The development of the industrial forest plantations in the province of Lampung, Indonesia : An economic assessment

THE DEVELOPMENT OF THE INDUSTRIAL FOREST PLANTATIONS IN THE PROVINCE OF LAMPUNG, INDONESIA : AN ECONOMIC ASSESSMENT

I NYOMAN YULIARSANA[1)]
Takeshi AKAHA[2)]

インドネシア・ランプン州における用材林造林の展開
―経済分析―

ニョマン　ユリアルサナ[1)]
赤　羽　　武[2)]

INTRODUCTION

Of the 141 million hectares of the total forest areas of Indonesia, there are approximately 64 million hectares of forests legally designated as production forest. This category of forest has played an important role as timber resources for the forestry based development program which has been undertaken in Indonesia up to now. In other words, the forestry development program which has been carried out over twenty years, has wholly emphasized on exploiting those natural production forests.

Since a rate of deforestation in Indonesia has been estimated by the World Bank (1989) at approximately 900,000 hectares per annum; in the meantime, the acceleration of depletion of the natural production forest is critical. As a result, the productivity of the production forest of the natural forests has been rapidly declining.

On the other hand, considering that the natural forests will be able to grow at a rate of 1.1 cubic metre annually and such rapid deforestation is still increasingly occurring, the estimate of their annual productions will be about 24 million cubic metres only.

The massive competition among the domestic forest products industries at present, needles to say, will bring about a shortage in logs supply in the near future.

In addition to this, a policy on forestry was introduced in 1979 which outlined a ban on

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1) and 2): Forest Economics Division, Institute of Agriculture and Forestry, University of Tsukuba.
（筑波大学農林学系）

log exports and change in orientation of forest products exports, consequently, the domestic forest product industries increased sharply within the following five years. In this context, it was noted that in 1985, for instance, the total capacity of those forest product industries reached 20.60 million cubic metres which was equal to a 200% increase as compared to 1980 (Apandi, M., 1986).

In the meantime, according to data which was newly published in 1990, the domestic pulp and paper industries appear to have a tendency to increase as well. In this context, based on a statistical data recorded by the World Bank from 1975 to 1987, the overall production of the Indonesian pulp and paper grew at an average of 28% per annum. Of the 42 domestic pulp and paper industries, which are operating at present, there are 10 pulp mills which are together capable of producing a total of 2,934,000 tons per annum. Investment in these pulp mills is planned to be expanded in the very near future and the new and old capacity will also use chiefly mixed tropical hard wood. As mentioned earlier, the growing stock of the existing productive forests will not be sufficient to satisfy the needs for raw materials of the timber industries, so it is very necessary that a forest plantation program be carried out soon.

A GLIMPSE OF THE INDUSTRIAL FOREST PLANTATION PROGRAM IN INDONESIA

As a countermeasure against the problem of the shortage of raw materials for the timber industries and increasing the unproductive production forest, in particular, since 1983/1984 the Ministry of Forestry has promptly launched a forestry plantation scheme which is the so-called *industrial forest plantation or timber estate.*

The target areas under this program is a total of 6.20 million hectares including the present 1.80 million hectares forest plantation that already exist all over Indonesia. Therefore, there would be at least some 4.40 million hectares of the industrial forest plantation that ought to be established by year 2000 which will consist of a total wood production capacity of 93.40 million cubic metres. In this context, as the 1990 World Bank country study reported, the planned plantation areas started in the fourth five-year plan was 120,000 ha/year increasing to 360,000 ha/year in the sixth.

Despite the fact that this plantation scheme is quite ambitious, more forest plantation is indeed required to rehabilitate the depleted forests and to improve the environment as well.

Locations of this activity are mainly the unproductive areas of the present production forests situated both in and outside the concession forests (and so includes the logged-over

forests and the grassland areas).

Tree species covers a variety species of both fast growing and slow growing trees such as Dipterocarpaceae, mahogany, *Acacia spp.*, *Parienthes falcataria*, and the like which will be used to establish of energy, pulpwood and sawn timber plantations for industries. In other words, based on the timber utilization plan, plantations may be classified into management units aimed at the following: (1) supplying raw materials for a pulp and paper industry which will occupy an area of at least 30,000 hectares; and (2) feeding raw materials to sawmill and the other mills which will occupy an area of 60,000 hectares. The chief goals of the industrial forest plantation are addressed in detail in the following points:

(1). to support development of the domestic forest products industries, in order to be capable of boosting revenues coming from the added-value production as well as foreign exchange from exports.

(2). to increase productivity of the existing forestlands and, in particular, the quality of the environment in general.

(3). to extend and to create both employment and business opportunities, especially for the local inhabitants.

In addition to managing these plantations in a professional manner, they must be carried out based on sound concepts of both business and sustained yield principles. The legal institution which are allowed to conduct these schemes are the state-owned forestry enterprises, private companies, and cooperatives as well as other organizations interested in doing so. Silvicultural systems that should be adopted are clear cutting followed by planting.

I. A CASE STUDY OF THE INDUSTRIAL FOREST PLANTATION DEVELOPMENT IN THE PROVINCE OF LAMPUNG: AN ECONOMIC ASSESSMENT

1. Background

One of the realizations of the ambitious plan of industrial forest plantation establishment is located in the province of Lampung, Sumatra which has been carried out in the form of two projects situated respectively in the Way Terusan area in the central region and in the Rebang Dan Sekitarnya (the Rebang DS) area in the northern region and. Both projects has been implemented and managed by the state-owned forestry enterprise PT. INHUTANI I (Indonesian Forest Industry Company, Ltd, First Unit). These areas have been selected, because the present condition of the production forests within those areas is very critical and may be categorized as a state of unproductive lands in which most of the land is

predominantly covered with alang-alang grass (*Imperata cylindrica*). Another factor which motivates the immediate implementation of the industrial forest plantation is that, according to data of several studies on demand and supply of timber in Lampung region, there has already been a shortage of wood for local consumption such as construction timber, due to the fact that the present production forest is not capable of satisfying supply of wood any more for the local timber industries. It has been further clearly demonstrated through a study conducted by the faculty of Forestry of the Bogor Agriculture University (IPB) in 1988, that a total of 83 of saw mills with a total capacity of 225,400 cubic metres per annum and one plywood mill with a 35,700 cubic metres per annum capacity, seem to be confronted with a shortage of raw materials for feeding those industries at the time of survey and in the future. Also, based on data on timber production from 1979/1980 to 1985/1986, the total supply of logs appears to have sharply decreased, that is, from 108,802 cubic metres to only 35,700 cubic metres per annum. As a result, an industrial forest plantation which can produce at least a 15 cubic metres per hectare per annum is urgently required to be implemented immediately. As a result, the forest plantations composing of the fast growing species of *Acacia mangium* and *Eucalyptus spp.*, and the slow growing fancy wood, *Swietenia macrophylla*, have been planted since 1986/1987.

A. mangium and *E. urophylla* plantations are located in the Rebang DS and were planted in the 1986/1987 fiscal year and are now occupying a total area of 1,770 hectares, while *S. macrophylla* plantation is located in the Way Terusan area and was also planted in same year and occupies a total area of 2,151 hectares.

However, in the viewpoint that these plantations are considered as a forestry investment, a criteria is needed to determine whether they have the potential to generate an economic profits and this is the main issue that it is necessary to examine. In other words, a judgment of the potential return is a crucial point for those who willing to participate in conducting forest plantation program.

2. Objective of this study

Firstly, in relation to the industrial forest plantations developed in the province of Lampung, this study attempts to explore and to assess the potential economic profitability of the plantations of *A. mangium* (hereafter referred to as *"mangium"*) and *E. urophylla* (hereafter referred to as *"eucalypt"*) and also *S. macrophylla* (hereafter referred to as *"mahogany"*) which have been established in the Way Terusan and the Rebang DS projects.

Secondly, a sensitivity analysis is carried out for: determining and displaying the relative importance of the four designated variables (establishment/silvicultural cost, harvest cost,

yield and market price of timber); examining their effect on the attractiveness of the investment; and exploring the risk and uncertainties in the four designated variables which it is supposed would likely appear within the given rotation.

Thirdly, to be able to estimate a reasonable wood price level as well as an optimum establishment cost for each plantation, a minimum level criterion of Net Present Value (NPV) = 0 at a certain price and cost levels was adopted.

3. Method of study and analysis

In order to explore the potential economic return of the forest plantation which is mainly linked with silviculture and management practices, this study seeks to adopt three models of plantation management associated with the outputs produced which is the so-called management regime (Sedjo, Roger A. 1983 p:12). They contain two models of a mutually exclusive plantation regimes for both the mangium and the eucalypt plantations, and one model of a management regime of the mahogany plantation. The following are the details of each management regime.

1). *Integrated regime*

The plantation categorized under this regime is for simultaneously producing both sawlogs and pulpwood within the given length of rotation. Thinning is scheduled for year 8 for the mangium plantation and in year 10 for the eucalypt plantation respectively. The thinning wood, thus, will be commercially treated as pulpwood and will presumably be merchantable, while the final harvest clear-cut will be done in year 15 and to be treated as sawlogs. The length of rotation is set at 15 years.

2). *Pulpwood regime*

The plantation under this regime is directed to produce only pulpwood within the given rotation length. Thus there would be no thinning so that the wood produced from the final harvest which is scheduled in year 10 would be commercially treated as just pulpwood. The plantations to be managed under this regime are the mangium and the eucalypt in which the rotation length is set at 10 years.

3). *Sawlog regime*

The plantation assumed to be managed under this regime would produce only sawlogs within the given rotation length. The Commercial thinnings are scheduled in years 10, 15, and 20 and the final harvest clear-cut would be conducted in year 30; the thinning wood would be totally treated exclusively as sawlogs. The plantation supposed to be managed under this regime is the mahogany which has a 30 year rotation length.

The method of analysis employed in assessing the potential economic profitability of

these industrial plantations is the application of a Discounted Cash Flow (DCF) model which involves discounting all costs and revenue/benefit flows generated by the given plantations by using a given discount rate over the given rotation length. Variables utilized in the DCF, therefore, are establishment/silvicultural costs, thinning costs, harvest costs, market prices of wood, the rotation length and the discount rate.

Since this study perceives the plantation establishment as an forestry investment in which the investor is the state-owned enterprise PT. INHUTANI I which is regarded as a private investor investing its own capital in the forest plantation project, it ought to maximize its own financial returns. In other words, this study will just assess the financial profitability of the industrial forest plantation by using market prices rather than shadow prices of the products of the plantations.

To calculate the rate of returns which will indicate viability of the investment, the conventional investment criteria models of Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit Cost Ratio (BCR) were used. These may be described in great detail with the following equations:

$$NPV = \Sigma \text{ PV revenues/benefits} - \Sigma \text{ PV costs}$$

$$= \Sigma\, Rt/(1+i)^t - \Sigma\, Ct/(1+i)^t \quad \cdots\cdots (1)$$

where; R = revenues (benefits)

C = costs

n = investment period

t = year of costs incurred or revenues received

i = discount rate.

$$IRR = \Sigma\, Bt/(1+i)^t - \Sigma\, Ct/(1+i)^t = 0 \quad \cdots\cdots (2)$$

where; B = benefits (revenues)

C = costs

t = year of costs incurred or revenues received

i = discount rate

$$BCR = \frac{\{\Sigma\, Bt - \Sigma\, Ct/(1+i)^t\} \quad (Bt - Ct > 0)}{\{\Sigma\, Ct - \Sigma\, Bt/(1+i)^t\} \quad (Bt - Ct < 0)} \quad \cdots\cdots (3)$$

where; Bt = benefits in year t

Ct = costs in year t

i = interest rate

t = time (year)

To recognize the sensitivity of the financial performance of the plantations with respect to changes in the given variables, a sensitivity analysis was carried out based on the follow-

ing changes:

(a). Sensitivity based on a 10% error in each variable by assuming that either such an error of this size is to occur once, or that a modest error in the variables will occur frequently.

(b). Sensitivity analysis based on optimistic and pessimistic estimates of values of the given variables. It is aimed at assessing : what extent of risk and uncertainty would be appear corresponding to the given variables; what is the extent of the degree of sensitivity to the given variables.

(c). Sensitivity analysis employing a variety of discount rates to determine in great detail their effects on the financial profitability performance of all the plantations.

II. Results and discussion

1. Results

1). Costs

Costs of the plantations which are considered as the crucial variables employed in the DCF for analysing the potential economic profitability may be categorized into establishment costs, stand improvement costs, pre-commercial and commercial thinning costs and final harvest costs. They are clearly depicted in the following Table.

Table 1. Costs of the plantations (US$ per hectare)

Activity	Management regime				
	INTR		PLP		SWLG
	A.m	E.u	A.m	E.u	S.m
1. Establishment*)	371	371	371	371	351
2. Stand improvement**)	118	45	—	—	—
3. Precommercial thinning**)					
*the first	—	—	—	—	17
*the second	—	—	—	—	39
4. Commercial thinning**)					
*the first	9	9	—	—	29
*the second	—	—	—	—	35
*the third	—	—	—	—	89
5. Final harvest costs**)	15	15	9	9	15

Remarks:
INTR : integrated regime
PLP : pulpwood regime
SWLG : sawlog regime
A.m : *Acacia mangium*
E.u : *Eucalyptus urophylla*
S.m : *Swietenia macrophylla*
*) the real cost expended by the projects in 1986/1987
**) the estimate value based a wide variety of sources
1 US$ = Rp 1,700 as of in 1987

2). The estimate of yield.

The estimate of yield of each plantation species is calculated by adopting the available yield tables as far as they exist, whilst for mangium and eucalypt, especially, the estimate of yields have been constructed by the use of an equation of a growth function of the tree.

Estimates of the yields of each plantation under the given management regime and the given rotation length are summarized as Table 2.

Table 2. The estimate of yields of the plantations

Management regime/ species	Yield (m^3/ha)					
	Thinning				final harvest	Estimate MAI (m^3/ha/yr)
	1	2	3	4		
1. INTREGATED						
a. mangium	60	—	—	—	303	20
b. eucalypt	51	—	—	—	215	14
2. PULPWOOD						
a. mangium	—	—	—	—	222	22
b. eucalypt	—	—	—	—	159	16
3. SAWLOG						
a. mahogany	4	19	34	43	253	8

Remarks:

MAI: Mean Annual Increment

The yield of mangium and eucalypt have been estimated by employing a tree growth function namely $V = (a+b/t)^{10}$, where a and b are parameters of growth, t is time. Based on several assumptions related to their estimated growth rates, it has been estimated that parameters a and b for mangium are 2.75 and −4.03, respectively, while for eucalypt, parameters a and b 2.60 and −4.00 respectively.

mahogany has been calculated just through the use of a correction function of $V = a(1-e^{+bt})^c$ over the existing Yield Table constructed by the state-owned enterprise of Perum Perhutani in the island of Java.

3). The estimate of market prices of wood

It is known that the plantations which are being examined are of a relatively young age, namely about three years under way, so that to estimate market prices of wood produced, an estimate based on various data and information obtained from either a feasibility study or statistical price data is needed.

The following Table 3 contains the estimated market prices of the wood produced which have been adopted from a wide variety of sources.

Table 3. The estimated wood prices

Management regime	Prices (US$ per cubic metre)	
	Commercial	Final harvest
1. INTEGRATED		
a. mangium	9	25
b. eucalypt	9	25
2. PULPWOOD		
a. mangium	–	18
b. eucalypt	–	18
3. SAWLOG		
a. mahogany	25*)	53
	35#)	

Remarks:

Market prices of wood of mangium and eucalypt under the integrated and the pulpwood regimes were taken from the results of feasibility studies and other studies made by Jaako Poyry of Finland, the World Bank and the like which are considered appropriate and of a reasonable value to be employed in the economic assessment here.

Market prices for mahogany, in the meantime, were accurately estimated based on the price data recorded by Perum Perhutani in the Java island.

*) the first commercial thinning

#) the second commercial thinning

4). The economic assessment

Based on the above-mentioned data, Table 4 shows estimates of revenue profiles generated for all plantations under management regimes that would be employed in subsequent DCF analysis.

Table 4. Estimates of revenue of the plantations

Regime/species (1)	MAI (m^3/ha/yr) (2)	Rotation (yr) (3)	Total volume (m^3/ha) (4)	Price (US$/$m^3$) (5)	Total cost (US$/ha) (6)	Net revenue (US$/ha) (7)
1. INTEGRATED						
a. mangium	20	15	303	25	5151	2812
b. eucalypt	14	15	215	25	3778	1972
2. PULPWOOD						
a. mangium	22	10	222	18	2464	1460
b. eucalypt	16	10	159	18	1862	935
3. SAWLOG						
a. the mahogany	8	30	253	53	4436	1072

(1). Discount rate

In the DCF analysis two discount rates of 10% and 12% are employed, where the discount rate of 10% is generally utilized by the government of Indonesia to justify public pro-

jects (Sedjo, R.A., 1988 p:7 and Kadariah et al, 1978 p:74). The other discount rate used, 12 %, is regarded as a risk-free discount rate or an inflation-adjusted discount rate. Both discount rates are within a range of commonly-used discount rates used by Indonesian economists and projects analysts, as well as in other developing countries for cost-benefit analyse of investment projects.

(2). The Potential financial profitability

As explained earlier, this study attempts, to explore the financial profitability performance of the plantations. In other words, it assesses only the financial returns generated the capital invested in the development of industrial forest plantation. Estimation of the economic returns in broader sense which include externalities of the projects is the beyond of scope of this study. The results of these calculations of the potential financial profitability of the plantations are presented in Tables 6 and 7.

Table 6. The financial profitability of the plantations at a 10% discount rate.

Regime/species	NPV (US$ per ha) Rotation cut 1 st	inf.	IRR (%)	NBCR	NPV per initial invested (US$ per ha) 1 st	inf.
1. INTEGRATED						
a. A.m	476	626	16.56	2.12	2.65	2.81
b. E.u	254	333	15.75	1.67	1.13	1.49
2. PULPWOOD						
a. A.m	360	586	18.70	2.04	1.62	2.63
b. E.u	157	256	14.49	1.45	0.71	1.15
3. SAWLOG						
a. S.m	490	519	14.12	2.39	2.41	2.56

Remarks:
1 st: first rotation
inf : infinite series of rotation

Table 7. The financial profitability of the plantations at a 12% discount rate.

Regime/species	NPV (US$ per ha) Rotation cut 1 st	inf.	IRR (%)	NBCR	NPV per initial invested (US$ per ha) 1 st	inf.
1. INTEGRATED						
a. A.m	295	361	16.56	1.70	1.33	1.62
b. E.u	122	149	15.75	1.32	1.88	1.49
2. PULPWOOD						
a. A.m	248	365	18.70	1.72	1.11	1.64
b. E.u	78	115	14.49	1.23	0.35	0.52
3. SAWLOG						
a. S.m	190	196	14.12	1.55	0.94	0.97

3). Sensitivity analysis

The result of the sensitivity analysis of each plantation under each given management regime at 10% and 12% discount rates, assuming that a 10% error occurs in each variable are displayed clearly in Figures 1 and 2.

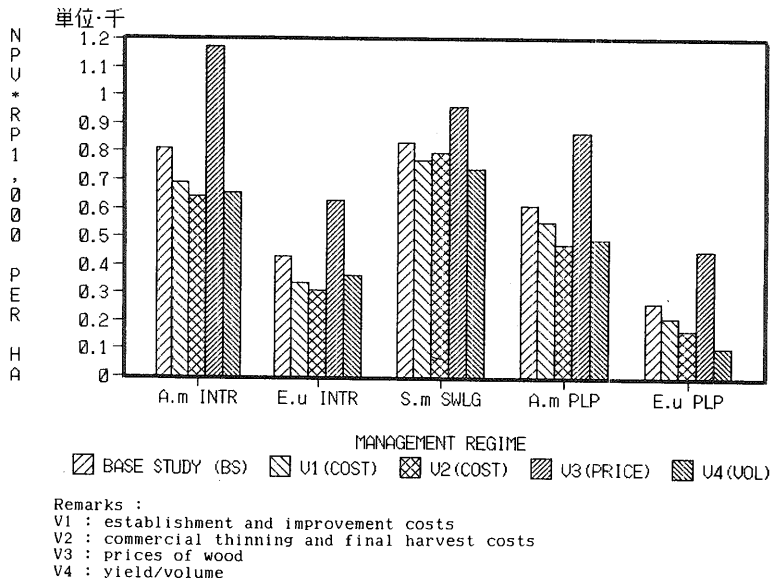

Figure 1. NPV of all plantations based on 10% error in each variable (DF 10%)

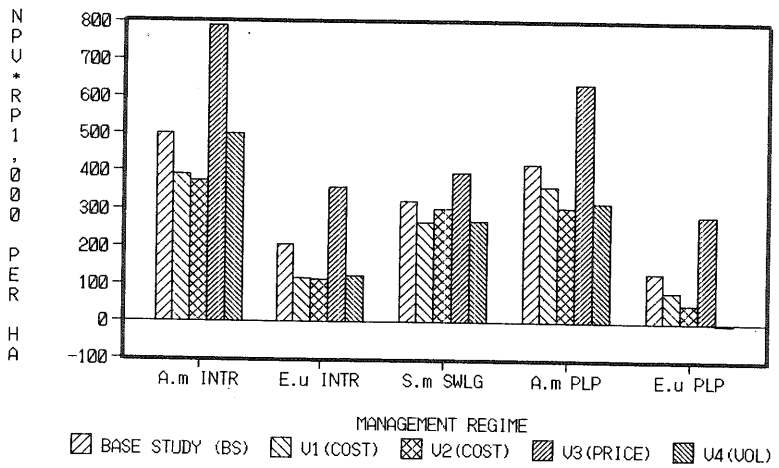

Figure 2. NPV of all plantations based on 10% error in each variable (DF 12%)

Meanwhile, the result of sensitivity analysis in terms of NPV based on values of an optimistic and a pessimistic estimate of each variable are presented in Tables 8 and 9.

Table 8. The result of sensitivity analysis of plantations based on optimistic and pessimistic estimates of each variable at 10% discount rate for a single rotation

Variable/ regime	NPV at (× Rp 1,000)							
	M.L. EST	OPT. EST	PST. EST	OPT. EST	PST. EST	SENS. COEF	SQUARE OF. COEF	RANGE OF. COEF
I. INTEGRATED								
A. Am								
V 1	829	609	949	1012	715	295	88661	0.12
V 2	42	37	46	1060	609	951	203203	0.24
V 3	73	100	50	2195	−323	2518	6339166	1.00
V 4	303	315	290	859	760	99	9853	0.05
B. Eu								
V 1	707	520	819	509	338	171	29258	0.15
V 2	42	37	46	602	291	311	96802	0.26
V 3	73	100	50	1471	−289	1759	3094679	1.00
V 4	215	225	200	540	437	103	10535	0.09
II. PULPWOOD								
A. Am								
V 1	630	460	739	626	502	124	15331	0.07
V 2	16	13	19	869	355	514	264515	0.03
V 3	30	40	20	1469	−245	1714	2939030	1.00
V 4	222	250	200	761	491	270	72835	0.16
B. Eu								
V 1	630	460	739	475	158	317	100603	0.59
V 2	16	13	19	451	84	367	13477	0.69
V 3	30	40	20	878	−344	1222	1493504	1.00
V 4	159	175	125	356	86	270	72900	0.59
III. SAWLOG								
A. Sm								
V 1	708	551	813	954	620	333	111156	0.06
V 2	33	30	35	869	814	55	3071	0.10
V 3	200	220	168	1028	477	551	303472	1.00
V 4	253	270	225	895	730	165	27242	0.30

Remarks
M.L. EST = most likely estimate
OPT. EST = optimistic estimate
PST. EST = pessimistic estimate
SEN. COEF = sensitivity coefficient
SQUARE OF. COEF = square of coefficient
RANGE OF. COEF = range of coefficient

Table 9. The result of sensitivity analysis of plantations based on optimistic and pessimistic estimates of each variable at 12% discount rate for a single rotation

Variable/ regime	NPV at (× Rp 1,000)							
	M.L. EST	OPT. EST	PST. EST	OPT. EST	PST. EST	SENS. COEF	SQUARE OF. COEF	RANGE OF. COEF
I. INTEGRATED								
A. Am								
V 1	829	609	949	703	412	291	84797	0.15
V 2	42	37	46	702	341	361	130487	0.18
V 3	73	100	50	1588	−391	1979	3916124	1.00
V 4	303	315	290	537	465	72	5180	0.03
B. Eu								
V 1	707	520	819	288	118	170	28876	0.13
V 2	42	37	46	341	96	245	60206	0.18
V 3	73	100	50	1013	−336	1349	1819612	1.00
V 4	215	225	200	290	211	78	6137	0.05
II. PULPWOOD								
A. Am								
V 1	630	460	739	400	311	88	7802	0.06
V 2	16	13	19	636	206	430	184470	0.31
V 3	30	40	20	1137	−259	1396	194796	1.00
V 4	222	250	200	546	320	225	50796	0.16
B. Eu								
V 1	630	460	739	338	24	315	99118	0.31
V 2	16	13	19	286	−20	306	9340	0.30
V 3	30	40	20	643	−377	1021	1041604	1.00
V 4	158	175	125	207	−8	215	46389	0.21
III. SAWLOG								
A. Sm								
V 1	708	551	813	442	112	329	108320	0.97
V 2	33	30	35	345	311	34	1159	0.10
V 3	200	220	168	444	106	339	114826	1.00
V 4	253	270	225	359	263	96	9241	0.28

The degree of sensitivity with respect to the variables at given discount rates is demonstrated in Table 10, while the result of sensitivity analysis based on various discount rates is shown in Table 11.

Table 10. The degree of sensitivity of the variables of based on the result of the sensitivity analysis at 10% and 12% discount rates

Regime/species	Discount rate			
	10%		12%	
	SENSITIVE	NON SENSITIVE	SENSITIVE	NON SENSITIVE
I. INTEGRATED				
A. A.m				
	V 3	V 4	V 3	V 4
	V 2		V 2	
	V 1		V 1	
B. E.u	V 3	V 4	V 3	V 4
	V 2		V 2	
	V 1		V 1	
II. PULPWOOD				
A. A.m	V 3	V 1	V 3	V 1
	V 2		V 2	
	V 4		V 4	
B. E.u	V 3	NONE	V 3	NONE
	V 2		V 1	
	V 4		V 2	
	V 1		V 4	
III. SAWLOG				
A. S.m	V 3	V 2	V 3	V 2
	V 1		V 1	
	V 4		V 4	

Table 11. NPV of plantations at various discount rates and rotation lengths

REGIME	ROTATION LENGTH	NPV (× RP 1,000) /HA						
		discount rate (%)						
		4	6	9	10	12	15	17
I. INTEGRATED								
a. Mangium	one(15)	2,480	1,756	998	809	502	174	19
(A.m)	two(30)	3,857	2,489	1,271	1,002	594	196	21
	inf(~)	5,577	3,013	1,375	1,063	614	199	21
b. Eucalypt	one(15)	1,657	1,124	567	429	205	−34	−146
(E.u)	two(30)	2,576	1,592	722	531	242	−38	−160
	inf(~)	3,725	1,928	781	564	250	−38	−162
II. PULPWOOD								
a. Mangium	one(10)	1,491	1,134	723	612	421	198	82
(A.u)	two(20)	1,008	1,768	1,028	848	556	247	99
	thr(30)	3,178	2,122	1,157	938	600	259	103
	inf(~)	4,595	2,595	1,251	996	621	263	104
b. Eucalypt	one(10)	887	635	345	267	133	−23	−104
(E.u)	two(20)	1,486	990	491	370	177	−29	−125
	thr(30)	1,891	1,188	553	410	190	−30	−130
	inf(~)	2,734	1,439	598	435	196	−31	−131
III. SAWLOG								
a. Mahogany	one(30)	5,694	3,153	1,205	832	323	−91	−239
(S.m)	two(60)	7,450	3,702	1,295	880	333	−92	−241
	inf(~)	8,232	3,818	1,303	883	334	−92	−241

Remarks:
one(10); one(15): one/single rotation with 10 years or 15 years rotation length
two(20); two(30) etc: two/double rotation with 20 years or 30 years rotation length
inf(~): an infinite series of rotation/ a perpetual series of rotation

4). Minimun establishment cost

The results of analysis of the minimum establishment cost for each plantation regime which has been computed on the basis of a NPV = 0 is presented in Figures 3, 4, 5, 6 and 7.

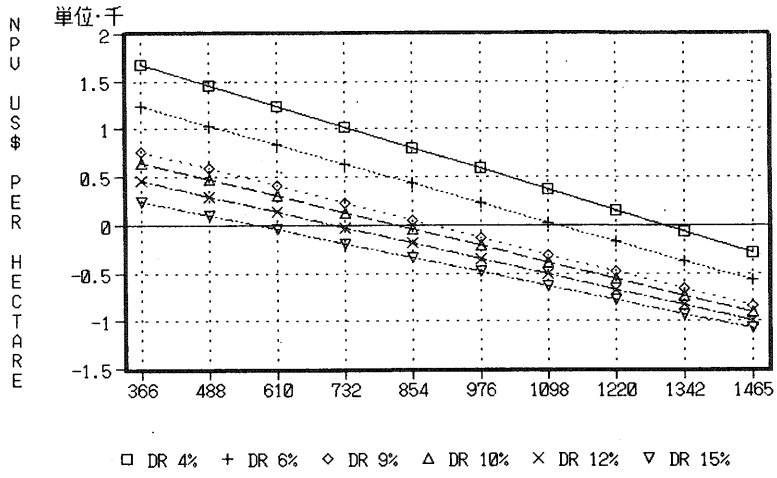

Figure 3. Minimum establishment cost of the mangium plantation (INTR)

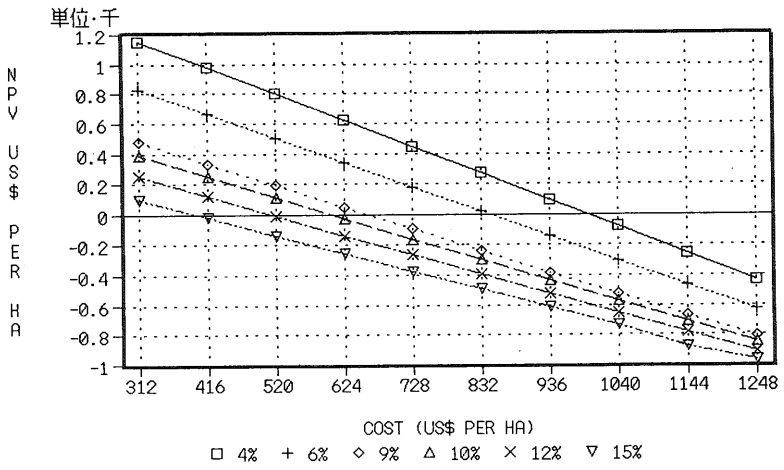

Figure 4. Minimum establishment cost of the eucalypt plantation (INTR)

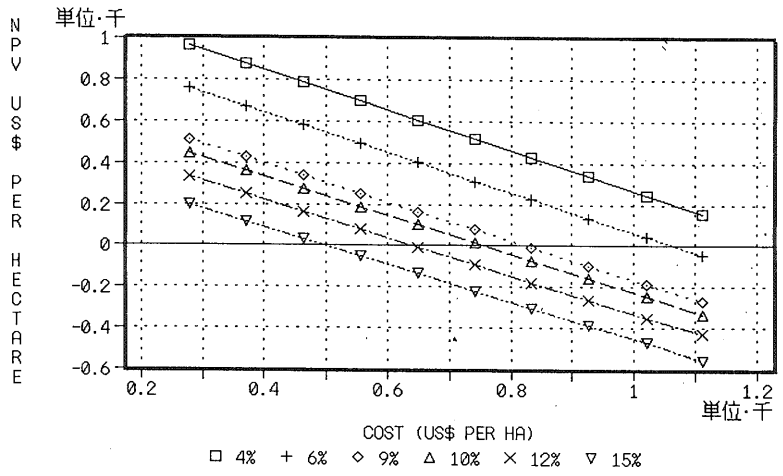

Figure 5. Minimum establishment cost of the mangium plantation (PLP)

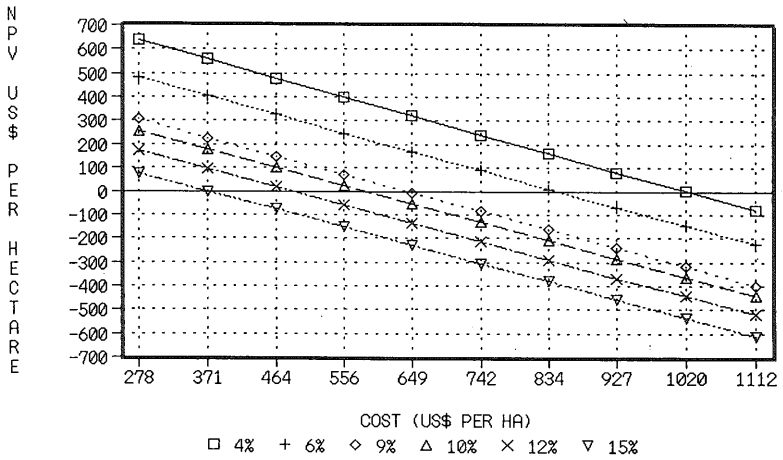

Figure 6. Minimum establishment cost of the eucalypt plantation (PLP)

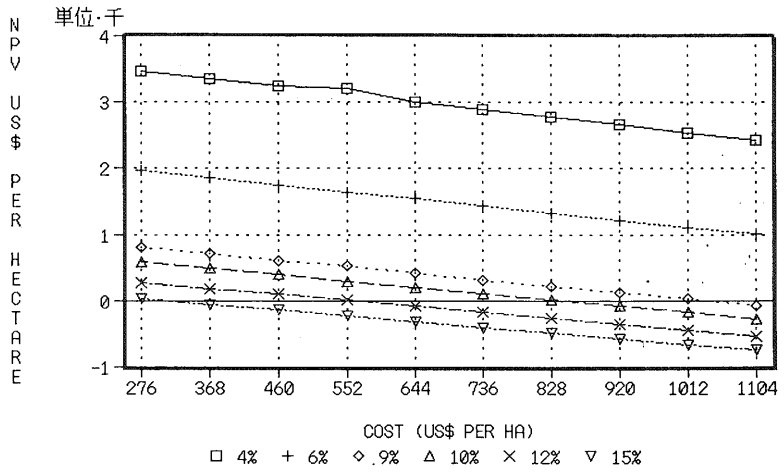

Figure 7. Minimum establishment cost of the mahogany plantation (SWLG)

5). Minimum prices of wood

The following Figures are the result of the minimum prices of wood for each plantation regime. They are also analysed on the basis of determining a NPV = 0.

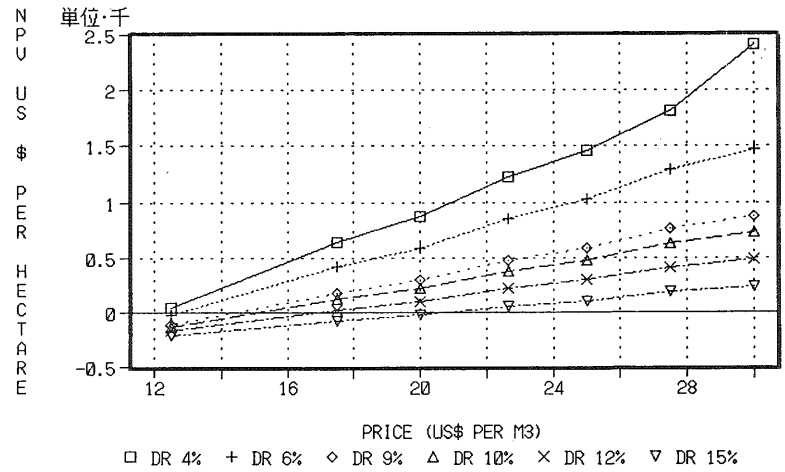

Figure 8. Minimum price of the mangium plantation at various discount rates (INTR)

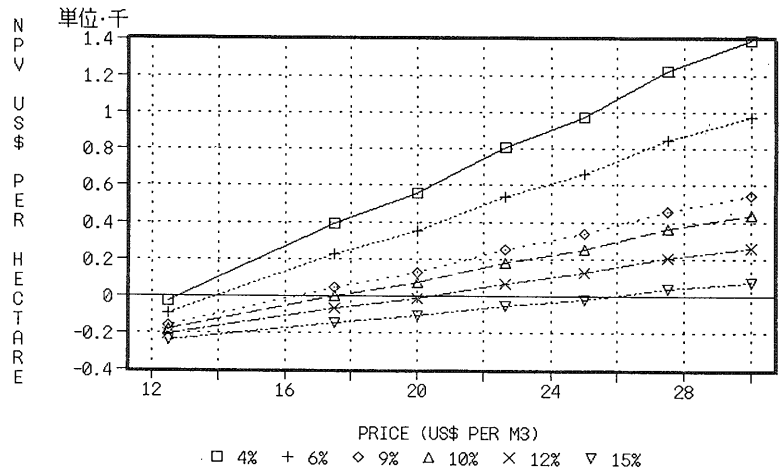

Figure 9. Minimum price of the eucalypt plantation at various discount rates (INTR)

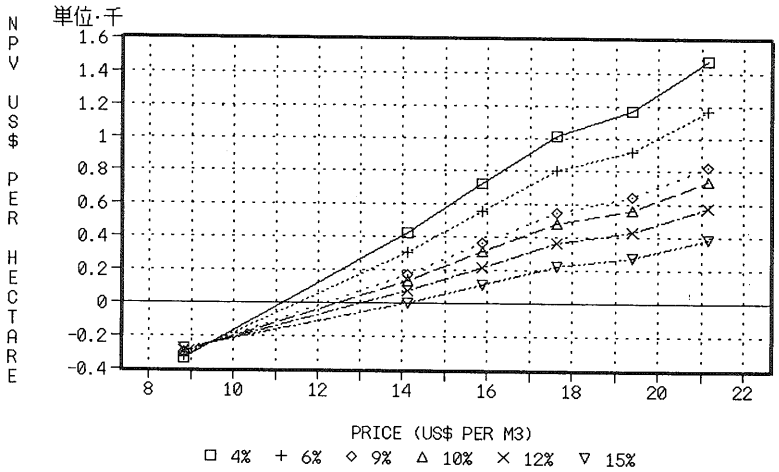

Figure 10. Minimum price of the mangium plantation at various discount rates (PLP)

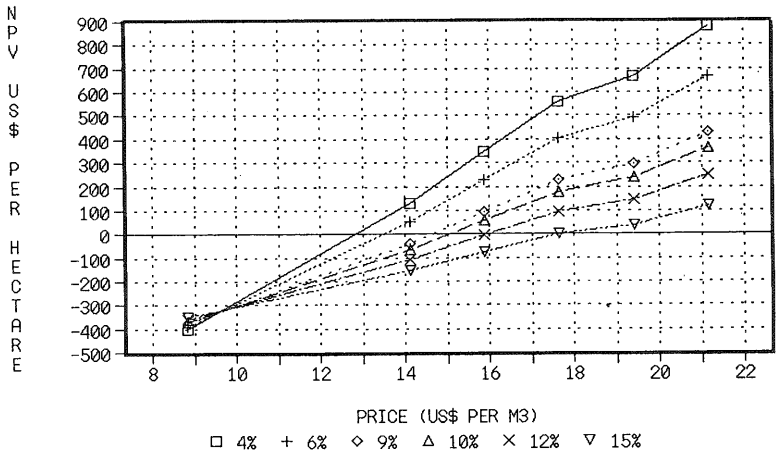

Figure 11. Minimum price of the eucalypt plantation at various discount rates (PLP)

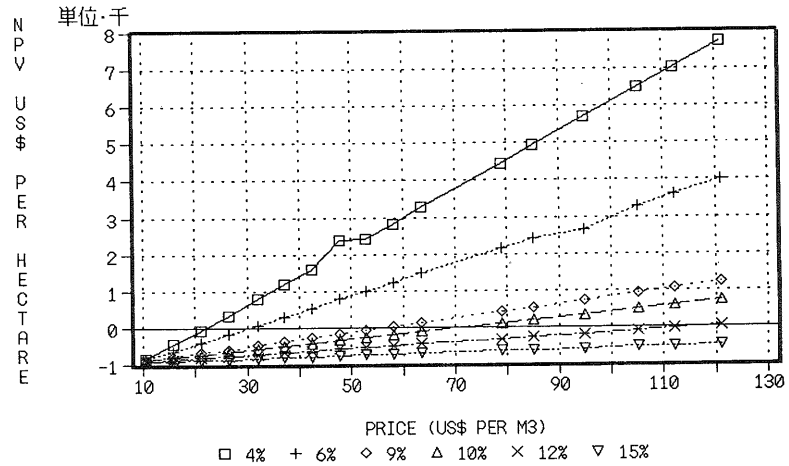

Figure 12. Minimum price of the mahogany plantation at various discount rates (SWLG)

2. Discussions

Based on the results of the analysis using conventional investment criteria such as NPV, IRR and NBCR, it is clear that, overall, the plantations managed under the given management regime at the given discount rates (10% and 12%) are financially viable. This is due to satisfying the conditions that NPV > 0, IRR > 12% and NBCR > 1; these conditions indicated that the investment is financially feasible enough and will generate profits, thus they are profitable to implement.

An attempt to examine the sensitivity of the analysis through three assumed changes in given variables demonstrated that it seems the plantations are still profitable. However, the sensitivity analysis that employed various discount rates indicated that at a 15% discount rate the mangium plantation under the integrated and the pulpwood regimes appears to be capable of generating reasonable financial profitability which is shown by its positive NPV, whilst the other are not. In this context, it is implied that the mangium plantation may be able to be established in the case of a discount rate of 15%. Also, an interesting finding emerged from the sensitivity degree analysis of the plantation shows that the profitability is much more sensitive to the price of wood than to the other variables. Thus, it may be concluded that the price of wood is a vital issue that should be considered in order to establish a financially viable forest plantations. In this context, a minimum wood price analysis was conducted in order to further investigate the financial profitability performance if wood prices move to a minimum level. The result of analysis indicated that for a pulpwood plantation of mangium and eucalypt, for instance, to be minimally financially viable, it needs a wood price range of a US$ 12.5−17.5 per cubic metre at a 10% discount rate and one of US$ 13−20.5 per cubic metre if a 12% discount rate is employed.

The minimum establishment cost calculated from the analysis implies that it would be profitable to establish a forest plantation with costs below US$ 1000 per hectare as shown in the previous figures above (Figures 3, 4, 5, 6 and 7). Therefore, in relation to this and as example, to develop a profitable pulpwood plantation composed of mangium and eucalypt species, it seems that the minimal establishment cost ranges between US$ 602−750 per hectare if a 10% discount rate is used, whilst a range of US$ 487−650 per hectare would be needed in case of a discount rate of 12%. From these results, therefore, it may be thought that indeed the establishment cost is directly influenced by the discount rate used. The results indicated clearly that the higher discount rate, the lower was the minimum establishment cost. To consider this point, the determination of establishment costs in US$ per hectare is an important issue but is often difficult to estimate, and planners are not precisely sure how much should be spent. But from the result of this study, we can see that these

costs certainly depend upon the level of the discount employed.

In other words, it is obvious from the above point that the magnitude of the establishment cost is closely and mainly associated with the discount rate employed.

To sum up, the development of the industrial forest plantations in the province of Lampung, particularly, offers a promising return to those who are interested in participating in the development of industrial forest plantation schemes. From the viewpoint of the effort of rehabilitating the unproductive forest in the province of Lampung, it appears quite effective in supporting the critical lands rehabilitation programme. It also promises positive externalities and benefits from the multiplier effect for the local inhabitants. Therefore, in the future plantations should be encouraged, esessentially with the aim of meeting the shortage of local timber supply.

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要　　旨

研究の目的と方法

インドネシアには，全土で約6,400万haの生産林が存在する。近年これが次第に非生産林化してきたため，インドネシア林業省は，1984年以来，生産力を高め，一度荒廃した林地に森林を復旧するとともに，住民の雇用の機会を作り出すことを目的として大規模な人工林プログラムを実行してきている。

このプログラム実現のため，インドネシアは，政府出資によって林業公社・インフタニ（PT. INHUTANI I）を設立した。この林業公社は現在，ランプン州の2ヵ所で用材林造成事業を行っている。公社は，1986年度設定のルバン・プロジェクトで2年生の*Acacia mangium*と*Eucalyptus urophylla*を植栽している。また同時に設定したワイテルサン・プロジェクトにおいても2年生の*Swietenia macrophylla*を植栽している。

こうした用材林の造林を経済的にどう評価するか，すなわち，用材林の造林は果たして採算がとれるか否かという問題を検討することは重要な課題である。

そこで，適切な人工林を造成し，経営することを目的として，インフタニIの2つのプロジェクトを事例に，その経済評価を行うことにした。

本研究では，人工林の採算性を検討するため，3つの施業タイプとそれに見合った伐期齢を想定し，検討することとした。

（1）複合生産：製材用とパルプ材の両方を同時に生産することを目的とする造林で，樹種は*A. mangium*と*E. urophylla*であり，伐期齢は15年である。

（2）パルプ材生産：パルプ材だけを生産することを目的とする造林で，樹種は*A. mangium*と*E. urophylla*であり，伐期齢は，10年である。

（3）製材用材生産：製材用材だけを生産することを目的とする造林で，樹種は，*S. macrophylla*であり，伐期齢は30年である。

本研究では，投資規準論の立場から純現在価値（Net Present Value, NPV），内部収益率（Internal Rate of Return, IRR），純費用便益比（Net Benefit Cost Ratio, Net BCR）を算出した。その際，造林費は上述の林業公社による2つのプロジェクトで実際に投下されている全ての造林費を積み上げた費用を，原木価についてはランプンにおける市場価格を，またパルプ材を北スマトラとランプンにおける市場価格を用い推定した。またこれらを使用して感度分析（Sensitivity analysis），採算可能最適造林費（Minimum establishment cost）および採算可能最低価格（Minimum wood prices）を検討した。

用いた計算式は次とおりである。

（1） $NPV = \Sigma\, Rt/(1+i)^t - \Sigma\, Ct/(1+i)^t$

（2） $IRR = \Sigma\, Bt/(1+i)^t - \Sigma\, Ct/(1+i)^t = 0$

（3） $$NBCR = \frac{\{\Sigma\, Bt - \Sigma\, Ct/(1+i)^t\}}{\{\Sigma\, Ct - \Sigma\, Bt/(1+i)^t\}}$$

$(Bt - Ct > 0)$

$(Bt - Ct < 0)$

R：収入

B：便益

C：費用

n：投資の期間

t：年

i：前価係数

分析結果

1．採　算　性

NPV, IRRとNet BCRについてみると，全ての造林樹種で収穫が所定の伐期1回限りの場合，前価係数が10%と12%の場合NPV＞0，IRR＞12%，Net BCR＞1となり，採算がとれることが明かになった。また，一定の伐期内に間伐が繰り返され，収穫される場合でも，前価係数が同様であれば，いずれも採算がとれることが明らかになった。さらに，もし間伐材市場が存在すれば，複合生産の方が他の2つの施業よりも採算性が高いことが明らかになった。また，一定の伐期で収穫が繰り返される場合，採算性の序列は，（1）複合生産の*A mangium*,（2）パルプ材生産の*A mangium*,（3）製材生産の*S. macrophylla*,（4）．複合生産の*E. urophylla*,（5）．パルプ材生産の*E. urophylla*の順となった。

2．感度分析結果

施業方法ごとに造林費，伐採費，木材価格，材積を変数としてNPVを計算した。本研究では，感度について以下の2つのケースを想定している。

1）．各変数が10%ずつ変化する場合。

2）．各変数を現地での聞きとり調査にも基づいて様々に変化させた場合。

その結果，前価係数10%と12%で全ての変数のうち，木材価格の不確実性が最も重要な要素であることがわかった。

3．採算可能最低造林費の分析結果

全ての施業方法において前価係数10%と12%で，採算可能最低造林費は，US$1,000以下であることが明らかになった。事例として取り上げた造林のケースでは，この前価係数の範囲内で，パルプ材生産を目的として造成する場合，1ヘクタル当たり造林費の範囲がUS$ 487.0～750.0にあって，採算がとれることがわかった。

4．採算可能最低価格の分析結果

複合生産とパルプ材生産の採算可能最低価格は，*A mangium*が*E. urophylla*より低くなった。パルプ材を生産するための*A mangium*と*S. macrophylla*の場合，前価係数10%で最低価格はUS$ 12.5～17.5/ m^3 の範囲であり，前価12%では最低価格がUS$ 13.0～20.5/ m^3 である。*S. macrophylla*では，前価係数10%で当初計算を用いた木材価格の1/3が採算可能最低価格となることが明らかになった。