	7,451	7,258	5,417	3,818	2,385
Scenario 3	4,505	4,326	4,097	3,224	2,089	1,087
Scenario 4	7,444	7,294	7,087	7,000	5,046	3,956

Table 7 Inputs, outputs and technical efficiency of reforestation with *C. album* after 5 years

Variable	Mean	SD	Min.	Max.
Planted land area (ha)	3.17	1.30	1.00	6.5
Family labor (person-day)	444.36	182.29	140	910
Capital (1,000 VND)	14,250	8,596	6,545	22,640
Successfully planted land area (ha)	2.15	1.43	0	6.5
Technical efficiency	0.66	0.32	0	1

duration is, the higher the level of risks that farmers face. This demonstrates that addressing uncertainty is a key requirement to follow the principle of precaution in sustainable forest management (Hildebrandt and Knoke 2009).

Finally, we compared *EAA* between these two reforestation approaches (Table 6). As shown, *EAA* of reforestation with *A. mangium* is higher and more stable. When comparing the two land use alternatives, the reforestation with *C. album* is financially not profitable any more as the opportunity cost is higher than the benefits. Our findings are consistent with those of many other authors. For example, Knoke et al. (2005) show that NTS are often the worse economic performers.

In summary, the analysis in this section shows that reforestation with *C. album* is financially profitable, but less profitable than with *A. mangium*. In addition, reforestation with *C. album* is more risky due to its sensitivity to the changes in input (labor) and output (timber) prices, and forest rotation length. The subsidy of the government for *C. album* is sufficient to cover the difference of the initial reforestation costs between *C. album* and *A. mangium* during the first years, but insufficient to cover the loss of income if farmers adopt *C. album*.

Technical efficiency of reforestation with *C. album*

The technical efficiency of reforestation with *C. album* is reported in Table 7. The different technical efficiency values among farms indicate that the performance of reforestation is different. Among 148 participating farms, 16 farms (10.8 %) were not successful as their successfully reforested areas were zero. 95 % of farmers reported that weeding is essential for the trees to survive. Some farmers did not have sufficient family labor for weeding. They also did not have sufficient income to hire labor. Some other farmers did not know how and which pesticides or insecticides should be used when the trees were disease

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Table 8 Determinants of reforestation with *C. album*

	Determinants of participation		Determinants of success	
	Dependent variable: share of reforested over degraded forest land area (%); nu. of obs. = 194		Dependent variable: Share of successfully reforested over reforested land area (%), nu. of obs. = 146	
	Full model LR $\chi^2(11) = 194.31$ $P > \chi^2 = 0.0000$ Log likelihood = −585.24	Significant factor model LR $\chi^2(9) = 188.57$ $P > \chi^2 = 0.0000$ Log likelihood = −588.11	Full model LR $\chi^2(11) = 90.86$ $P > \chi^2 = 0.0000$ Log likelihood = −480.79	Significant factor model LR $\chi^2(6) = 90.28$ $P > \chi^2 = 0.0000$ Log likelihood = −481.09
Education of farm head (ln)	27.72 (4.90)***	28.15 (5.69)***	14.14 (1.82)*	13.69 (1.95)*
Age of farm head (ln)	22.74 (1.91)*	19.53 (1.65)*	−2.48 (−0.18)	
Ethnic dummy of farm head (1 = Kinh)	14.72 (1.95)*	13.30 (1.76)*	21.29 (2.75)***	20.95 (2.78)***
Gender dummy of farm head (1 = male)	13.83 (1.38)		−1.74 (−0.15)	
Labor share	39.16 (2.93)***	37.79 (2.81)***	25.50 (1.71)*	25.58 (1.80)*
Household asset value (ln)	11.71(2.40)**	11.82(2.46)**	2.14 (0.38)	
Non−farm income share (%)	−32.37 (−1.91)*	−35.74 (−2.09)*	−12.11 (−0.67)	
Dummy if permanent non-farm income (1 = permanent)	19.08 (1.84)*	23.13 (2.27)*	−19.23 (−1.82)*	−19.83 (−2.01)*
Dummy for forest land title (1 = available)	35.93 (5.62)***	33.63 (5.29)***	24.24 (3.25)***	23.96 (3.37)***
Loan (ln)	−1.35 (−1.63)		−0.17 (−0.21)	
Extension visit	8.09 (2.65)**	7.67 (2.48)**	14.38 (4.63)***	14.78 (4.93)***
Constant	−242.00 (−4.64)***	−219.69 (−4.29)***	−16 (−0.28)	−10.74 (−0.73)

t values in parentheses

* $P < 0.1$; ** $P < 0.05$; *** $P < 0.01$

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affected. This indicates the need to provide farmers with more technical information on reforestation with *C. album* and more loans to invest in reforestation. However, 43 farms (29 %) were completely successful as all their reforested areas were evaluated as successful. The rest of the participating farms (89 farms or 60 %) were only partially successful because only a part of their planted area was evaluated as successfully reforested.

This exercise shows that it is still possible to improve the performance of farmers in reforestation with *C. album.* The mean value of the technical efficiency of the participating farms is 0.66, indicating that these farms might be able to reduce about one-third of their inputs while having the same level of successful reforestation. Apparently, reforestation with *C. album* can be more successful if farmers are more technically efficient. The next section on the determinants of successful reforestation with *C. album* might help to answer how to improve the performance of farmers in reforestation with *C. album*.

Determinants of reforestation with *C. album*

Different factors significantly influence the intensity of the participation and success of reforestation with *C. album* (Table 8). The education level and age of farm heads have statistically significant and positive impacts on the participation in reforestation with *C. album*. This is reasonable since the role of education and age (with accumulated experience on NTS) has been widely acknowledged. Labor share is also a significant factor because reforestation is labor intensive. Household asset value significantly affects the participation. This finding is confirmed by the fact that the influence of the loan is statistically insignificant. Non-farm income share has a negative impact on the intensity of the participation. This means that reforestation with *C. album* is less financially attractive to farmers than non-farm opportunities, at least in the sense that non-farm employment provides them with immediate income. Interestingly, if non-farm employment is permanent, it has a positive and statistically significant impact on the participation in reforestation with *C. album*. In other words, non-farm employment has a two-fold influence on the participation: if it is not permanent, its influence is negative; if it is permanent, its influence is positive. The impacts of non-farm income share are, however, statistically insignificant in determining the success of reforestation with *C. album*.

The education level and ethnic group of farm heads, labor share, forest land title and extension visits are the driving factors of the success of reforestation with *C. album*. The household asset value has a statistically significant and positive impact on the intensity of the participation. But its impact on the level of the success is insignificant. This is also similar in case of age of farm heads. Education level and ethnic group of farm heads, labor share, forest land title, and the number of extension visits are the determinants of both participation in and success of reforestation with *C. album*. These findings show the scope for the improvement in terms of successful reforestation with *C. album*. Obviously, promoting education, speeding up forest land titling procedure, and facilitating the supply of forest extension services should be considered to support participating farmers in reforestation with *C. album*.

Conclusions and policy implications

Farmers have contributed to the recovery of forest resources in Vietnam, and thus developing a more comprehensive understanding of the range of underlying factors that can help to promote reforestation is needed. Our study used different economic tools to investigate reforestation with a NTS (*C. album*) by farmers in Vietnam from an economic

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perspective. We compared the financial return of reforestation with *C. album* and with an ETS (*A. mangium*) using NPV and EAA. We then examined the comparative performance of farms in reforestation with *C. album* using DEA. Finally, we investigated the determinants of the participation and success of reforestation with *C. album* using Tobit econometric models. Our empirical study yielded several important findings as follows.

First, reforestation with *C. album* is less financially sound than that with *A. mangium*. The subsidy given by the government is not sufficient to compensate for the income loss of farmers in choosing reforestation with *C. album*. The participating farmers follow minimal capital and labor-intensive strategies in reforestation with *C. album*. However, they face a high level of income risks. Second, the performance of reforestation with *C. album* is different among participating farmers; and there is scope for the improvement of the performance, which would result in more successful reforestation. Third, aside from the financial return, the decision and intensity to participate in reforestation with *C. album* depend on the family labor, wealth status, characteristics of farm heads, security of forest land property, and diffusion of forest-related information. These two last factors and the education as well as ethnics of farm heads significantly influence the success of reforestation with *C. album*.

Our findings pose several important policy implications. First, the subsidy given by the government should be increased to provide a sufficient economic incentive to non-participating farmers for reforestation with *C. album*. Second, without major policy interventions, participating farmers could still improve their reforestation with *C. album* by being more technically efficient. This can be done by increasing extension services so that farmers may be able to deal with, for example, tree diseases. Additional policy improvements should take advantages of the proven value of extension programs and their ability to deliver information to farmers. Third, the forest land titling program should be sped up in order to provide farmers with long-term security over their reforestation efforts. Enhancing land and tree tenure would make reforestation with *C. album* more viable over the long-run. Finally, education could serve as a driver of reforestation and should be promoted in the study area.

Our study can be extended in several ways. First, our analysis includes only one NTS (*C. album*) and one ETS (*A. mangium*), whereas many tree species are used for reforestation in Vietnam. Thus, the analysis should be extended to include more species so that the generalization of the findings is more convincing. Second, not only timber but also other environmental goods and services provided by successful reforestation with NTS should be taken into account in the cost and benefit analysis in order to provide a more reliable estimate of the benefits to the society. The efficiency analysis could likewise be extended to take into account the environmental values that reforestation with NTS has brought. Obviously, increasing the scale of this analysis to include other provinces or to the whole country scale would be desirable.

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