Can native tree species plantations in Panama compete with Teak plantations? An economic estimation.

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Abstract: Panama has the highest rate of change in the area of primary forests within Central America. However, to meet growing timber demands, it became popular over the last decades to establish plantations made up of foreign species such as *Tectona grandis* or *Pinus* spp. In the majority of the cases the species used are well known; their characteristics such as growth performance have been reviewed intensively and can be accessed in numerous publications. Characteristics of Panama's native tree species of commercial relevance such as *Hieronyma alchorneoides*, *Swietenia macrophylla* and *Terminalia amazonia* are largely unknown and have been investigated within the study at hand. Using valuation methods of financial mathematics, the competitive position of these three indigenous species was assessed, the results compared to those of *T. grandis* stands in the same area. Land costs and taxes were not considered, as they would be the same for all species. Financial estimates for indigenous species will enlarge their acceptance for use in reforestation and plantation projects.

Using the NPV method and applying the standard scenario, the profitability of *T. grandis* is lower than that of *T. amazonia* and *S. macrophylla* and lies only slightly above the profitability calculated for *H. alchorneoides*. This result clearly indicates that the investigated native tree species are comparable with *T. grandis* regarding their economic profitability. Besides its ecological impact, growing native tree species is now also economically legitimate. By calculating land expectation values for all tree species, ideal rotation lengths could be determined. For these species, considerable flexibility exists regarding the optimal rotation length.

Keywords: reforestation; financial analysis; land expectation value; net present value; growth; yield; profitability

1 Introduction

In the countries of Central America, traditional culling of tropical timber from primary forests is expected to come to a standstill within the next years, due to the depletion of remaining stands (Solorzano-Soto 1995). Especially in Latin America and the Caribbean, featuring high population densities, the timber trade forms an important economic factor and an important source of income for the rural population, just as it is in temperate regions. Growing difficulties of timber supply as well as increasing demand for land have led lead to rapid deforestation in these countries, according to FAO (2005).

As the country with the highest rates of change within its existing primary forest the study at hand subjects Panama to an exemplary closer inspection:

In Panama there are 1.2 M. ha of land suitable and available for plantation establishment (Boyd 1998). Because of ongoing deforestation, this area is expected to increase. In 1990, Panama, with a total land surface of 7.5 M. ha., still had 3.7 M. ha of primary forests. In 2005, only 3.0 M. ha were left. According to the FAO (2005) the annual deforestation rate is 1.23%. Accordingly, Panama’s primary forests are heavily declining. To protect the remaining tropical primary forests, mainly two alternatives are discussed:

1) Establish of plantation forests (Günter et al. 2008; Cubbage et al. 2007; Pandey and Ball 1998; Lamprecht 1989),
2) Sustainably manage remaining natural forests (Günter et al. 2008; Cubbage et al. 2007; Finegan 1992; Quesada 1990).

The driving force for all activities in forest management, environmental protection and investment is cost effectiveness. Comparing the management of natural forests with plantations financially, plantations often seem to be the better option. Natural forests tend to show a lower productivity, which leads to a lower cost-effectiveness, while plantations tend to show a higher cost effectiveness (Cubbage et al. 2007). The establishment of a plantation however, also requires substantial initial investment. Alternative financing models can be a solution. Investment opportunities that offer competitive rates of return while also showing low risks are in demand. With growing environmental awareness, considerations of long term stability and real investment versus pure monetary values come to the forefront more and more. Many large-scale investors already are aware of this situation. The UBS AG (Union Bank of Switzerland), the world's largest asset manager, also is one of the largest forest owners worldwide (Kollmansberger 2006). In spite of growing interest in non market values, so called Ecosystem Services, the return of investment still ranks first for investors. Estimates of rates of return are often based on optimistic assumptions to spark interest in forest plantations as an investment opportunity. Furthermore, in the majority of cases, operations are limited to monocultures of exotic species. Often, even for timber of indigenous tree species with a market, no published financial optimization in terms of forest management exist (Nichols et al. 2006).

In Panama, *Tectona grandis* is frequently planted (Simmons et al. 2002). The following hypothesis is therefore to be tested with a particular focus on this tree species for Panama:

H_1: *The profitability of Teak plantations cannot be equalled by planting native tree species.*

Indigenous tree species have some advantages compared to fast-growing exotic species. Native species are adapted to the site conditions and are therefore also more tolerant towards natural risks, while achieving comparable growth rates (Piotto et al. 2004a). Many native species can be grown on a broader scale of sites than exotic species. All these features may lead to a competitive edge for the less well known native species over the exotic *Tectona grandis*. But there are also risks in growing native species. Besides testing the hypothesis above on the basis of the available data, possible risks as well as chances related to growing indigenous tree species are to be discussed. In addition to *Tectona grandis* being considered for the reforestation in the investigation area, indigenous species have also been used. Alongside the species *Anacardium exelcium* (Espavé), *Cordia aliodora* (Laurel), *Xantoxilum sp*. (Tachuelo), *Sterculia apetala* (Panamá), *Calicophylum candidisimun* (Madroño), *Didimopanax morototori* (Pava), *Cedrela odorata* (Cedro), *Miconia gobulifera* (Pipi), *Cassia mochata* (Cañafistula) and *Byrsonima crasifolia* (Nance), that mainly answer the purpose of enriching biodiversity, are these three indigenous species of commercial value: *Hieronyma alchorneoides*, *Swietenia macrophylla* and *Terminalia amazonia*.

Many studies also show that by varying rotation lengths, the productivity of forest plantations can be considerably improved (e.g. Brazee and Mendelsohn 1988). Using the data available for the study at hand, a third hypothesis is therefore to be verified:

H_2: *By varying rotation lengths, financial productivity can be increased.*

Valuing plantations of native forest species

Establishment of forest plantations generally increases the contribution of forestry to the national economy (Alam et al. 2009). By establishing plantation forests on degraded areas that are abandoned such as former cattle ground, timber can be provided for the market and the impact of exploitation of natural forests can be mitigated. Furthermore, environmental conditions in the country are positively influenced and therefore upgraded (Gutierrez and Diaz 1999).

In the year 1990 forest plantations covered 10,000 ha of Panama´s land area, of which 7,000 ha where established using *Pinus caribaea* (INENARE 1990). In 1997 plantations already covered around 30,000 ha, of which 14,000 ha consisted of *Tectona grandis* and another 10,500 ha of *Pinus caribaea* both in monoculture. But choosing different tree species for the species composition in a forest plantation project is an important silvicultural instrument that will later heavily influence the susceptibility for risks. By homogenising ecosystems to gain short term benefits, negative effects on biodiversity are generated, which often lead to a diminished financial robustness of the ecosystem, especially if natural risks exist (Knoke 2008). In this connection, Knoke and Hahn (2007, p.312) assert:

“(...) against the background of different production risks of tree species, comparison with a portfolio of shares stands to reason. In a forest stand that is made up of various tree species, effects that are subsumed as «diversification of risk» or «balancing of portfolio» may occur (...)”

Planting a combination of tree species that are adapted to site conditions therefore is useful for ecological and financial aspects as well as for mitigating risks. But to fully embrace portfolio aspects in mixed species stands, prospective indigenous species have to be economically assessed.

Existing literature about the economy of plantation forestry in the tropics concentrates on economically productive species, most usually exotics, such as *Pinus sp., T. grandis* or *Eukalyptus sp.* (Cubbage et al. 2007). *Tectona grandis* is a well known species, whose characteristics such as growth performance have been reviewed intensively and can be accessed in numerous publications. But the characteristics of Panama's native tree species of commercial relevance like *Hieronyma alchorneoides, Swietenia macrophylla* and *Terminalia amazonia*, are largely unknown. Regarding native species, we can at the most and if anything at all, find information about growth behaviour (Piotto et al. 2004b; Redondo-Brenes and Montagnini 2006). A comprehensive case study that measures mixed stands and projects growth performance over entire production periods and delivers an economic evaluation is initially provided by the present study.

2 Material and Methods

2.1 The Study Area

The study was carried out on the Pacific coast of the Central American republic of Panama. In Las Lajas, Province of Chiriquí (81°53' W, 8°15'N) at an elevation of about 8 to 50 m above sea level. The region is part of the tropics with an average annual precipitation of 3000-3500 mm and average annual temperature of 26.7° Celsius. The 3-4 month dry season lasts from January to April (Worldwide Bioclimatic Classification System, 1996-2009).

In 1995 the first plantation was established. It was planted on 23.5 ha former cattle ground. In 1996 and 1999 the plantation was complemented by adjacent and nearby areas, leading to a total plantation area of about 100 ha managed under the same concept.

The history of the research site being former cattle ground makes the site an ideal example, as equivalent sites are typical for future reforestation.

The main criteria for allocation of the different tree species within the area were the pre-conditions, such as varying soil conditions, of each microsite. Experience in managing the species as well as growth potential and commercial relevance of the species were taken into consideration just as well. The tree species were planted in different mixtures. Areas in which valuable tree species are discretely admixed are spread over the area, tessellated to gain a small-area mixture.

Before planting, the pre-existing vegetation was cleared. Remaining long-standing or valuable trees are mainly of the species *Cassia grandis, C. moschata, Enterolobium cyclocarpum* and *Byrsonima crassifolia.* According to the existing laws, 15 m adjacent to river banks were left unplanted. On these riparian strips and in other areas that are inappropriate for plantation establishment, like gullies, natural vegetation was kept. These areas are thus considered designated sanctuaries.

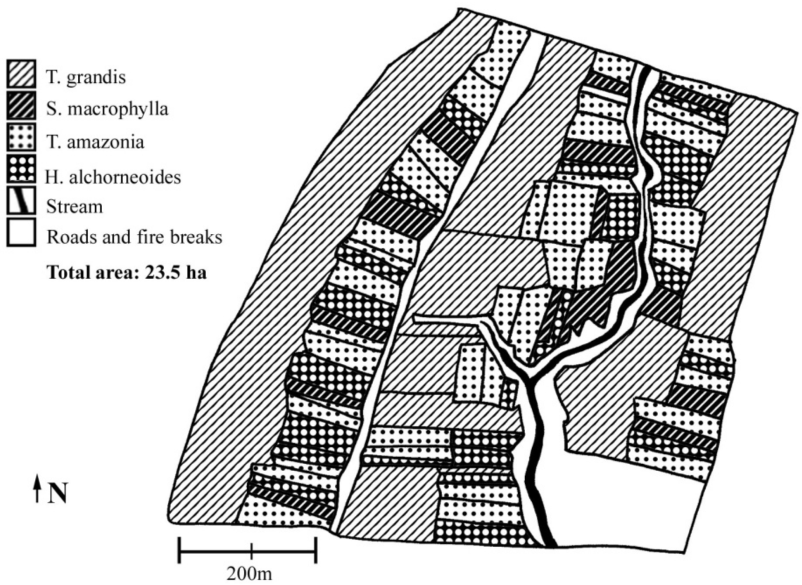

Figure 1: Plantation layout at the study site

The seeds were obtained regarding to the provenance recommendations of CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) in Costa Rica. For both *Tectona grandis* (Teak) and *Hieronyma alchorneoides* (Zapatero) the provenience “Pérez Zeledon“ was suitable, delivered by the seed trader “Coopeagri”. For the species *Swietenia macrophylla* (Caoba) a Colombian provenience sold by “Semicol” was chosen, for *Terminalia amazonia* (Amarillo) the Panamanian provenience “Carta Vieja“, sold by “Particular”. Suitable seeds were sown in a nursery close to the plantation area, the seedlings raised for six month to a year before being hand planted into a planting pit of 60 x 45cm. The top soil that accrues during this process is mixed with an organic fertilizer and put back into the planting pit. For three years after planting, the organic fertilizer “Bokashi” is deployed around the seedlings. The components of this fertilizer are fermented bird faeces, calcium, rice pellets, saw dust and ash. Furthermore, during the first six years after planting, the site was kept free of weeds by manual cutting six times a year. In the following years, natural regeneration between the planted rows was only cut if it grows directly into the rows of trees.

However, the most important management technique is pruning. Pruning was done during dry season; initially after the trees have reached a height of 4 m, a dbh of at least 10 cm and a branch diameter of more than 3 cm. Branches were removed up to a height of 50% of individual tree height. Thinning were carried out at age 8 and 10; rotation period has been scheduled to 25 years.

The prescribed approaches to plantation establishment as well as management comply with the actions proposed by Lamb (1998) for the protection of biodiversity in plantations. The reforestation is an approach to sustainable and commercial plantation operation. Therefore, the plantation offers a suitable research area, to evaluate effects of ecologically managed plantations towards the potential of natural regeneration. A study regarding this has been taken in the form of a thesis by Paul (2006).

2.2 Financial Analysis

To evaluate the economic performance *Tectona grandis* as well as of the three native species of financial importance, *Hieronyma alchorneoides* (Zapatero), *Swietenia macrophylla* (Caoba) and *Terminalia amazonia* (Amarillo), all management activities from plantation establishment until final harvest have to be collected and financially valued. Costs for purchase of land and taxes were omitted as they would not affect the decision as to choice of species. All expenses arising for plantation establishment and forest management activities were documented by the plantation management and have been used as data basis for all subsequent calculations. Additionally, all expenses arising for the thinning taken out on the plantation in 2005 have been documented and are used in the following calculations. The income gained by timber sales had to be reconstructed.

2.2.1 Costs for plantation establishment

For plantation establishment, the first step was to prepare the site. In year 0 therefore expenses arise for clearing pre-existing vegetation, digging out planting pits, as well as for buying seeds and necessary tools etc. In the following years, expenses arise from management actions like pruning, weed-control, tools and material, fertiliser and herbicides. The necessary management actions were comprehensively described in chapter „2.1 The Study Area “ and have been accounted for by the plantation management. An overview of these expenses arising from year 0-5 after plantation establishment can be found in the following Table 1.

Table 1: Arising expenses year 0-5 according to plantation management

	[US$] / ha
Site preparation and planting, year 0	974
Management and material year I	748
Management and material year II	871
Management and material year III	871
Management and material year IV	514
Management and material year V	504

For the following years 6-25, for which no expenses were documented, an average of the previous years was used for valuation. Following common conventions, annual inflation rates have been disregarded (cp. Sagl 1995) rather all valuations used actual costs and prices

2.2.2 Costs for thinning and final harvest

All expenses arising from the thinning in 2005 have been documented in detail. For the first thinning, accomplished in 2003, this information was not available. Therefore its financial data was calculated upon the assumption that the expenses are equal to the costs of the later thinning, as was done for annual spending for management activities and material above. Particular expenses arose for activities to keep the chain of custody complete and to later assign the harvested timber to certain parcels. In detail, these are hours of work for applying number tags as well as material costs for the tags themselves. Furthermore, the costs of forwarding the logs three kilometres to the wood yard by tractor are included. Total expenses for the thinnings taken out at age 8 and age 10 are made up of costs for transporting timber to the wood yard, arising costs for harvesting by chainsaw, costs for safety equipment, material and tools, as well as costs for general workings, that form the largest entry. In consideration of the fact that the thinnings are not commercial thinnings in the classical meaning, the expenses per hectare of around 300US$ are relatively high.

Expenses for working time during final harvest at age 25 are calculated using the formula developed by Cruz Madariaga (2003):

$$T[s] = \frac{50.03161 + 27.56265 * dbh[cm]}{2}$$

T= Working time for logging [sec.], dbh = diameter at breast height [cm]

Using the diameter at breast height of the mean basal area tree at age 25 and the number of trees per hectare the working time for logging is calculated. The expenses for wages are set at US$ 10.14 per day (8 working hours), following average wages paid by the plantation management in 2006 including social security. Additionally, the costs for skidding and material according to the costs arising during thinnings are considered. Total costs for final harvest operations at age 25 are around US$ 1300/ha, whereas the costs slightly vary between the tree species due to differences in timber dimensions and numbers of trees per hectare.

2.2.3 Income gained by timber sales

In Panama, the timber price realised for teak logs in 2007 was, according to the timber market report of ITTO, close to the worldwide midrange. For the other three tree species that are grown in the research area no timber market data was available. The timber obtained during thinnings in the research area could be sold irrespective of the species for a uniform price of US$ 200/m^3 off the wood yard. Considering the growing demand for certified tropical timber and the possible development of market premiums paid for it (Kollert and Lagan 2006), it is assumed that in the following years equal prices will be achieved for all tree species investigated in this study. This view is also supported by personal communication with employees of the plantation management. In view of growing diameters and strong dimensional effects, future timber sales revenues (Table 2) are assumed, according to ITTO timber market reports (ITTO Tropical Timber Market 1998-2010).

Table 2: Round wood revenues and estimated future price trend for bigger sized logs of all four species

Round wood revenues and future price trend		
Circumference [cm]	Diameter [cm]	Average price per m³ off wood yard [US$]
~44-66	~14-21	200
67-79	22-25	223
80-99	26-34	275
110-130	35-41	335
131+	42+	365

It is assumed, that logs of stem wood of all four species, according to the assortment of the thinning in former years, can be sold at one standard price. This assumption is fortified by the comparable physical characteristics of the timber of all four species, shown in Table 3.

Table 3: Physical characteristics of timber of all four species investigated, taken from Posch *et al.* (2004); Rijsjdijk and Laming (1994), USDA Forest Service, Center For Wood Anatomy Research (2010)

Species	Density*	Modulus of elasticity**	Shrinkage from green to ovendry***	Colour
	[kg/m³]	[N/mm²]	[%]	
Tectona grandis	0.64	13740	r: 2.5% t: 5.8% v: 7%	yellow brown
Hyeronima alchorneoides	0.63	22700	r: 5.4% t: 11.7% v: 17%	chocolate brown
Swietenia macrophylla	0.61	14200	r: 3% t: 4.1% v:7.8%	red brown
Terminalia amazonia	0.65	23000	r: 6.4% t: 8.7% v: 14.9%	light brown to reddish yellow

* ovendry

** moisture content 12%, based on 2cm standard

*** r = radial, t = tangential, v = volumetric

Furthermore, a 60% stem wood proportion out of total timber harvested is assumed. For fuel wood a net price of zero US$ is set. This means that the costs for primary conversion of fuel wood are just covered by the attainable revenue for this particular assortment.

2.3 Yield projections

The information on growth performance presented below provides the basis for all economic calculations. For the inventories taken out annually by the plantation management, permanent monitoring plots for all tree species were established. Each plot measures 20x20 m, and is located within the plantation by random selection. In total there are 16 plots of 400m² each. Because the spacing between trees is different for each species, the number of trees per plot is between 10 and 48 individuals. The measured data was later converted to analogous values for hectares.

To evaluate the economic performance of *T. grandis* and *S. macrophylla* data from the permanent inventory plots, yield tables and information from literature was used. Both tree species have frequent appearances in the literature. Because of this advantage, a rather high validity of the results can be assumed. For *H. alchorneoides* and *T. amazonia* only scarce additional information regarding their growth was available from literature (Piotto et al. 2003, Redondo-Brenes and Montagnini 2006). Regarding the reliability of the results it has to be noted that at the research site all four tree species investigated were not planted randomly, but according to their site requirements after a soil sampling was carried out. This leads to systematic differences in site qualities between the tree species. For the growth behavior of the tree species in reality, slight divergences therefore have to be anticipated, that are covered by the optimistic and pessimistic scenarios.

The first thinning was carried out at age 8. During this thinning the number of trees per hectare of each species fell by an amount related to the number of trees planted. In *T. grandis* stands 41% of the trees were cut, for *H. alchorneoides*, the number of trees per hectare fell off by an average of 22%, the average number of *S. macrophylla* trees per hectare was reduced by 6% and in *T. amazonia* stands 40% of the trees were cut.

During the second thinning at age 10 another 14% of *T. grandis* trees, 4% of *H. alchorneoides*, 2% of *S. macrophylla* and 25% of *T. amazonia* were harvested. A detailed overview over yield surveys taken out at the study site and expected future growth can be found in the appendix (Table A 1 through Table A 4).

To classify growth performance at the study site and to extrapolate it into the future beginning with age 11, appropriate yield-tables were analyzed. For *T. grandis,* from comparative data by Pérez and Kanninen (2005), expected diameter and height growth at the study site as well as a form factor of 0.45 for round wood calculation was derived.

To forecast further development of growth of the natural forest species *H. alchorneoides*, we had to revert to a study by Redondo-Brenes and Montagnini (2006) and another study by Piotto et al. (2003). Both studies deal with growth performance of the species *H. alchorneoides* and *T. amazonia*. It is assumed that increments at the study site evolutes comparably. To avoid growth prognoses becoming too optimistic, the lower increments for tree height and diameter determined in each of the two studies were used. For calculating the volume of merchantable *H. alchorneoides* timber, a form factor of 0.45 enters into the calculation. This form factor is according to that used for internal calculations by the management and emanates empirical value (Camacho 2008)[1].

According to the approach used for the yield estimation of *T. grandis*, for *S. macrophylla* yield tables from comparable sites were consulted to classify growth performance. For calculating the stem volume of *S. macrophylla* a form factor of 0.65 was used, as determined by Mora-Chacón et al. (2002).

To project growth performance of *T. amazonia* according to the approach used for *H. alchorneoides* results gained by Redondo-Brenes and Montagnini (2006) and Piotto et al. (2003) were used. An overestimate of the growth performance is obviated by using the lower increments determined by Redondo-Brenes and Montagnini (2006). A form factor of 0.45 was used, also taken from the calculations used by the forest enterprise and is based on the experience of the on-site forest engineers (Camacho 2008).

2.3.1 Comparative analysis of yield

For years 11-25 for all tree species no further thinnings were planned. The stem number determined for each species in the research area takes into account an annual mortality of 0.5% of the standing trees per hectare in years 11-25 (Camacho 2008). Comprehensively a loss of 20% of the commercial volume is considered, to factor in bark and losses during harvesting to calculate felling value (Camacho 2008). As mentioned before, all potentially commercial timber (80% of standing timber over bark) is then split into 60% stem wood and 40% fuel wood.

In the research area, *Tectona grandis* - compared with *Hieronyma alchorneoides*, *Swietenia macrophylla* and *Terminalia amazonia* - gained the highest growth performance until age 10. With advancing age, *T. amazonia* and *S. macrophylla* turn out to be more productive. For *S.*

[1] Yaels Camacho, Forest engineer at the research site.

macrophylla this traces back to the advantageous stem form and higher form factor arising from it. Whether it is at all possible to grow *S. macrophylla* in plantations for equivalent rotation lengths continues to be debated. In the literature, many reports about failures in *S. macrophylla* stands starting with age 10 exist. In the discussion section of this paper, this problem will be taken up again in detail. For this work, it will be assumed that the species will reach age 25.

T. amazonia displays high increment in other studies as well (Piotto et al. 2003; Redondo-Brenes and Montagnini 2006) a very good growth performance is strongly related to the site quality though (Calvo-Alvarado et al. 2007). A comparative overview is given in Fig. 1.

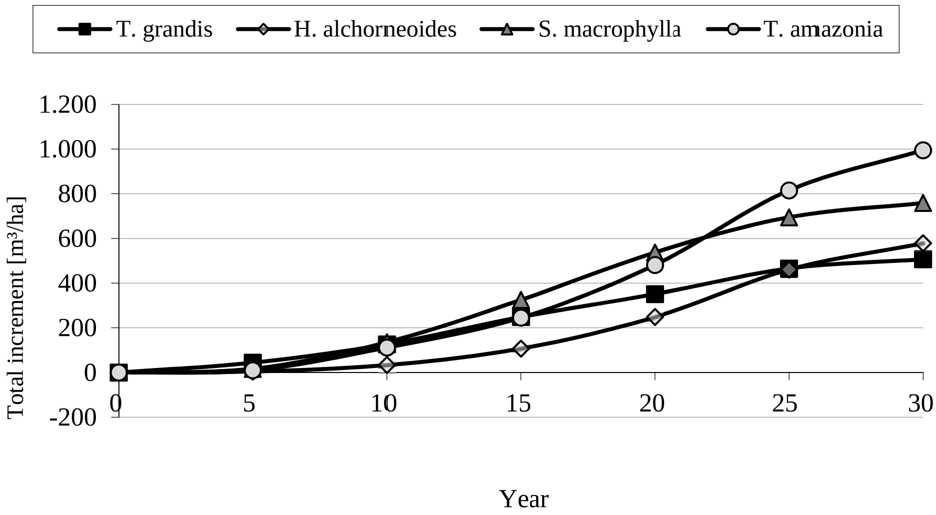

Fig. 1: Total increment of the four tree species in the research area

2.4 Ranking method

For Panama, Benitez et al. (2007) estimated risk adjusted discount rates of around 9.9%. International investors aiming at forest investments to diversify existing portfolios come to a much lower receivable interest. Private landowners have very individual receivable interest. As current asset portfolios of private landowners are unknown, a range is necessary to display all possible situations. In South American *Tectona grandis* plantations, Cubbage et al. (2007) assessed rates of return of 5% to 13%. These values were used as an indication for general assumptions regarding the profitability of plantations as well as to allow general assessment of forest plantations.

2.4.1 Net present value method

The economic performance of the different species is described with an indicator that is derived from capital budgeting. The net present value (NPV) method is a discounted cash-flow method and counts among the methods of capital budgeting. By discounting payments that are made at different points in time to the start date of an investment, payments made at different moments become comparable using the NPV method. The NPV of an investment is the sum of all present values, thus all cash flows, both inflows and outflows of cash that are caused by the investment. It differentiates between absolutely profitable investments, with a NPV greater than or equal to zero and relatively profitable investments with a NPV greater than or equal to the NPV of an alternative investment. The first case answers the question whether or not an investment generally is to be made; the second case answers the question of which of the alternatives is more profitable. It is the latter case that concerns us here.

For calculating the NPVs the following equation according to Thommen and Achleitner (2009) is used:

$$NPV_o = \sum_{n \in T} (I_n - O_n) \cdot (1+i)^{-n}$$

NPV_0 = Net present value, T = years between stand establishment and final harvest, I_n = Cash inflow in year n, O_n = Cash outflow in year n, i = discount rate (in hundredth), n = time after stand establishment in years

The terms cash inflow and cash outflow that are common in financial mathematics correspond with the terms incoming payments and out payments. To calculate the NPV an interest factor or discount rate *i* is needed. *i* can be the rate of return required by an investor, the rate of return that can be achieved with an alternative capital asset, or it can be chosen as a target rate of return, including all influencing factors. In many cases *i* is chosen as the rate of return an alternative investment offers. Because of the controversial opinion regarding suitable interest rates for forest enterprises and forests, for calculating the NPV, interest rates between 0% and 15% have been used in this study.

2.5 Considering uncertainties and optimization

2.5.1 Uncertainty and sensitivity analysis

Damages to a forest stand which can result from insect outbreaks, volatile timber markets and other factors influence possible revenues. Also, it is impossible to forecast all relevant factors. For the paper at hand, the future risk situation in form of environmental circumstances or damages to the stand is deemed to be unknown by the decision maker. One way to factor these risks into the analysis is to perform a sensitivity analysis.

Within a sensitivity analysis, the marginal values of the results are elaborated. One or more parameters influencing the investment are changed (Heidingsfelder and Knoke 2004). It is tested at what point the target return values are affected (for example the NPV). By this approach, the sensitivity of the investment towards the change of influencing values like timber market development in form of timber prices, total increment, and others can be tested systematically. For this purpose, various input parameters were changed by posing a range of alternatives for the incoming payments.

2.5.2 Varying rotation lengths

The land expectation value (LEV) represents the present value of annuity of a perennial periodic annuity made up of the sum of the future felling value and all cash inflows compounded to the moment of final harvest, minus all compounded cash outflows for tending, material and other costs (Faustmann 1849). The sum is then diminished by the perennial annuity of administrative expenses. With the LEV it is possible to consider effects of different durations of investments, such as rotation, which is one of the most important control factors in forest management. Even for well investigated species, the optimal rotation length is still being discussed. For many tropical species a rotation period of 25 years is assumed to be ideal (Evans and Turnbull 2004). By investigating the development of LEVs under varying rotation lengths, production periods can be optimised. Furthermore the calculation of LEVs is necessary to assure that longer rotation periods are not estimated too optimistically, as well as to achieve comparability with other studies. Therefore the LEVs of all four investigated tree species were calculated for rotation periods between 10 and 30 years and a regression analysis was carried out with the ascertained values to smooth the curves relative to time.

3 Results

3.1 Results of the ranking methods

The description of the valuation results first goes into cash in- and outflows as well as felling values and other performance indicators. In a first step, a situation without uncertainty is implied.

3.1.1 Cash inflow and outflow

The observations made in chapters 2.2.3 “Income gained by timber sales“ and 2.3 “Yield ” result in annual cash in- and outflows of varying amounts for *Tectona grandis* as shown in Fig. 2. The cash outflows are displayed as hanging columns because of their negative algebraic sign. The cash inflows from thinnings in year 8 and year 10, as well as cash inflows from final harvest in year 25 are displayed as standing columns. In all other years, no cash inflows are being set.

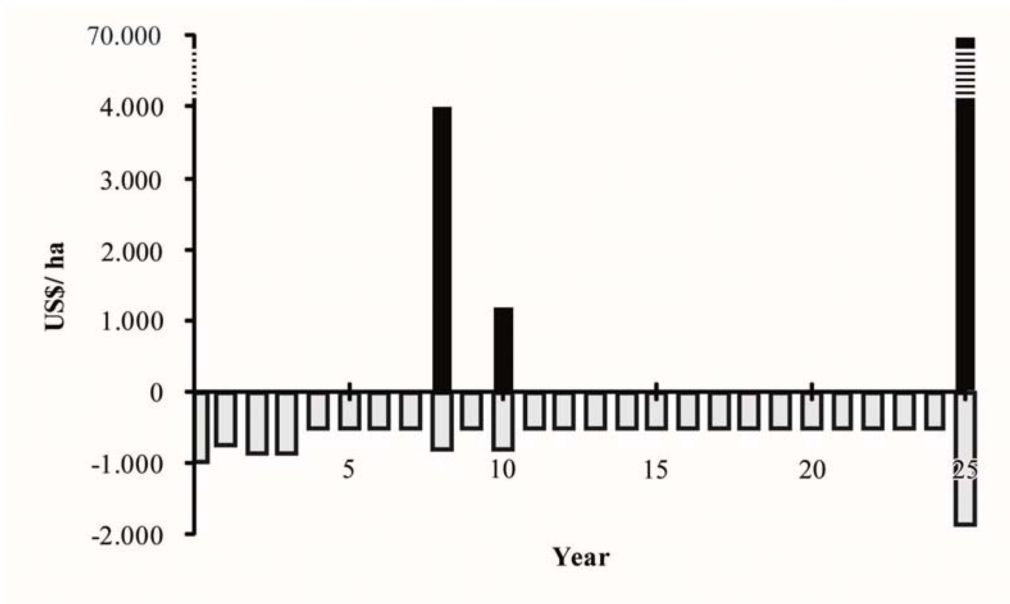

Fig. 2: Cash in- & outflows *Tectona grandis*

The cash outflows for the tree species *H. alchorneoides*, *S. macrophylla* and *T. amazonia* only marginally differ from the cash outflows for *T. grandis* and are therefore not displayed in detail.

3.1.2 Net present value method

Considering the change of the NPV depending on the required rate of return, the criteria of relative profitability introduced in chapter 2.4.1 is taken as basis. Fig. 3 illustrates how the NPV for all four tree species changes depending on the discount rate used.

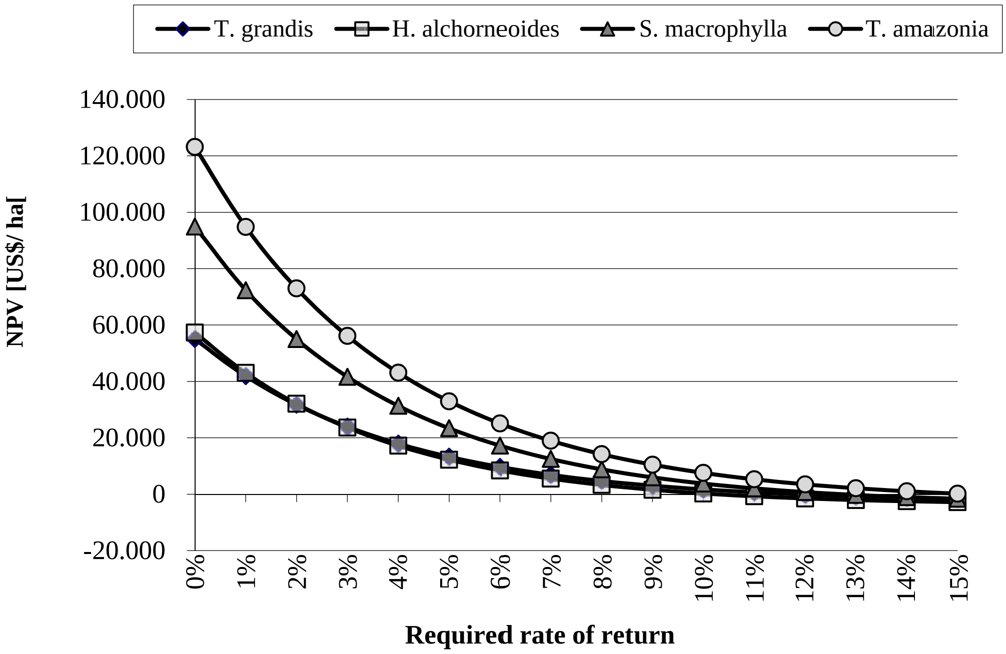

Fig. 3: Net present value function of all four tree species

At a required discount rate of 0%, the NPV is equivalent to the total sum of all in- and outflows. The graph of the NPV always intersects with the axis of the discount rate at the internal rate of return. In the example above, the tree species achieve internal rates of return of up to 15%. The internal rates of return for the investigated tree species appear in the marked cells in Table 4.

Table 4: Net present values and internal rates of return

Internal rate of return	Net present value [US$/ha]			
	T. grandis	*H. alchorneoides*	*S. macrophylla*	*T. amazonia*
0%	55023	57340	94921	123139
1%	41860	43016	72335	94809
2%	31738	32049	54980	72975
3%	23940	23642	41622	56113
4%	17920	17192	31324	43062
5%	13267	12240	23375	32942

6%	9663	8438	17233	25079
7%	6868	5520	12483	18960
8%	4698	3282	8807	14191
9%	3013	1568	5963	10468
10%	1702	258	3763	7559
11%	683	-739	2062	5283
12%	-109	-1494	750	3501
13%	-725	-2063	-261	2106
14%	-1202	-2487	-1037	1013
15%	-1572	-2799	-1629	157

Furthermore, the dependency of the required final stand value in year 25 and the internal rate of return can be displayed as in the following graph (Fig. 4).

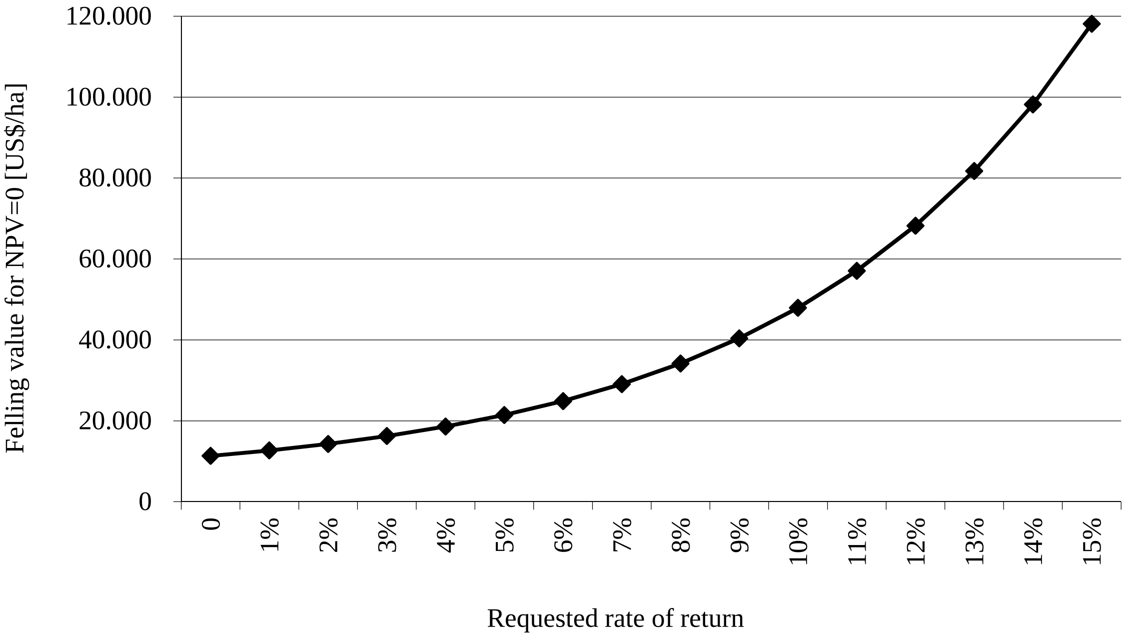

Fig. 4: Felling value year 25 necessary for a NPV=0

The graph displays the felling value the investment must attain in year 25 to still reach a NPV of 0 and therefore to still be considered profitable. This graph can be used as a simple tool to assess the profitability of an investment, if a rough idea of the future felling values, that also holds true in practice, exists.

Because cash outflows are equivalent for all tree species, *H. alchorneoides*, *S. macrophylla* and *T. amazonia* follow as for the displayed species *T. grandis*.

For a required rate of return of 15% a felling value of around US$ 120.000/ ha would be necessary to avoid a negative NPV. Therefore, such a high internal rate of return appears to be unlikely.

3.2 Considering uncertainties. A Sensitivity analysis of net present value and internal rate of return

The sensitivity analysis gives an overview of the reactions of the NPVs and internal rates of return on changes in the input variables.

3.2.1 Varying initial cash outflow

A change in the initial cash outflow - meaning the costs of stand establishment - at the beginning of the period under consideration results in a parallel downwards shift of the NPV graph for all tree species. Any such change can for example evolve from rising costs for seedling or rising wages. If the initial cash outflow rises for a certain amount, the NPV declines by the same amount, irrespective of the used rate of return, and vice versa.

This effect is originated by using a discount rate $(1+i)^0$ at the beginning of the period under consideration. The parallel shift furthermore results in a change of the point of intersection of the graph with the X-axis is moving to the left, which means that the internal rate of return declines as shown by the example of *T. grandis* in Fig. 5.

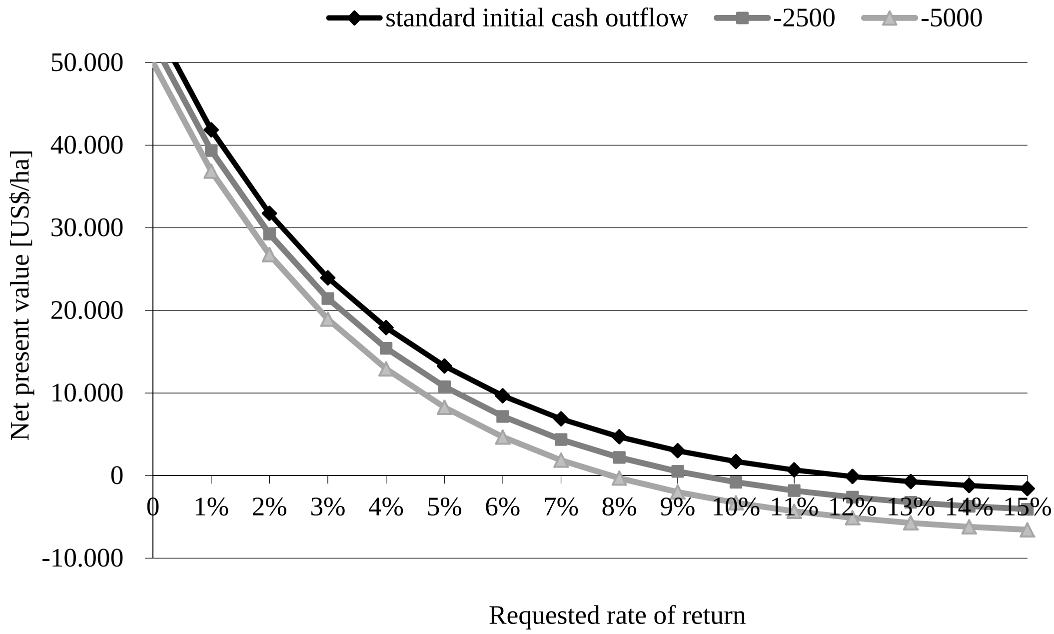

Fig. 5: Changes in the graph of the net present value function with rising initial cash outflows for stand establishment of *T. grandis*

The changes in the payments made for stand establishment by US$ 2500, and US$ 5000 respectively, are deliberately chosen to be very high to clearly point out the parallel shift of the graph. For the sensitivity analysis itself, additional 25%, 50%, 75% and 100% are charged for the initial cash outflow. A possible decline of the costs for stand establishment is not being considered, as an initial cash outflow of around US$ 1000 / ha including all plants is already set rather low. Detailed results for all four species investigated can be found in the appendix, Table A 5 through Table A 8.

Even for changes of up to 100%, the internal rate of return for all tree species only varies in a range of less than one percent. Even a considerable increase of the costs for stand establishment has only very little influence on the NPVs. Furthermore it is to be tested how the NPV changes over all requested rates of return if the cash inflow earned by final harvest varies.

3.2.2 Varying cash inflow from final harvest

Varying earnings from final harvest can for example be caused by declining timber prices. Also, lower increments - for example caused by changing environmental conditions – that lead to lower dimensions in the produced timber and lower standing volumes, can influence the earnings gained during final harvest. Vice versa, timber prices, saw wood proportions and many other factors can also change in a positive way. To asses financial consequences of all possible future developments, the cash inflow by final harvest in year 25 for the four tree species considered was varied from -50% through +50%, resulting in a change of the NPVs. The possible range of the NPV at higher, and lower incomes gained by final harvest is shown for *T. grandis* in Fig. 6.

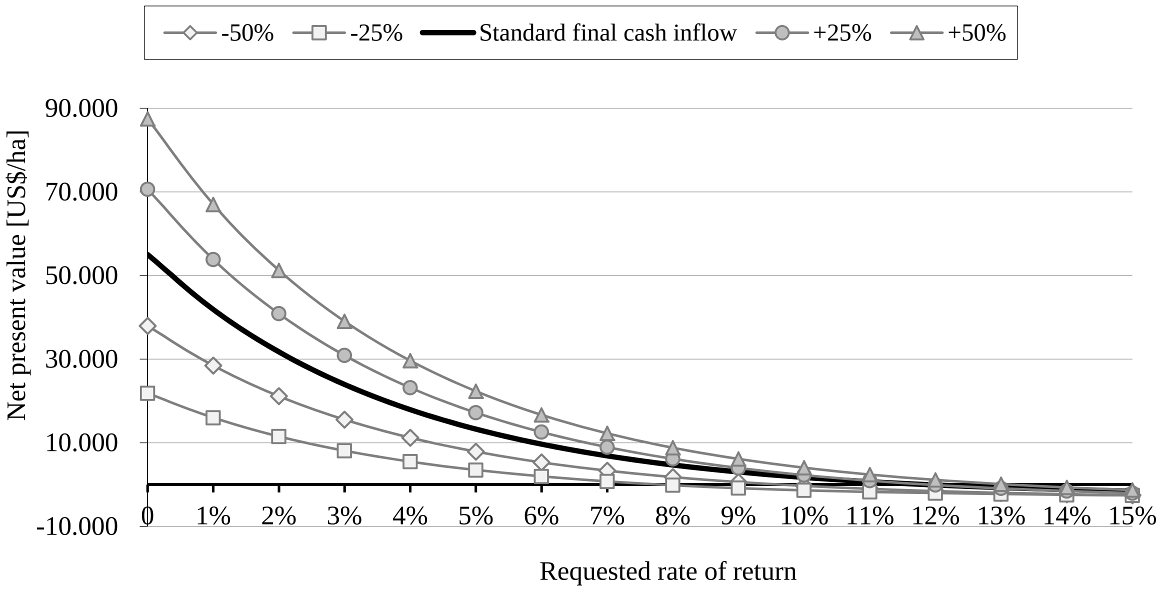

Fig. 6: Changes in the graph of the net present value function with rising and declining cash inflows from final harvest, *T. grandis*

The NPV at lower cash inflows from final harvest is below the NPV of the standard scenario. Likewise, the NPV gained with a higher final cash inflow as a basis are above the standard scenario. However, in both cases the difference between the standard scenario and the other scenarios becomes smaller and approaches zero with rising discount rate. This is due to the fact that the discount factor used for the cash inflow after final harvest ($(1+i)^{-25}$) quickly becomes very small due to rising interest rates and the discounting period of 25 years,.

3.2.3 Pessimistic and optimistic combinations

Within a framework of pessimistic and optimistic combinations, the paper at hand investigates the fluctuation margin of the NPVs for the investigated tree species, if rising cash outflows for stand establishment occur along with sinking cash inflows after final harvest and vice versa. To consider a pessimistic development of the NPV, initial cash outflows are increased by 50% whilst simultaneously decreasing the cash inflow after final harvest by 50%. To consider an optimistic development of the NPV, decreased cash outflows for stand establishment by 50% are combined with 50% higher cash inflows gained by final harvest. The results for all four tree species can be seen in Table 5.

If the internal rate of return is considered, the following ranking results: If a pessimistic development occurs, *T. amazonia* still reaches the highest internal rates of return. Already at a slight increase of the cash inflows, *T. amazonia* can compete with the results of the other three species in the situation of an optimistic development.

T. grandis turns out to be least susceptible to the alternative scenarios, whilst *H. alchorneoides* in a pessimistic case scores lowest and is therefore rather susceptible towards changes.

Table 5: Pessimistic and optimistic net present values in US$/ha at varying interest rates

Internal rate of return	***T. grandis***		***H. alchorneoides***		***S. macrophylla***		***T. amazonia***	
	Pessimum	Optimum	Pessimum	Optimum	Pessimum	Optimum	Pessimum	Optimum
0%	21358	88688	20190	94489	39031	150811	54840	191439
1%	15502	68218	13941	72091	28647	116023	41444	148174
2%	11028	52448	9215	54882	20723	89236	31155	114796
3%	7607	40272	5645	41639	14674	68569	23238	88987
4%	4988	30853	2952	31431	10055	52593	17138	68987
5%	2982	23551	927	23553	6528	40223	12430	53454
6%	1445	17880	-591	17467	3837	30629	8792	41366
7%	268	13468	-1722	12762	1788	23178	5979	31942
8%	-633	10030	-2559	9122	231	17384	3802	24580
9%	-1322	7347	-3171	6306	-949	12875	2117	18819
10%	-1847	5251	-3613	4129	-1837	9363	813	14304
11%	-2246	3612	-3924	2447	-2503	6627	-196	10761
12%	-2548	2329	-4138	1149	-2996	4495	-975	7977
13%	-2774	1325	-4277	151	-3358	2835	-1575	5786
14%	-2943	538	-4359	-615	-3617	1544	-2037	4062
15%	-3067	-77	-4400	-1199	-3799	541	-2390	2704

3.2.4 Varying rotation lengths

By calculating LEVs under varying rotation lengths, production periods can be optimized. Therefore the LEVs of all four investigated tree species are calculated for rotation periods between 10 and 30 years and a regression analysis was carried out with the ascertained values.

The development of the LEV of *T. grandis* is exemplary displayed in Fig. 7, the graphs for the three native species can be found in the appendix (Fig. A 1 through Fig. A 3). Whereas the smoothed curve is pictured as a bold line, the “real” values are pictured as a dashed line. The partially remarkable leaps of the LEV graphs originate from the variation in incomes from timber due sales due to increasing log sizes.

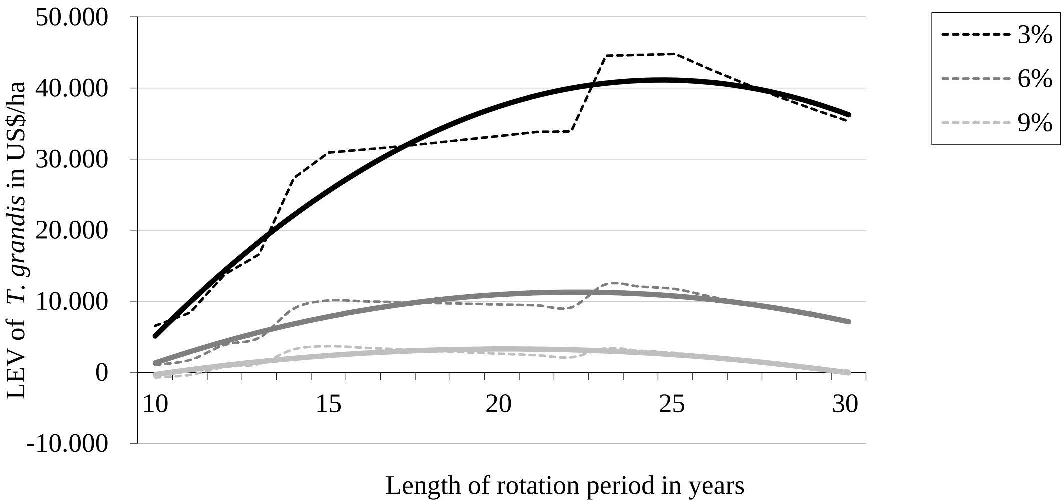

Fig. 7: LEV development for *T. grandis* under varying rotation lengths

For all four species a rotation period of 25 years turns out to be ideal at a discount rate of 3%. At discount rates larger than 3%, the ideal rotation decreases, but the differences of the LEVs with age however are comparatively low. Overall, the trend line added to Fig. 7 clearly shows the bell-shaped development which is typical for corresponding graphs, whereas the assumed optimal rotation length of 25 years is close to the maximum value at all times. The explicit increase of the LEVs between a 22 year and a 23 year rotation length rests on the rising incoming payments for timber sales due to larger dimensions. Furthermore, the flat run of the graph that occurs in all four species points out a wide range of management options regarding ideal market situations for harvesting operations.

4 Discussion

4.1 Reassessing the hypothesis

Calculating the net present values (NPV) for a standard scenario at a rotation length of 25 years led to the result that *T. grandis* reaches internal rates of return of approximately 11-12%. The natural forest species *H. alchorneoides* reaches values of 10-11%, *S. macrophylla* reaches internal rates of return of approximately 12-13% and the third natural forest species *T. amazonia* even reaches internal rates of return of > 15%. The calculations of the NPVs were carried out for the standard scenario without considering the costs for purchase of land, costs for maintaining an administration, taxes or a distribution system. If all these costs are considered, the results will shift towards the results of the pessimistic development scenario. For plantations growing selected indigenous tree species, Cubbage et al. (2007) calculated rates of return between 5% and 13%. An equivalent result is aimed for at the research site mixing the four species *T. grandis, H. alchorneoides, S. macrophylla* and *T. amazonia*.

The rates of return calculated here do turn out to be comparatively low. As predictions regarding timber markets at the rotation age are difficult to make, it has to be mentioned that with increasing volumes of wood becoming available from maturing plantations (Clark 2001), price expectations may not necessarily be realized, even though a market premium for certified logs may be fetched in the future (Kollert and Lagan 2006). The pessimistic scenarios considered here however, display future performances at price declines of up to 50%.

Furthermore there exist large uncertainties regarding the survival probability for the natural forest species. As mentioned before, especially for *S. macrophylla* there are indications that a rotation period of 25 years in a plantation cannot be assumed offhand. One of the largest known problems with *S. macrophylla* in plantations are calamities of the insect pest *Hypsipyla spp.* which can be found in all of Central America (Mayhew and Newton 1998). An infestation results in a damage of the main shoot and therefore forked trees and a considerable decrease of increments. At the research site, single appearances of *H. grandella* were observed during inventories.

On our assumtions, native species appear competitive with *T. grandis* in this area. The comparison of the NPVs shows that the profitability of growing *T. grandis* is below the profitability of *T. amazonia* as well as *S. macrophylla* and only slightly higher than the profitability of growing *H. alchorneoides* if the standard scenario is used. However, for *S. macrophylla* high uncertainties regarding future outcomes have to be considered, leading to the assumption that results will strongly tend towards the pessimistic scenario if the stands of this species are able to reach the rotation age. Furthermore, the timber may turn out to be mainly sapwood, unless a much longer rotation is used. These uncertainties also raise the question if *S. macrophylla* should be planted at all. If trees of this species are planted in small groups or as single tree admixtures the risk of insect losses can be minimized. If the trees of *S. macrophylla* should then fail to reach rotation age, surrounding trees of other species will be able to fill in the gaps. We therefore recommend understanding the admixture of *S. macrophylla* as an investment that offers certain chances at a high risk and should therefore be planted in proportions smaller than 5% only.

For *H. alchorneoides* it is likely that the revenues from timber sales will in reality turn out to be higher than the revenues used in the paper at hand, as according to Piotto et al. (2003), an increasing demand for saw timber of this species is to be expected. In this case, the small advantage of *T. grandis* towards *H. alchorneoides* would wear off in the occurrence of an according scenario. Our hypothesis - *the profitability of Teak plantations cannot be gained by planting native tree species* – is therefore refuted, provided that all assumptions turn out to be true in the future.

4.2 Conclusions

This paper was able to show how the investigated species behave regarding their financial performance. To our knowledge it is the first paper delivering actual data for financial comparison of the three investigated native species with *Tectona grandis*, as so far very little is known about the financial competitiveness of natives. Regarding the NPV of all four tree species, the profitability of *T. grandis* drops below the profitability of *T. amazonia* and *S. macrophylla* applying the standard scenario already and lies only slightly above the profitability calculated for *H. alchorneoides*. This result clearly indicates that the investigated native tree species are comparable with *T. grandis* regarding their economic profitability assuming that in the future the wood can be sold at comparable prices. Besides its ecological impact (Evans and Turnbull 2004, Hartley 2002) growing native tree species now also obtains economic legitimacy and should therefore be considered to be used alongside *Tectona grandis* in plantation establishments. Reconciliation between ecology and economics is made possible as the only obstacle so far was the lack of knowledge existing in this field of research.

An increase in the revenues from final harvest in year 25 has a great influence on the total profitability of the investment. Alongside the timber prices, which cannot be influenced by small enterprises, especially quality and dimension of the grown stem wood plays an important role for increasing revenues. Special attention should therefore be paid to the tending of such timber.

The information provided here makes a substantial contribution to the acceptance of native tree species within commercial forestry in Central America. The information regarding their profitability and growth also provides a basis for further calculations. However, it has to be noted that the extrapolation of growth from year 10-25 is very long and therefore holds uncertainties. For more reliable results, future evaluation of the profitability and economy of the investigated species to ages beyond age 10 has to be carried out. By integrating risk, as done for by Heidingsfelder and Knoke (2004) in a comparable study, the insecurity of an investment decision can be quantified. Such risk integration can for example consider the uncertainty regarding the future revenues gained by future timber sales. Furthermore, the tendency to risk taking by the decision maker can be integrated into evaluating the profitability of the investment. The relevance of integrating risks was determined by Knoke and Wurm (2006). Assessments of the diversification that results by growing the four different tree species would be reasonable as well. Diversification effects were first described by Markowitz (1952) in his Portfolio-Theory. An investment made up of a combination of different capital assets can – compared to a single investment – lowers the risk at equivalent rates of return. Also, the rate of return can be positively influenced by combining different capital assets. Knoke et al. (2005) devolved this approach on forest economics, determining mixed species plantations to be equivalent to a mixed portfolio. They observed that the ecologic concept of “mixed forests” leads to considerable economic benefits. To assess the diversification effects for the four tree species investigated would further advance the clarification of the economy and productivity of *T. grandis, H. alchorneoides, S. macrophylla* and *T. amazonia*. To increase the accuracy of assessing such forest investments there is also further need for information about tree species interaction in mixed stands, according to the research carried out by Petit and Montagnini (2006).

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7 Appendix

Table A 1: Yield projection for *Tectona grandis* at the study site

Tectona grandis (Teak)							
Age	**N**	**Intensity of thinning [%]**	**d_g [cm]**	**h_g [m]**	**Remaining Vol. [m³/ha]**	**Harvested Vol. [m³/ha]**	**TI [m³o.b./ha]**
2	714	0	4,3	5,5	3	0	3
3	"	0	8,3	8,8	15	0	15
4	"	0	11,0	11,8	36	0	36
5	"	0	12,4	11,4	44	0	44
6	"	0	12,8	12,2	50	0	50
7	"	0	13,7	13,1	62	0	62
8	420	41	15,9	15,8	59	42	115
9	"	0	17.1	16.5	66	0	122
10	362	14	18,3	17,1	73	12	127
11	360	0	20,2	17,7	92	0	145
12	358	0	22,1	18,3	114	0	167
13	357	0	24,1	18,9	138	0	191
14	355	0	26,0	19,5	165	0	218
15	353	0	27,9	20,1	195	0	248
16	351	0	28,9	20,7	214	0	267
17	350	0	29,8	21,2	233	0	286
18	348	0	30,8	21,8	254	0	307
19	346	0	31,8	22,3	275	0	328
20	344	0	32,7	22,9	298	0	351
21	343	0	33,7	23,4	322	0	375
22	341	0	34,5	23,9	343	0	396
23	339	0	35,4	24,4	365	0	419
24	337	0	36,2	24,9	389	0	442
25	336	100	37,0	25,4	413	413	467

N: Number of trees/ha; Intensity of thinning: In percent of number of standing trees; dg: Diameter of mean basal area tree; hg: Height of mean basal area tree; TI: Total increment

Table A 2: Yield projection for Hieronyma alchorneoides at the study site

Hieronyma alchorneoides (Zapatero)							
Age	**N**	**Intensity of thinning [%]**	**d_g [cm]**	**h_g [m]**	**Remaining Vol. [m³/ha]**	**Harvestes Vol. [m³/ha]**	**TI [m³o.b./ha]**
2	400	0	1,7	2,5	0	0	0
3	"	0	3	4,05	1	0	1
4	"	0	4,65	5,35	2	0	2
5	"	0	6,6	7,05	4	0	4
6	"	0	7,6	8,7	7	0	7
7	"	0	9,3	9,9	12	0	12
8	321	22	10,7	11,7	15	4	16
9	"	0	12,6	13,4	24	0	28
10	299	4	13,4	15,3	29	1	34
11	298	0	14,80	17,00	39	0	44
12	296	0	16,20	18,70	51	0	56
13	295	0	17,60	20,40	66	0	71
14	293	0	19,00	22,10	83	0	87
15	292	0	20,40	23,80	102	0	107
16	290	0	21,80	25,50	124	0	129
17	289	0	23,20	27,20	149	0	154
18	287	0	24,60	28,90	178	0	182
19	286	0	26,00	30,60	209	0	214
20	284	0	27,40	32,30	244	0	249
21	283	0	28,80	34,00	282	0	287
22	282	0	30,20	35,70	324	0	329
23	280	0	31,60	37,40	370	0	375
24	279	0	32,86	38,93	414	0	419
25	277	100	33,98	40,29	456	456	461

N: Number of trees/ha; Intensity of thinning: In percent of number of standing trees; dg: Diameter of mean basal area tree; hg: Height of mean basal area tree; TI: Total increment

Table A 3: Yield projection for Swietenia macrophylla at the study site

Swietenia macrophylla (Caoba)							
Age	**N**	**Intensity of thinning [%]**	**d_g [cm]**	**h_g [m]**	**Remaining Vol. [m³/ha]**	**Harvested Vol. [m³/ha]**	**TI [m³o.b./ha]**
2	400	0	2,1	3	0	0	0
3	"	0	3,8	4,7	1	0	1
4	"	0	6,1	6,2	5	0	5
5	"	0	9,3	9,6	17	0	17
6	"	0	12,3	13	40	0	40
7	"	0	13,2	14,3	51	0	51
8	375	6	14,9	16,1	68	5	73
9	"	0	17,1	17,8	100	0	104
10	368	2	18,8	19,5	129	1	135
11	366	0	20,52	20,24	159	0	165
12	364	0	22,24	20,98	193	0	199
13	363	0	23,96	21,72	231	0	237
14	361	0	25,68	22,46	273	0	279
15	359	0	27,4	23,2	319	0	325
16	357	0	28,62	23,86	356	0	362
17	355	0	29,84	24,52	396	0	402
18	354	0	31,06	25,18	438	0	444
19	352	0	32,28	25,84	484	0	489
20	350	0	33,5	26,5	531	0	537
21	348	0	34,16	27,04	561	0	567
22	347	0	34,82	27,58	592	0	597
23	345	0	35,48	28,12	623	0	629
24	343	0	36,14	28,66	656	0	661
25	341	100	36,8	29,2	689	689	695

N: Number of trees/ha; Intensity of thinning: In percent of number of standing trees; dg: Diameter of mean basal area tree; hg: Height of mean basal area tree; TI: Total increment

Table A 4: Yield projection for Terminalia amazonia at the study site

Terminalia amazonia (Amarillo)							
Age	**N**	**Intensity of thinning [%]**	**d_g [cm]**	**h_g [m]**	**Remaining Vol. [m³/ha]**	**Harvested Vol. [m³/ha]**	**TI [m³o.b./ha]**
2	625	0	1,6	2,7	0	0	0
3	"	0	3,1	4,1	1	0	1
4	"	0	5,7	6,2	4	0	4
5	"	0	7,6	7,9	10	0	10
6	"	0	10,3	11,2	26	0	26
7	"	0	12,2	13,6	45	0	45
8	378	40	14,8	15,6	46	30	75
9	"	0	16,2	17,8	62	0	92
10	284	25	18,8	20	71	11	112
11	283	0	20,50	21,60	91	0	132
12	281	0	22,20	23,20	114	0	155
13	280	0	23,90	24,80	140	0	181
14	278	0	25,60	26,40	170	0	211
15	277	0	27,30	28,00	204	0	245
16	276	0	29,00	29,60	242	0	284
17	274	0	30,70	31,20	285	0	326
18	273	0	32,40	32,80	332	0	373
19	271	0	34,10	34,40	384	0	425
20	270	0	35,80	36,00	440	0	482
21	269	0	37,50	37,60	502	0	543
22	267	0	39,20	39,20	569	0	611
23	266	0	40,90	40,80	642	0	683
24	265	0	42,43	42,08	709	0	750
25	263	100	43,79	43,36	774	774	815

N: Number of trees/ha; Intensity of thinning: In percent of number of standing trees; dg: Diameter of mean basal area tree; hg: Height of mean basal area tree [m]; TI: Total increment [m³o.b./ha]

Table A 5: Changes in the NPV of T. grandis with rising initial cash outflows

Internal rate of return	NPV *T. grandis* [US$/ha]	Increase of initial cash outflow			
	Standard initial cash outflow	25%	50%	75%	100%
0%	55023	54780	54537	54293	54050
1%	41860	41616	41373	41129	40886
2%	31738	31494	31251	31008	30764
3%	23940	23696	23453	23209	22966
4%	17920	17677	17434	17190	16947
5%	13267	13023	12780	12536	12293
6%	9663	9419	9176	8932	8689
7%	6868	6625	6381	6138	5894
8%	4698	4455	4212	3968	3725
9%	3013	2769	2526	2282	2039
10%	1702	1459	1215	972	728
11%	683	440	196	-47	-291
12%	-109	-353	-596	-840	-1083
13%	-725	-968	-1212	-1455	-1699
14%	-1202	-1446	-1689	-1933	-2176
15%	-1572	-1815	-2059	-2302	-2546

Table A 6: Changes in the NPV of H.alchorneoides with rising initial cash outflows

Internal rate of return	NPV *H. alchorneoides* [US$/ha]	Increase of initial cash outflow			
	Standard initial cash outflow	25%	50%	75%	100%
0%	57340	57096	56853	56609	56366
1%	43016	42772	42529	42285	42042
2%	32049	31805	31562	31318	31075
3%	23642	23398	23155	22912	22668
4%	17192	16948	16705	16461	16218
5%	12240	11997	11753	11510	11266
6%	8438	8195	7951	7708	7464
7%	5520	5276	5033	4790	4546
8%	3282	3038	2795	2551	2308
9%	1568	1324	1081	837	594
10%	258	15	-229	-472	-716
11%	-739	-982	-1226	-1469	-1713
12%	-1494	-1738	-1981	-2225	-2468
13%	-2063	-2306	-2550	-2793	-3037
14%	-2487	-2730	-2974	-3217	-3461
15%	-2799	-3043	-3286	-3529	-3773

Table A 7: Changes in the NPV of *S. macrophylla* with rising initial cash outflows

Internal rate of return	**NPV *S. macrophylla* [US$/ha]**	Increase of initial cash outflow			
	Standard initial cash outflow	25%	50%	75%	100%
0%	94921	94678	94434	94191	93947
1%	72335	72091	71848	71605	71361
2%	54980	54736	54493	54250	54006
3%	41622	41378	41135	40891	40648
4%	31324	31081	30837	30594	30350
5%	23375	23132	22888	22645	22402
6%	17233	16990	16746	16503	16259
7%	12483	12239	11996	11753	11509
8%	8807	8564	8321	8077	7834
9%	5963	5720	5476	5233	4989
10%	3763	3519	3276	3033	2789
11%	2062	1819	1575	1332	1088
12%	750	506	263	19	-224
13%	-261	-505	-748	-991	-1235
14%	-1037	-1280	-1524	-1767	-2010
15%	-1629	-1873	-2116	-2359	-2603

Table A 8: Changes in the NPV of *T. amazonia* with rising initial cash outflows

Internal rate of return	**NPV *T. amazonia* [US$/ha]**	Increase of initial cash outflow			
	Standard initial cash outflow	25%	50%	75%	100%
0%	123139	122896	122653	122409	122166
1%	94809	94565	94322	94078	93835
2%	72975	72732	72489	72245	72002
3%	56113	55869	55626	55383	55139
4%	43062	42819	42575	42332	42089
5%	32942	32699	32455	32212	31968
6%	25079	24836	24593	24349	24106
7%	18960	18717	18474	18230	17987
8%	14191	13947	13704	13461	13217
9%	10468	10225	9981	9738	9494
10%	7559	7315	7072	6828	6585
11%	5283	5039	4796	4552	4309
12%	3501	3258	3014	2771	2527
13%	2106	1862	1619	1375	1132
14%	1013	769	526	282	39
15%	157	-86	-330	-573	-817

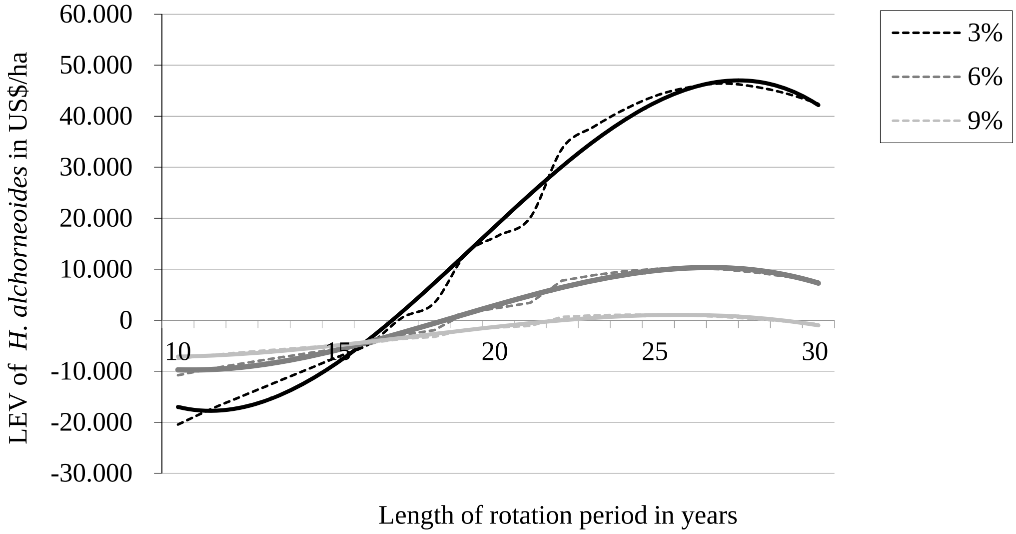

Fig. A 1: LEV development for *H. alchorneoides* under varying rotation lengths

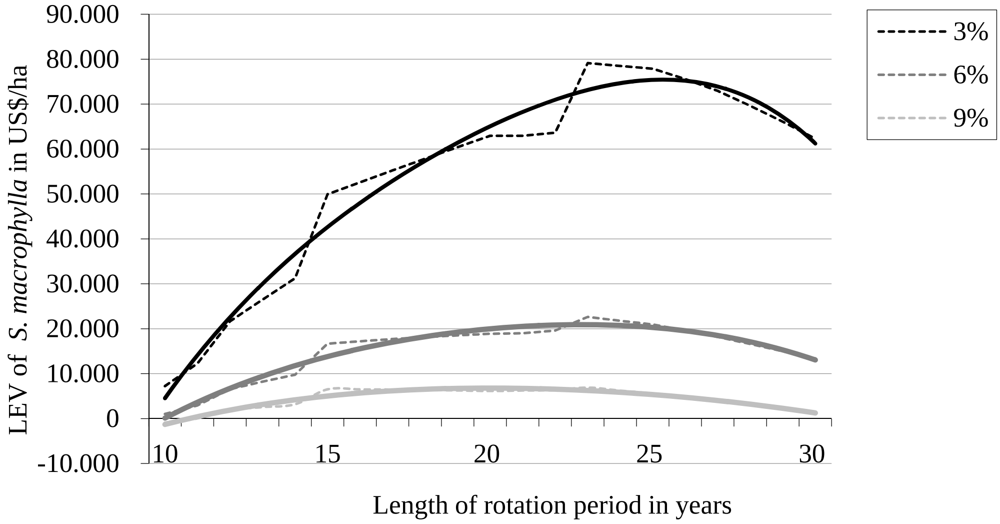

Fig. A 2: LEV development for *S. macrophylla* under varying rotation lengths

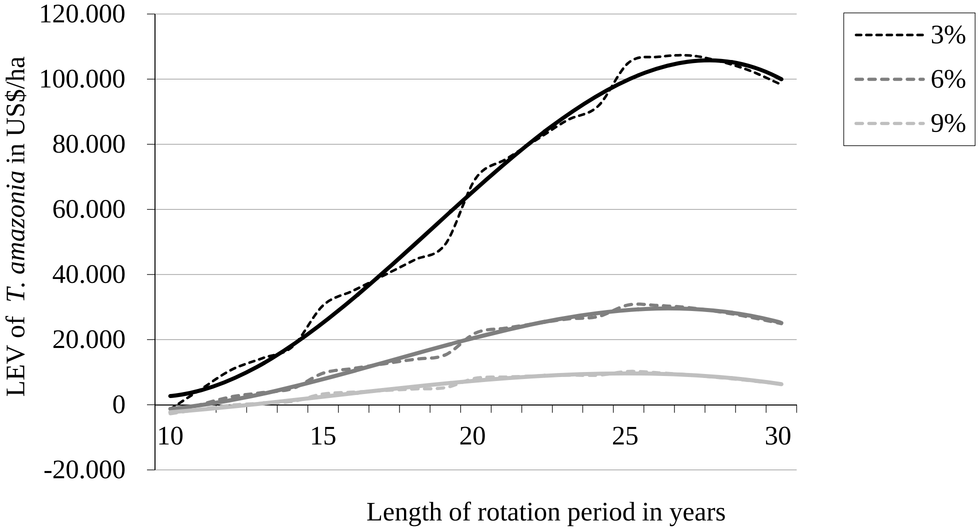

Fig. A 3: LEV development for *T. amazonia* under varying rotation lengths