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Economic evaluation of proposed pure and mixed stands in Central Vietnam highlands

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Abstract

In comparison with mixed forest stands, the cultivation of pure plantations in Vietnam entails serious ecological consequences such as loss of biodiversity and higher rate of soil erosion. The economic evaluation is elaborated between pure plantations and mixed forests where the fast-growing tree species are mixed with slow growing tree species which are planted in stripes separating the segments with fast-growing tree species (*Acacia* sp.). For the evaluation, the input values were used from local costs of goods, services and labour. The results show that the internal rate of return is the highest in the case of pure plantation in comparison with mixed forests – 86 % to 77 % (first planting pattern: *Acacia* sp. + noble hardwood species) and 54 % (second planting pattern: *Acacia* + *Dipterocarpus* sp. + *Sindora* sp.). The average profit per hectare and year is almost five times higher in the case of mixed stands. The first planting pattern reaches 2,650 $, the second planting pattern 2,280 $ and the pure acacia plantation only 460 $. From an economic point of view, the cultivation of mixed forests that corresponds to the principles of sustainable forestry generates a good economical profit while maintaining habitat complexity and biodiversity.

Keywords: Economic evaluation, plantations, Central Vietnam, mixed stands, average profit, net present value

Abbreviations

Lao PDR	–	Lao People Democratic Republic
CBFM	–	Community Based Forest Management
FLR	–	Forest Landscape Restoration
IUCN	–	International Union for Conservation of Nature
WWF	–	World Wildlife Fund
USD	–	United States dollar
NPV	–	Net Present Value
IRR	–	Internal Rate of Return

1 Introduction

Vietnam as well as other states in Southeast Asia faces serious problems in forestry and environment (Xu *et al.*, 2006). It is estimated that there are currently more than 23 million ha of bare land that was previously forested in the four countries Cambodia, Lao PDR, Thailand and Vietnam. Much of this bare land would be suitable for rehabilitation (Gilmour *et al.*, 2000). However, the rehabilitation is oriented towards an establishment of large plantations of fast-growing tree species, mainly from genus *Acacia* and their hybrids (*Acacia mangium*, *Acacia auriculiformis*). The new plantations are established according to the new forest policy expressed in the five million hectare afforestation program adopted in the 1998 (Whiteman, 2004; Tran, 2006). This program targets the protection of the environment and focuses on the increase of living standards of local people (Ducourtieux & Castella, 2006; Tran, 2006). According to Xu *et al.* (2006) an initial decline in forest cover due to deforestation is later reduced, offset and eventually outweighed at some point by forest recovery and secondary forest expansion. However, the deforested areas which are now in the process of secondary

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forest expansion are object of planting pure plantations accompanied with repeated burning which reduces biodiversity and causes soil degradation.

The afforestation program is also linked with new phenomena on Vietnam, reallocation of forest land to farmers and establishment of household forestry (Sikor, 1998). Decentralization is not based on community-based forest management (CBFM) even though the decision of individuals to manage their forest is very similar; it is derived from their economic calculation of the costs and benefits (Tole, 2010).

At first view it is promising, new plantations ensure the growing demands for timber and seem to mitigate the pressure to native forests (Hieu, 2004). However, as it is the native forests that were converted to the plantations at the first place, the overall results of this process include negative consequences mentioned above. The common practice of slash-and-burn is used especially in forest land newly allocated to local farmers and leads to the loss of top soil (Poffenberger, 2006). Moreover, there are number of reasons for forest losses including logging, harvesting of forest products and industrial agriculture (Nguyen & Gilmour, 2000). McElwee (2009) mentioned that the reforestation based on planting exotic fast growing tree species such as acacia and eucalyptus on "bare hills", which are covered the initial stages within natural forest succession, includes limited access to land where economically important non-timber forest products are collected. Her study is focused northern of our area but with the similar natural conditions and she could show that the diversification of products connected with the level of biodiversity is higher on bare hills than in plantations of exotic fast growing tree species.

The same forest practices have been carried out in the area in Central Vietnam where the Czech Republic financed the project Rehabilitation and Sustainable Development of Forests in Phong My Commune. A part of the project was a forest management plan focussing on the conversion from monocultures to mixed forests. As the conversion cannot be made immediately because local forest economy is based on plantation production, the plan proposes new patterns for the reforestation on bare land or for the conversion into a mixed forest stand with fast-growing and slow-growing tree species. This strategy corresponds with principles of the Forest Landscape Restoration (FLR) promoted by IUCN and WWF to meet the challenge to restore the provision of goods and services in modified and degraded forest landscapes by explicitly integrating the concept of human well-being, mainly through improving the quality of existing forests (Ianni & Geneletti, 2010).

Nevertheless, economic evaluations about the benefits that new stands will generate and how the investments will return are needed. In addition, this evaluation could help to convince local farmers and foresters that the proposed planting patterns in this study contribute significantly to the sustainability of natural sources.

2 Materials and method

2.1 *Study area*

The area of community Phong My where the proposed patterns are planned is located approximately 40 km west from regional capital Hue and beyond the border between coastal lowland and mountain ridges in the watershed of rivers Sông Ó Lâu and Rao Cáo and their tributaries (Figure 1). Mountain ridges are oriented from northwest to southeast and separated by the deep valleys with streams and rivers.

The average annual amount of precipitation is 2,868 mm with the maximum of rainy days in October, November and December. The average monthly temperature is 25,1 °C. Because of meteorological station absence in the locality the data were taken from the nearest meteorological station in Hue city.

The complete project area including agricultural land encompasses 10,491.1 ha from which forests are on 7,840.6 ha (74.7 % of total area). Forests in the area are divided into forest types according to the forest cover. The types described as bare lands are lands covered by grass and shrubs (forest type IB) or shrubs and scattered trees (forest type IC).

The two forest types represented 21.8 % (2,285.3 ha) from the total area. A part of bare land is allocated for afforestation in the next decade (460.5 ha) and various afforestation patterns were proposed within the new forest management plan.

2.2 *Planting patterns*

For the evaluation three patterns were selected. The first two planting patterns (Figure 2, 3) are acacia plantations with stripes of slow-growing tree species bringing valuable timber especially for veneer and furniture (noble hardwood). The third planting pattern constitutes an acacia monoculture (planting distance of 2×3 m). The selection of slow-growing tree species corresponds to the local natural conditions and tree species composition of former indigenous forests and was carried out in accordance with conversational results that were obtained by discussions with local farmers and foresters. For the first planting pattern noble hardwood species,

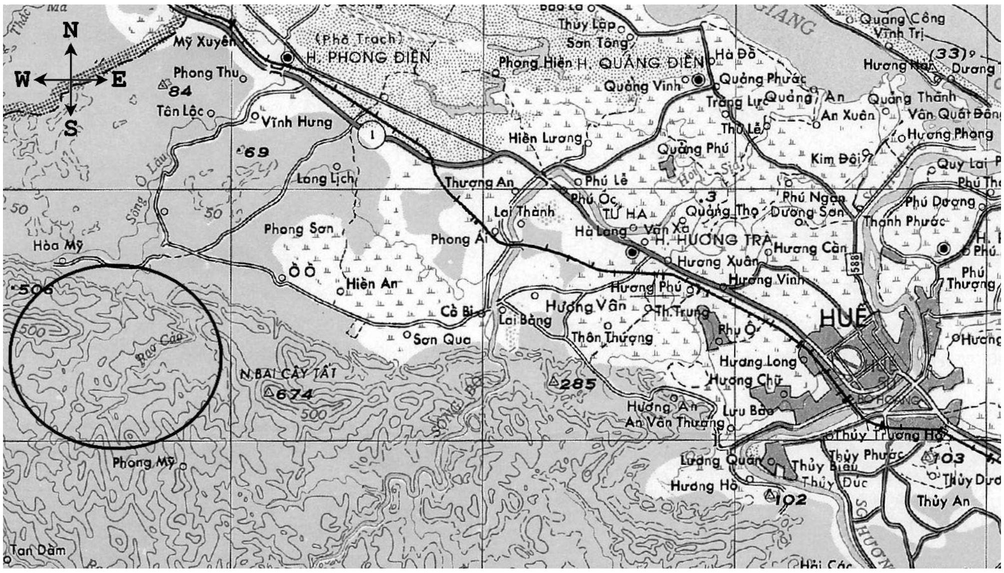

Fig. 1: *Information map of the study area (black circle), based on the state map HUE NE-48-16, 1:250000.*

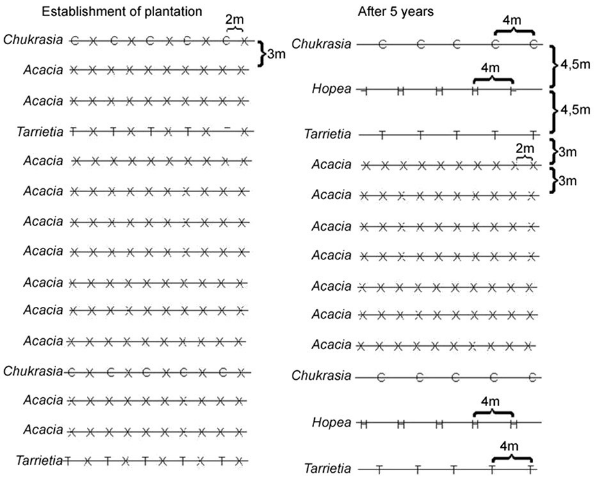

Fig. 2: *First planting pattern of reforestation mixing Acacia with noble hardwoods Chukrasia tabularis, Tarrietia javanica and Hopea odorata (Source: Šálek & Výlupek, 2012).*

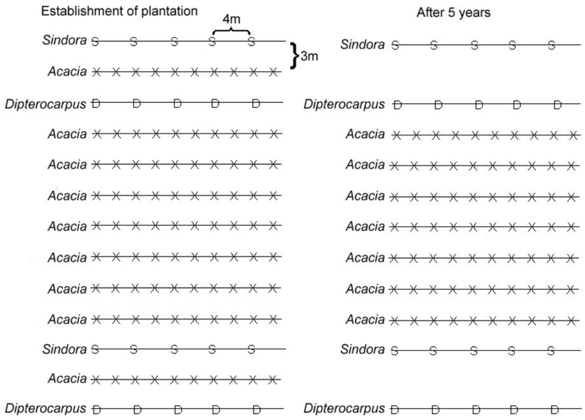

Fig. 3: *Second planting pattern of reforestation mixing Acacia with noble hardwoods Sindora tonkinensis and Dipterocarpus alatus (Source: Šálek & Výlupek, 2012).*

namely *Chukrasia tabularis*, *Tarrietia javanica* and *Hopea odorata* were choosen. For the second planting pattern *Dipterocarpus alatus* and *Sindora tonkinensis* were selected.

During the first five-year cycle the noble hardwood tree species will grow conjointly with Acacia and thereafter separately while forming the stripes among acacia sections. Thus Acacia will serve as nurse tree. Studies could show that Acacia is initially needed to facilitate the establishment of several native species, while growth is inhibited when the Acacia overstorey lasted beyond seven years (ACIAR, 2006). Norisada *et al.* (2005) found that three dipterocarp species that were planted simultaneously with *Acacia mangium* showed a better growth than when planted without *A. mangium*.

The number of seedlings was calculated according to these planting patterns and distances among rows and individual plants. The acacia segments are repeatedly regenerated with rotation cycle of five years while the noble hardwoods have a rotation cycle of 40 years. Therefore the existing income coming from plantations would be only slightly reduced and new mixed stands will constantly fulfil production function during the whole rotation cycle of slow-growing tree species.

2.3 Calculations

According to the proposed planting patterns the number of seedlings per hectare was calculated as well as changes in number of trees during the development of stands to the rotation cycle of noble hardwood (40 years). For calculations the area of one hectare for each planting pattern including the Acacia monoculture was chosen. To obtain the equalized harvest per year the area was divided into five parts and initial afforestation was divided into five years as well. The number of plants (Table 1) and the amount of presumed yield will be calculated per hectare as well as the need of services and labour for planting, timber transport and prices per 1 m^3.

Table 1: *Proposed tree species for individual planting patterns and number of seedlings.*

Planting pattern	*Tree species*	*Plants per hectare*
Mixed 1	*Acacia* sp.	1,515
Mixed 1	*Chukrasia* sp.	76
Mixed 1	*Tarrietia* sp.	76
Mixed 1	*Hopea* sp.	75 *
Mixed 2	*Acacia* sp.	1,333
Mixed 2	*Sindora* sp.	83
Mixed 2	*Dipterocarpus* sp.	83
Monoculture	*Acacia* sp.	1,667

* (after 5 years since 1st afforestation)

In the first planting pattern the third noble hardwood species (*Hopea odorata*) is added after the first five-year rotation cycle of *Acacia* segments (Figure 2). The number of these plants is involved to the calculation of expenses as well.

For the calculation of cost and benefits the average local prices of goods, services and labour were used as well as the local productivity for forest activities (planting, harvesting and transport).

Calculations were made using the USD as the currency for comparison. The exchange rate between Vietnamese dongs and USD was used as the average from February 2010 (1 USD = 18000 VND). The input data that were used for model comparison were collected during the project phase in the area of Phong My community (Table 2). The used prices are based upon price information gathered from local foresters, nursery owners and farmers possessing forest stands. While the prices of plants are the average from offers of local nurseries in the year 2008, the prices of Acacia timber are the average from years 2007–2008. The prices of noble hardwood round wood are based upon price information from local foresters from the branch office of the Forest Inventory and Planning Institute located in Hue city. The transport distance is the distance between forests in Phong My (centre of the wooded area) and Hue where the processing companies (sawmills) and the harbour are located.

Table 2: *Input economic data that were used for model comparison.*

Variable	*Price*
Plant price (in $ /plant):	
Acacia mangium *	0.056
Chukrasia tabularis	0.167
Tarrietia javanica	0.167
Hopea odorata	0.167
Sindora tonkinensis	1.111
Dipterocarpus alatus	0.833
Timber (in $/$m^3$):	
Acacia	40
Noble hardwood	240
Services:	
Transport distance	50 km
Transport 10 m^3 *Acacia*	42 $
Transport 10 m^3 noble hardwood	70 $
Labour cost planting	0.0158 $/plant
Cutting-dragging cost *Acacia* †	2.4 $/$m^3$
Cutting-dragging cost noble hardwood ‡	0.9 $/$m^3$

* Cuts – vegetative propagation,
† Manual cutting – dragging,
‡ Chain saw cutting, tractor dragging

The condition for benefit calculation is that the price of Acacia timber in the future will be on the same level of 40 $/$m^3$, including transport cost to a processing factory. Regarding the enlargement of a plantation of fast-growing tree species it is supposed that the price will remain on the same level or, in the case that the supply is higher than demand, the prices could be lower within a long-time horizon of prices development. The growth of noble hardwood prices is not calculated in the comparison because of the uncertainty of future price development. The price of noble hardwood roundwood (240 $/$m^3$) enters to income calculation. However, the rough timber from fallen trees does not include only roundwood but also firewood which price is not taken into account. Thus the production of noble hardwood rough timber is reduced by the ratio of 0.75 within the calculations.

The forest production is calculated according to the local Acacia production (80 m^3/ha per five years) and noble hardwood (500 m^3/ha per 40 years). These estimates of the production were obtained from farmers and local foresters during preparation of the forest management plan.

The calculation of investment effectiveness is about 5 % and is based on the discount rate in Vietnam of 2009. The expenses of the purchase of land or of land rent are not calculated because farmers obtained the land from the state. The proposed cycle of the project is 45 years. This age is derived from the rotation cycle of noble hardwood and from the principle of equability when the plots are divided into five segments and gradually regenerated within *Acacia* parts.

Although the mixed forests consist of the tree species with various rotation period and different growth rates, they do not influence costs of utilization because the both parts (*Acacia* and noble hardwood species) are on the same plots (stands) that will be visited once in every five-year period. It means that even in mixed forest the *Acacia* part will be harvested once in the mentioned period.

The net present value (NPV) and the internal rate of return (IRR) are calculated according to Pulkrab *et al.* (2008):

$$NPV = \sum_{t=0}^{n} \frac{V_t}{(1+k)^t} - \sum_{t=0}^{n} \frac{N_t}{(1+k)^t} \quad (1)$$

$$\sum_{t=0}^{n} \frac{V_t}{(1+IRR)^t} = \sum_{t=0}^{n} \frac{N_t}{(1+IRR)^t} \quad (2)$$

where V_t is expected returns, N_t is expected expenses, t is period from 1 to n years, n is expected time of cycle and k is discount rate.

3 Results

Calculating the costs of plants, costs of labour for reforestation (planting) and number of plants from the input economic data the first planting pattern shows that total number of seedlings per one hectare during 39 years (40-year rotation period for noble hardwood) is 9,170 seedlings while the number of seedlings for the second planting pattern is 9,625 and for the *Acacia* monoculture 13,360. The total cost of planting expenses is 680.35 $ for the first planting pattern, 842.53 $ for the second planting pattern and 953.17 $ for the *Acacia* monoculture.

Results from calculation of timber production, incomes from timber sale and costs for harvest and repeated reforestation in the *Acacia* segments show that for the first planting pattern the total timber production of the *Acacia* segments during 40 years is 422.7 m^3 and for noble hardwood 600 m^3, the total costs are 8,210.17 $ and the total yield value derived from timber production is 20,241.39 $ (see also supplementary information, examples for calculation Table *S1* and Table *S2* [1]). The values for the second planting pattern are an *Acacia* timber production of 456 m^3, noble hardwood timber production of 500 m^3, total costs of 7,802.13 $ and a total yield of 18,175.48 $. The values for the *Acacia* monoculture are a timber production of 640 m^3, total costs of 5,177.17 $ and a total yield of 13,143.79 $.

While for the *Acacia* monoculture the net present value (NPV) is $7,115, the NPV for the first and second planting patterns is $18,252 and $16,122. The internal rate of return (IRR) for the *Acacia* monoculture is the highest with 86.3 % and the IRR for the first and second planting pattern is 77.7 % and 54.1 % (Table 3).

Table 3: *Comparison of economic evaluation of the planting patterns.*

Comparison of planting patterns	1st *Pattern*	2nd *Pattern*	*Acacia*
NPV (5 % disc. rate)	$18,252	$16,122	$7,115
IRR	77.7 %	54.1 %	86.3 %
Time of payment	5 years	5 years	5 years
Total profit per ha and per project time	$116,698	$100,438	$20,423
Average annual profit per ha	$2,652	$2,283	$464

Concerning possible changes of economic conditions in the future, sensitivity analyses were carried out. They give an overview of the reaction of the NPVs on changes in the input variables.

Changes in discount rates show that NPVs for all planting patterns are practically the same beyond the discount rate of 12 % (Figure 4). The NPV for the first planting pattern at the discount rate of 13 % is 2,324 $, for the second planting pattern 2,096 $ and for the *Acacia* monoculture 2,297 $.

If the inflation of 3 % is added to the changes in discount rate, the results show that the NPVs at the discount rate of 5 % are 15,810 $ for the first planting pattern, 13,836 $ for the second planting pattern and 5,661 $ for the *Acacia* monoculture (Figure 5). The NPVs on the discount rate 10 % are 3,760 $ for the first planting pattern, 3,356 $ for the second planting pattern and 2,819 $ for the *Acacia* monoculture. The NPV for the first planting pattern on the discount rate of 13 % is 2,051 $, for the second planting pattern 1,819 $ and for the *Acacia* monoculture 2,002 $.

[1]available online at: http://jarts.info/public/journals/1/documents/339/339-SP1.pdf

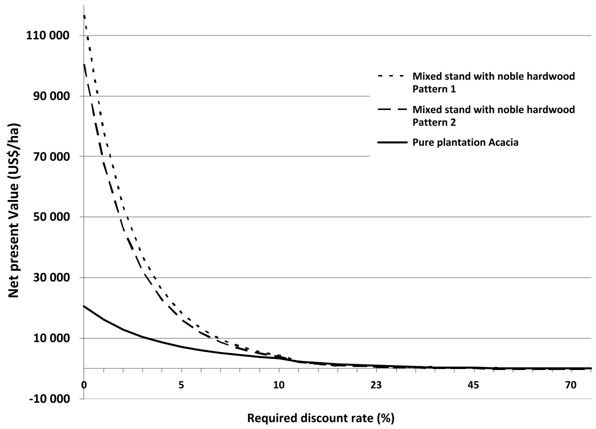

Fig. 4: *Net present values within changes of discount rates of the three different planting patterns.*

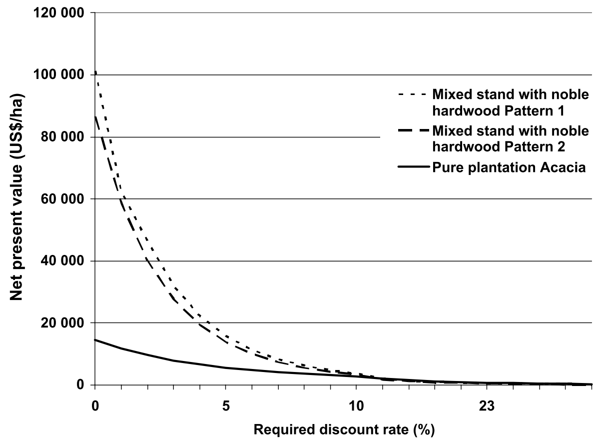

Fig. 5: *Net present values within changes of discount rates and an inflation rate of 3 % of the three planting patterns.*

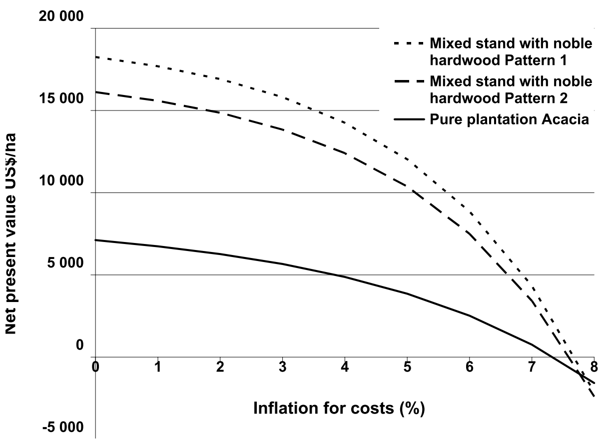

Fig. 6: *Net present values within changes of inflation for costs and fixed discount rate of 5 % of all three planting patterns.*

One of the most pessimistic options would be the stagnation of timber prices in the future and an increase in costs. The increase in costs can be expressed by the inflation rate for costs. If the discount rate is the same (5 %) and the inflation rate for costs varies from 0 % to 9 % the result displays that the crucial inflation rate for costs is 7 % because above this rate the NPVs for all planting patterns reach negative values (Figure 6).

Future noble hardwood timber production may not be clearly predictable within long rotation cycle. Therefore in case of reduced noble hardwood production the changes in NPVs were calculated (Table 4). On the discount rate of 5 % the NPV for the first planting pattern is $14,919 (-25 %) and $11,585 (-50 %). The NPV for the second planting pattern is $13,344(-25 %) and $10,565 (-50 %). In comparison with the NPVs for the *Acacia* monoculture the discount rate of 7 % is decisive because when comparing the NPVs of the first planting pattern with those of the *Acacia* monoculture the differences are +14.9 % (-25 % expected yield) and -7 % (-50 % expected yield). A comparison of the NPVs of the second planting pattern with the NPVs of the *Acacia* monoculture revealed differences of +3.4 % (-25 % expected yield) and -14.3 % (-50 % expected yield).

Table 4: *Net present values for the first and second planting pattern with changes of expected noble hardwood yield.*

Discount rate %	*100 % yield*	*75 % yield*	*50 % yield*
	$NPV_{pattern\ 1}$ ($)		
0	116,698	90,883	65,068
1	78,666	61,668	44,669
2	53,575	42,333	31,092
3	36,911	29,445	21,979
4	25,765	20,783	15,807
5	18,252	14,919	11,585
6	13,146	10,905	8,664
7	9,644	8,131	6,618
8	7,216	6,191	5,166
9	5,514	4,817	4,120
10	4,305	3,829	3,354
	$NPV_{pattern\ 2}$ ($)		
0	100,438	78,925	57,413
1	67,990	53,824	39,658
2	46,324	37,156	27,787
3	32,222	26,001	19,779
4	22,621	18,474	14,323
5	16,122	13,344	10,565
6	11,682	9,815	7,947
7	8,620	7,356	6,098
8	6,483	5,629	4,775
9	4,974	4,394	3,812
10	3,894	3,498	3,102

4 Discussion

This study presented an economic evaluation of forests on degraded soils in the highland areas of Vietnam. Other alternatives of land use such as agriculture or agroforestry were not taken into consideration because the project was aimed to implementation of sustainable forestry. It is desirable that the land in this area is planted with forests primarily for erosion control of the skeletal soils, despite the fact that potential revenue generated from the forests is likely to be low relative to agricultural crops (Hieu, 2004).

For planting mixed forests certain trials were established mixing *Acacia* and *Eucalyptus* (Laclau *et al.*, 2008). However, these trials do not solve the establishment of mixed forests where native tree species play an important role. Mixing the slow-growing tree species (noble hardwood) and fast-growing tree species is described by Wachrinrat *et al.* (2005). Nevertheless they used only two tree species (*Acacia mangium* and *Dipterocarpus alatus*) mixed in the beginning in the proportion 1:1 and after five years only *Dipterocarpus remains* on the plot. In contrast, the proposed planting patterns solve the situations with repetitive *Acacia* production. The proposals in the study come also from the assumption that noble hardwood is generally able to grow better under a canopy or within a forest mixture with fast growing tree species than in open areas (Kamo & Jamalung, 2003). Therefore it can be expected that the mixed forests with *Acacia* and noble hardwood contribute to the better growth of the noble hardwood.

Other trials with mixed stands where *Acacia* is present were carried out in Indonesia on degraded land cover by the invasive grass *Imperata cylindrica*. Otsamo (1998) confirms that some dipterocarps (*Anisoptera marginata*) grow better in a mixture stand with *Acacia* even if they are planted as understory tree under the one or two-year old *Acacia* stands. According to his experience the forest management is oriented not only to the production but also to the biodiversity maintenance. It must be stressed that the careful planning, planting and harvesting are the necessary conditions to obtain the correct results.

Ianni & Geneletti (2010) described a situation with different socio-economic and natural conditions in South America, where farmers are presently influenced by timber industry and forestry consultants who supported forest plantations of exotic species that grow faster than native species.

The production figures obtained from farmers and local foresters correspond with the figures from Adjers *et al.* (1995) who could show that the dipterocarps exhibited an annual volume increment between 8–17 m^3 per ha and per year. Sist *et al.* (2003) also asserted that dipterocarps growed in a mixed dipterocarp forest can achieve a diameter at breast height (d.b.h.) of about 60 cm in 30 years.

The values of IRR in this study are different to calculated values of other studies. Griess & Knoke (2011) displayed that within a 25-year rotation cycle for the tree species *Tectona grandis*, *Hieronyma alchorneoides*, *Swietenia macrophylla* and *Terminalia amazonia*, the IRR varies from 10 to 15 %. McNamara *et al.* (2006) calculated an IRR of 19 % for *Acacia* nurse crop with an age of 17 years. The IRR in our study is significantly higher, mainly for two reasons. Firstly, repeated five-year productions of *Acacia* segments are figured in the income during the whole rotation cycle of noble hardwood. Secondly, forest land prices did not enter into the calculations because farmers had obtained the forest land free of charge from the state. Furthermore, the costs of afforestation are low and during the forest development no pruning and thinning is planned for the *Acacia* segments as well as for the noble hardwood segments. For those reasons comparison of the results of the study with results of other studies can lead to misinterpretation. Including the price of forest land in the calculation would have likely lowered IRR significantly and made it more readily comparable to other studies.

The time of payment (time of return), namely five years, is equal for all calculated models. If the discount rate of 5 % (Vietnam, 2009) is calculated, results indicate that both mixed planting patterns bring a better NPV than pure *Acacia* plantations. Even the IRR is highest within the pure *Acacia* plantation wherefore differences between *Acacia* plantation and both planting patterns of mixed stands are not crucial (4.6 % and 32.2 %).

The economic evaluation based on presumed harvest and market situation in the future (costs and benefits within 40-year prospect) seems to be speculative. Griess & Knoke (2011) solved a similar problem using the sensitive analyses which investigate the reaction of NPVs on changes in the input variables. They compared four species of noble hardwood growing in Panama including teak (*Tectona grandis*). We carried out similar sensitivity analyses to assess the effect of variability in the factors that are likely to change during the plantation rotation cycle (40 years). Sensitivity analyses assessed changes in discount rate (at inflation rate 3 %), changes in inflation (at discount rate 5 %) and change of the noble hardwoods production (production loss of 25 % and 50 %).

In case the presumed production is reduced the discount rate higher than 7 % discriminates the mixed stands in favour of the *Acacia* monoculture.

In our study the price of noble hardwood timber is supposed to be consistent for the whole rotation cycle of 40 years, which can appear doubtfully. However, relation between supply and demand leads to the supposition that the prices of this species will grow in the future because the stock volume of noble hardwoods in tropical countries is limited, even now noble hardwood is extremely searched and exploited (FAO, 2001). In case of higher prices the mixed stands would be more profitable.

Therefore the implementation of sustainable forestry based on mixed stands in Vietnam should be requested not only from ecological but also from economical point of view. From farmers' point of view there is a struggle between two expectations, higher benefit per annum (higher IRR) or higher benefit in total (higher NPV). Incorporating inflation only in costs and decline in hardwood production over 50 % are the highest risk factors affecting the expected economic profit.

The proposed mixed patterns reconcile this conflict by not excluding the Acacia from the plantation and thus only slightly reducing the annual income in order to increase the total future income. This fact played a very important role in convincing farmer in the area to adopt these models.

One model of mixed forests was used for reforestation on a demonstration plot and neighbouring farmers who were not involved to the project had spent their own money buying more expensive noble hardwood seedlings and planted them in stripes among *Acacia* plantations according to the planting pattern on the demonstration plot. Adjers *et al.* (1995) also claim that planting of dipterocarp is much profitable than the commonly applied practice to convert low-volume forests into plantations of fast-growing exotic tree species.

Furthermore, the short-rotation plantations also exhibit the lowest levels of biodiversity (McNamara *et al.*, 2006). Introduction on segments of species with longer rotation into the mixed stands can contribute to dispersal and survival of organisms linked with the native forest ecosystems. Such a trend was described by McElwee (2009) in a neighbouring province.

Economic evaluation is one of the most important parts of forest planning for considering which type of forest will be proposed and which pattern of reforestation will be used. Solving the time factor when the more valuable tree species (noble hardwood) need a longer rotation period the mixed forests show the way for forming sustainable forestry without damage to the local economy based on plantation production. Our economic evaluation approved that in comparison to a pure Acacia plantation, mixed forest cultivations can lead to a higher total income for farmers and will maintain the pure segments of Acacia as a repeated intercrop. Further, due to mixed forest cultivation environmental risks such as erosion, loss of soil fertility and loss of biodiversity can be minimised. Besides, the production potential of tropical forests which is significantly higher than in a temperate zone should be utilized more effectively.

Basically, there are various capabilities for forming mixed forests. In our study, only two models corresponding to the natural and socio-economic situation in Vietnam were chosen.

This economic evaluation with clearly calculated effectiveness of each model could persuade farmers that plans combining short-rotated plantations with slow-growing valuable native tree species can be economically superior to establishment of pure-species plantations accompanied by the practice of slash-and-burn.

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