VI PLANTATION MANAGEMENT

6.1 Growth, yield and economic rotations of plantation species

6.1.1 Introduction

In sustainable forest management framework, growth and yield are two essential aspects that should be considered to manage forest optimally. Gadow and Hui (1999) stated that the key to successful in timber management is a proper understanding of growth processes. In forestry, Vanclay (1994) defined growth as increment in dimensions of one or more individuals in a forest stand over a given period of time, for instance volume growth in $m^3\ ha^{-1}\ yr^{-1}$. Meanwhile, yield refers to their final dimensions at the end of certain period, for instance volume in $m^3\ ha^{-1}$.

Commonly, forester formulates growth and yield of a stand into mathematical models. In addition, for practical purposes, growth and yield are also can be expressed in a plantation yield table. Currently, in Indonesia there is a plantation yield table consisting of ten industrial wood species that published by Forestry Research and Development Agency (Suharlan *et al*., 1975).

Plantation forests in Indonesia are considered as a solution to overcome degradation of natural forests productivity in accomplishing of wood requirements. Therefore, researches related to growth and yield of plantation forests are mostly exploring tree and stand parameters as timber products. Accordingly, this review concentrates on growth and yield of plantation forests in Indonesia related to timber products.

6.1.2 Growth and yield of some plantation forests species

Growth and yield are two interrelated aspects that can be used to depict stand development of managed plantation forests. Stand parameters that commonly measured are: upper-height, age, site index, diameter, height, basal area, and volume of stand. In recent issue, non-wood aspect such as stand biomass is also being concerned in order to increase productivity of plantation forests. The following review will explore some aspects related to growth and yield of some plantation forests species in Indonesia.

6.1.2.1 Age, upper-height, and site index of stand

Age and upper-height of stand are two of key parameters to determine site index of stand. Age defined as growth period of a stand since planting until certain time. Upper-height is an average of a hundred of highest trees distributed on one hectare area. While, site index are classes of site quality that determined by relationship between upper-height and an index age. In Indonesia, site index is symbolized as Roman's numbers, whereas the highest number represents the best site quality and vise-versa.

Some researches concerning relationship among age, upper-height and site index of some plantation forests species in Indonesia can be summarized as in Table 6.1.

6.1.2.2 Diameter, height and basal area of stand

In a plantation forest, growth of stand diameter, height and basal area are highly correlated with stand age and its site index. Growth of diameter, height and basal area will determine stand volume at a certain age as well as at final rotation. Moreover, diameter and height increment are urgently required to determine silvicultural treatments, such as thinning.

Growth of stand diameter and stand height of a plantation forest can be formulated into mathematical models. Some results of researches on diameter and height growth of some plantation forests species can be explained such as follows :

1. Acacia mangium

Research on growth of stand diameter and stand height of *Acacia mangium* has been developed by some researchers, namely: Wahjono (1995) and Herbagung (1997) for some various sites in Indonesia.

Table 6.1 Some models of relationship among age, upper-height and site index of some plantation forests species in Indonesia

No.	Stand species	Model/equation	Statistical criteria	Source
1.	*Acacia mangium*	*Upper-height* : $Ln\ H_O = 4.11011 + (b_{si} - 4.14291)(1/A)^{0.57645}$ *where* : $b_{si} = (Ln\ S_i - 3.12107)/0.23873$ *Site index (at 12 years age-index)* : $Ln\ S_i = 0.23873 + (Ln\ H_0 - 4.11011)(A)^{0.57645} + 4.11011$	MD=5.7%	Herbagung (1991a)
2.	*Acacia decurrens*	*Upper-height* : $H_O = -6.11844 + b_{si}(Ln\ A)^{0.61109}$ *where* : $b_{si} = (S_i + 6.11844)/1.74409$ *Site index (at 12 years age-index)* : $S_i = (H_O + 6.11844)(2.49461/(Ln\ A))^{0.61109} - 6.11844$	AD=2.28% MD=6.50%	Herbagung (1986)
3.	*Eucalyptus deglupta*	*Upper-height* : $H_O = 4.17413 + (2.59898 + b_{si})(Ln\ A)^{1.04385}$ *where* : $b_{si} = (S_i - 10.89534)/2.58609$ *Site index (at 12 years age-index)* : $S_i = 4.17413 + (2.58609 H_O - 10.7947)/(Ln\ A)^{1.04385}$	AD=0.66% MD=7.79%	Herbagung (1991b)
4.	*Eusideroxylon zwageri*	*Site index* : $Ln\ S_i = (Ln\ H_O - 6.48607)(A/40)^{0.22012} + 6.48607$	MD<8%	Herbagung (1984)
5.	*Paraserianthes falcataria*	*Upper-height* : $H_O = 4.90466 + b_{si}(Ln\ A)^{1.08562}$ *where* : $b_{si} = (S_i - 4.90466)/2.68632$ *Site index (at 12 years age-index)* : $S_i = (H_O - 4.90466) + (2.48491/(Ln\ A))^{1.08562} + 4.90466$	AD=1.08% MD=2.60%	Herbagung *et al.* (1985)
6.	*Agathis loranthifolia*	*Upper-height* : $Ln\ H_O = 4.42522 + b_{si}(1/A)^{0.51437}$ *where* : $b_{si} = (Ln\ S_i - 4.42522)(30)^{0.51437}$ *Site index* : $Ln\ S_i = (Ln\ H_O - 4.42522)(A/30)^{0.51437} + 4.42522$	AD=0.64% MD=2.69%	Parthama and Herbagung (1985)
7.	*Swietenia macrophylla*	*Upper-height* : • *Site index* II : $H_O = 3.230\ A^{0.614}$ • *Site index* III : $H_O = A/(0.670 + 0.0102A)$	R^2 = 98.08% R^2 = 98.08%	Tiryana *et al.* (1998)
8.	*Tectona grandis*	*Upper-height* : $Ln\ H_O = 6.0375 + b_{si}(1/A)^{0.1435}$ *where* : $b_{si} = (Ln\ S_i - 6.0375)(80)^{0.1435}$ *Site index* : $Ln\ S_i = (Ln\ H_O - 6.0375)(A/80)^{0.1435} + 6.0375$	AD=0.174 % MD=3.56%	Budiantho (1986)

Notes : *A = age of stand (year), H_O = upper-height of stand (m), b_{si} = regression coefficient for each site index, S_i = site index; AD = aggregative deviation, MD = mean deviation*

Based on periodic measurement on four permanent sample plots in Subanjeriji area, South Sumatra, Wahjono (1995) developed growth model of stand diameter and stand height of *Acacia mangium* such as follows :

$D = 30.15259928 - 59.491371\,(1/A)$, ($R^2$ = 84%, s = 0,05635)

$H = 27.08193211 - 51.866813\,(1/A)$, ($R^2$ = 79%, s = 0,078674)

where : D = diameter at breast height of stand (dbh, cm)

H = stand height (m)

A = stand age (year)

Projections of stand diameter and stand height growth based on such models shown that growth of stand diameter and stand height of *Acacia mangium* would reach optimal values at age 8 years and then tend to decrease. Diameter increment up to age 8 years reach more than 3 cm/year and its height increment reach approximately 3 m/year.

Herbagung (1997) studied 30 permanent sample plots which located in Sumatra, Java and Kalimantan. He obtained a model for estimating basal area of plantation forest of *Acacia mangium* as follows:

$$Ln\left(B_{A2}\right) = 2.761 + 0.149\left[\left(B_{A1}/Ln(N)\right)\right]^{(w/A_1)}\left(Ln(S_i)\right) - 396.585\left[\left(Ln(S_i)\right)/\left(N.A\right)\right]$$

where : B_{A1} = basal area in the early growth period (m^2/ha)

B_{A2} = basal area in the end of growth period (m^2/ha)

A_1 = stand age in the early growth period (year)

w = growth period (year)

S_i = site index

N = stand density (number of trees per hectare)

Statistically, such model was considered accurate since its coefficient of determination was 91.3%, mean deviation was 9.0%, and aggregative deviation was 0.6%. Therefore, the model would applicable to make a projection of stand basal area of *Acacia mangium* when estimator variables (i.e. age, site index, basal area, and stand density) are well known.

2. Agathis loranthifolia

Stand growth is highly influenced by silvicultural treatments such as thinning. The research conducted by Tujuanto (1992) shown that growth of stand basal area of *Agathis loranthifolia* which thinned one times was influenced by: time period between initial and final of measurement, age of stand, basal area of standing stock, and number of trees in standing stock. Moreover, based on stand growth data of *Agathis loranthifolia* on some permanent sample plots located in West Java, Central Java, and East Java, he developed some growth models for estimating basal area of *Agathis loranthifolia* such as follows :

- For site class II :

$$\ln Y = -0.8194 + 3.8700\left(B_p / \ln N_2\right)^{W/A_1} - 0.1737 N_2^{W/A_1} - 0.3027W, \quad (R^2 = 95.89\%)$$

- For site class III :

$$Y^{-1} = 0.1366 - 0.2854\, e^{-W} - 0.0485\left(B_p / \ln N_2\right)^{W/A_1}, \quad (R^2 = 89.05\%)$$

- For site class IV :

$$\ln Y = 0.3867 + 2.0560\left(B_p / \ln N_2\right)^{W/A_1}, \quad (R^2 = 53.48\%)$$

where :

Y	=	basal area of one times thinned stand
B_p	=	basal area of standing stock
N_2	=	number of trees in standing stock
W	=	time period between initial and final measurement
A_1	=	age of stand

Another research on growth of stand diameter and stand height of *Agathis loranthifolia* was conducted by Budiyanto (2002) that analyzed data taken from periodical measurements of 20 permanent sample plots located at Probolinggo forest district, East Java. The growth models that he developed were as follows :

- $D = 52.9 - 0.0105\, N - 286(1/A)$, ($R^2$ = 81.5%)
- $H = 40.9 - 311(1/A)$, (R^2 = 75.7%)

where : D = average of stand diameter (cm), N = stand density (stems/ha), H = average of stand height (m), and A = stand age (year)

Based on the growth models of stand diameter and stand height, Budiyanto (2002) concluded that rotation for maximum production would occur at 13 – 15 years old of stand. Mean annual increment (MAI) of stand diameter was starting to decrease at 14 years old and MAI of stand height was starting to decrease at 16 years old. While, current annual increment (CAI) of both stand diameter and stand height were starting to decrease at 11 years old.

3. *Eucalyptus urophylla*

Research on growth of stand diameter and height of *Eucalyptus urophylla* has been conducted by Herbagung (1991) in Pujon, West Java, at *Eucalyptus urophylla* stand of 4, 10, 18, and 23 years old. Based on the result of his research, Herbagung (1991c) developed two models for estimating stand diameter and stand height growth of *Eucalyptus urophylla* such as follows :

$$Ln\ D = 4.00002 - 4.60841(1/A)^{0.84327},\ (R^2 = 96.5\%)$$

$$Ln\ H = 3.46726 - 6.83380(1/A)^{1.38713},\ (R^2 = 98.8\%)$$

where : D = stand diameter (cm), H = stand height (m), and A = stand age after 4 years

The aggregative deviations of those equations respectively were -0.42% and -0.08%, and the mean deviation were 7.26% and 6.82%.

Those growth models of stand diameter and stand height can be used to determine increment of stand diameter and stand height of *Eucalyptus urophylla* as could be seen on Table 6.2.

Table 6.2 Mean annual increment (MAI) and current annual increment (CAI) of stand diameter dan stand height of *Eucalyptus urophylla* in Pujon, West Java

Age	Stand diameter		Stand height	
(*year*)	Mean annual incremen (MAI) (cm)	Current annual increment (CAI) (cm)	Mean annual increment (MAI) (m)	Current annual increment (CAI) (m)
4	3.2	-	2.9	-
5	3.3	3.7	3.1	3.6
6	3.3	3.0	3.0	2.7
7	3.2	2.7	2.9	2.1
8	3.1	2.2	2.7	1.7
9	2.9	1.9	2.6	1.3
10	2.8	1.7	2.4	1.0
11	2.7	1.5	2.3	0.9
12	2.6	1.3	2.1	0.7
13	2.5	1.1	2.0	0.6
14	2.4	1.1	1.9	0.5
15	2.3	0.9	1.8	0.4
16	2.2	0.9	1.7	0.4
17	2.1	0.8	1.6	0.3
18	2.0	0.7	1.6	0.3
19	2.0	0.7	1.5	0.3
20	1.9	0.6	1.4	0.2
21	1.8	0.6	1.4	0.2
22	1.8	0.5	1.3	0.2
23	1.7	0.5	1.3	0.1

Based on Table 6.2, the following items can be concluded :

- Current annual increment of stand whose old more than 4 years have declined.
- Rotation of maximum volume that suitable for pulp and paper industry is 6 years, whereas for sawn timber industry will require a rotation of at least 25 years.

4. Eucalyptus deglupta

Herbagung (1996) has studied the growth of stand diameter and stand height of *Eucalyptus deglupta* in Benakat and Kenangan, East Kalimantan. The research conducted on 10 permanent sample plots that measured periodically for 5 times of measurement. Based on the stand growth at both locations, he developed models for estimating stand diameter and stand height growths of *Eucalyptus deglupta* such as follows:

$$Ln\ D_A = 5.7594 + b_i\left(1/A\right)^{0.2536}$$

$$Ln\ H_A = 4.7984 + b_i\left(1/A\right)^{0.3210}$$

where : D_A = stand diameter (cm) at A age (year),
H_A = stand height (m) at A age (year),
A = stand age (year)
b_i = regression coefficient for each sample plot

In this case, value of b_i can be calculted using the following equation :

$$b_i = \frac{Ln\ D_A - 5.7594}{\left(1/A\right)^{0.2536}} \quad \text{(for stand diameter growth)}$$

$$b_i = \frac{Ln\ H_A - 4.7984}{\left(1/A\right)^{0.3210}} \quad \text{(for stand height growth)}$$

Statistically, the stand diameter growth model was considered accurate since its mean deviation was 7.28% and its aggregative deviation was 0.83%, whereas the second model has mean deviation was 9.18% and aggregative deviation was 1.12%. These equations were used by Herbagung (1996) to developed the following stand diameter and stand height growth models:

- Benakat : $Ln\ D_A = 5.7594 - 6.2469\left(1/A\right)^{0.2536}$ and

  $Ln\ H_A = 4.7984 - 4.9699\left(1/A\right)^{0.3210}$

- Kenangan : $Ln\ D_A = 5.7594 - 4.8226(1/A)^{0.2536}$ and

  $Ln\ H_A = 4.7984 - 3.6166(1/A)^{0.3210}$

5. Khaya anthotecha

Khaya anthotecha is an exotic species that potential to be developed for industrial plantation forests in Indonesia. In order to know its growth performance, Mindawati dan Tiryana (2002) conducted a research on stand growth of *Khaya anthotecha* in six experimental sites in West Java, namely Pasir Hantap, Cikampek, Pasir Awi, Cikole, Carita, dan Yanlappa. The growth data obtained from periodical measurement at 35 permanent sample plots that have 2 – 50 years old.

Mindawati and Tiryana (2002) concluded that site was a significant factor that affected to the growth of stand diameter and height. Therefore, they developed growth models for predicting stand diameter and height of *Khaya anthotecha* for each site location as seen on Table 6.3.

6. Swietenia macrophylla

Commonly, stand growth models are developed based on periodical measurement data taken from permanent sample plots. Unfortunately, this method requires long times observation since we have to measure stand dimensions periodically until the end of stand rotation, usually more than 10 years. In this context, Tiryana et al. (1998) developed a method for estimating stand growth of mahogany (*Swietenia macrophylla*) based on temporary sample plots data using partial replacement sampling technique as proposed by Cunia and Ware (1962).

The stand growth data were taken from 106 temporary sample plots that represented stand condition of 6 – 39 years old which distributed at three locations of plantation forests, namely Pasuruan, Probolinggo, and Malang. Based on such data, Tiryana et al. (1998) developed some models for estimating stand diameter and height of mahogany at site index II and III such as follows:

- Site class II : $D = 2.758\ A^{0.784}$ (R^2 = 98.92%)

  $H = 2.298\ A^{0.689}$ (R^2 = 97.58%)

- Site class III : $D = 2.758\ A^{0.784}$ (R^2 = 98.92%)

  $H = 2.298\ A^{0.689}$ (R^2 = 97.58%)

where : D = stand diameter (cm), H = stand height (m), and A = stand age (year)

Table 6.3 Growth models of stand diameter and stand height of *Khaya anthotecha* at several locations in West Java, Indonesia

No.	Site Locations	Growth Variables	Models	R^2 (%)	s
1.	Carita	Diameter (cm)	$D = \frac{A^{0.3823}}{0.1967 - 0.0319A^{0.3823}}$	96.09	4.133
		Height (m)	$H = \frac{A^{0.9459}}{0,4956 + 0.0179A^{0.9459}}$	97.69	1.345
2.	Cikampek	Diameter (cm)	$D = \frac{A^{1.2525}}{0.8856 + 0.0059A^{1.2525}}$	80.79	12.128
		Height (m)	$H = \frac{A^{1.6014}}{1.3669 + 0.0279A^{1.6014}}$	84.63	4.043
3.	Cikole	Diameter (cm)	$D = \frac{A^{0.6516}}{0.4229 - 0.0158A^{0.6516}}$	98.83	2.310
		Height (m)	$H = \frac{A^{1.0429}}{1.0455 + 0.0153A^{1.0429}}$	97.52	1.875
4.	Pasir Awi	Diameter (cm)	$D = \frac{A^{0.2971}}{0.1792 - 0.0416A^{0.2971}}$	97.08	2.906
		Height (m)	$H = \frac{A^{0.4006}}{0.1606 - 0.0051A^{0.4006}}$	91.79	2.258
5.	Pasir Hantap	Diameter (cm)	$D = \frac{A^{0.4324}}{0.2142 - 0.0265A^{0.4324}}$	86.09	8.857
		Height (m)	$H = \frac{A^{1.0723}}{0.5831 - 0.0246A^{1.0723}}$	83.72	3.724
6.	Yanlapa	Diameter (cm)	$D = \frac{A^{1.4364}}{2.7650 - 0.0153A^{1.4364}}$	70.42	8.555
		Height (m)	$H = \frac{A^{1.1058}}{1.1748 - 0.0268t^{1.1058}}$	86.07	3.131

Notes : D = stand diameter (cm), H = stand height (m), A = stand age (year), R^2 (%) = corrected coefficient of determination, s = standard deviation of residuals

Comparison between the estimated values of stand diameter and stand height of this method and the corresponding values of yield table (which developed based on permanent sample plots method) shown that there were not significant differences. Accordingly, Tiryana et al. (1998) recommended to use this method as an alternative method in developing stand growth models especially when permanent sample plots method is impossible to be applied.

7. Tectona grandis

Management of teak plantation forest in Java has been practicing for a long time and well established, so that the stand growth data were available more better than other stands. In this case, Parthama (1991) used the growth data of teak stand to develop models for predicting before and after thinning basal area. Prediction of before thinng basal area is required to detemine stand basal area at certain projection age based on current stand condition. While, prediction of after thinning basal area is required because it would be starting point of stand development to a subsequent projection age.

Based on his research, Parthama (1996) obtained two models for calibrating basal area of teak stand in Java as follows:

- $Ln(B_2) = \left(\frac{A_1}{A_2}\right) Ln(B_1) + 2.927\left(1 - \frac{A_1}{A_2}\right) + 0.044H\left(1 - \frac{A_1}{A_2}\right)$, (R^2 = 90%)
- $B_t = 1{,}074\left(\frac{N_t}{N_T}\right) B_T$, (R^2 = 93%)

where :	A_1 and A_2	=	age 1 (current age) and age 2 (projection age)
	B_1 and B_2	=	basal area at age 1 and age 2
	H	=	upper-height (m)
	B_t and B_T	=	basal area after and before thinning
	N_t and N_T	=	number of stems per hectare after and before thinning

The first model can be used as a tool to predict stand basal area at future ages as well as at current age. The second model can be used to simulate some effects of various thinning intensity. If the value of N_t is changed but other variables are constant, then we can determine an optimal thinning intensity that would give the best of total volume.

Another research on thinning effects in improving diameter growth of teak stand has been conducted by Wiratmoko (1990). Based on growth data taken from some permanent sample plots, Wiratmoko (1990) developed growth models for estimating diameter growth of teak stand after thinning such as follows:

- For site class III :

$$\log D = 1.198 + 0.4417\ \log A_2 - 0.1830\ \log N\text{ , } (R^2 = 93.19\%)$$

- For site class IV :

$$\log D = 1.563 + 0.3461\ \log A_2 - 0.1445\ \log N\ ,\ (R^2 = 93.94\%)$$

where : D = average of stand diameter per hectare (cm), A_2 = age of stand after thinning (year), N = number of trees in standing stock at time of thinning (stems/ha)

6.1.2.3 Volume of trees and stand

Volume of stand is a parameter that commonly estimated to represent yield of stand in both plantation forests and natural forests. Usually, financial value of a production forest stand is measured by its volume that can be sold.

In plantation forest, stand volume can be estimated using yield table, growth and yield models, and volume table of trees. Commonly, prediction of stand volume using yield table is applied to predict "normal volume" of stand at certain age based on current condition of the stand. In this case, the following formula is commonly used:

$$V_{A2} = \frac{BA_a}{BA_t}.V_t$$

where : V_{A2} = estimated volume at certain projection age

V_t = volume of yield table at certain projection age

BA_a = actual basal area of stand at current age

BA_t = basal area of yield table at current age

Currently, in Indonesia there are ten plantation forests species that already have their yield table, that are: *Tectona grandis, Altingia excelsa, Agathis loranthifolia, Pinus merkusii, Dalbergia latifolia, Swietenia mahagoni* and *Swietenia macrophylla, Acacia decurrens, Paraserianthes falcataria, Ochroma bicolor,* and *Anthocephalus cadamba*. The values of their stand parameters can be seen on the book entitle "Yield Table of Ten Industrial Wood Species" published by Forest Research and Development Agency, Department of Forestry of Indonesia (Suharlan *et.al.,* 1975).

Another way in estimating stand volume that commonly used in plantation forests is using tree volume table. Principally, a volume table is a table that displays the values of a tree volume according to either tree diameter or height. Then, stand volume can be determined by adding each tree volume in a stand. In practice, there are two type of volume table that are local volume table and standard volume table. In a local volume table, which is also known as tariff, tree volume is only estimated by its diameter (dbh). Whereas, in standard volume table, tree volume is not only estimated by its diameter (dbh) but also by its height as well as other parameters (such as form factor, site index, etc.). A tree volume table is constructed based on data taken from sample trees by using regression models. In order to achieve an accurate estimation of tree volume, usually a tree volume table is developed for a specific location as well as certain tree species. Moreover, type of volume stated on a tree volume table is depended on necessities of stand management, that is can be total volume of tree, volume up to crown base, or volume up to a specified minimum top diameter (such as 10 cm, 7 cm, or even 5 cm). Some of volume table equations that developed for some plantation forests species in Indonesia can be seen as on Table 6.4.

6.1.3 Economic rotation of some plantation forests species

Rotation is a time period between planting and harvesting. In exertion of plantation forests, rotation that commonly used is economic rotation since it would give financial profit maximally.

Table 6.5 Economic rotation of some plantation forests species in Indonesia

No.	Stand Species	Economic Rotation
1	Akasia (*Acacia mangium*)	8 – 15 tahun
2	Balsa (*Ochroma bicolor*)	10 tahun
3	Bakau (*Rhizophora* spp.)	10 tahun
4	Damar (*Agathis loranthifolia*)	20 – 25 tahun
5	Gmelina (*Gmelina arborea*)	7 – 15 tahun
6	Jabon (*Anthocephalus cadamba*)	20 tahun
7	Jati (*Tectona grandis*)	40 – 80 tahun (years)
8	Mahoni (*Swietenia* spp.)	30 – 60 tahun
9	Meranti (*Shorea* spp.)	70 tahun
10	Pinus (*Pinus merkusii*)	25 tahun (years)
11	Rasamala (*Altingia exelsa*)	40 – 60 tahun
12	Sengon (*Paraserianthes falcataria*)	8 tahun
13	Sonokeling (*Dalbergia latifolia*)	40 – 60 tahun

Source : Appendix of Decree of Perum Perhutani's Director No. 378/Kpts/Dir/1992 dated on 25 April 1992 concerning the Guideline for Composing a Plan of Sustainable Forest Regulation

In practice, stand rotation is mostly determined by management decision of the owner that possibly varies although for the same stands. For instance, teak stand rotation in Java that managed by Perum Perhutani use difference rotations, namely: 40 years for teak stands in West Java, and 60 years for teak stands in both Central Java and East Java.

6.2 Harvesting systems and wood transportation of forest plantation in Indonesia

6.2.1 Introduction

Intensive management of plantation forest in Indonesia started in the year 1850, during the Dutch colonial government in Indonesia. During that time provisions and regulation for forest harvesting were enacted. The system was selective clear cutting without diameter limit and requirement on the minimum number of residual trees. Wood extraction was done either by human labour or animal power. In the year 1896, efforts to regulate forest was started, especially for teak forest, which tended toward systematic regulation of logging.

The first plantation forest, was teak forest, developed in Java island, exactly in the place which is at present under the management of Perum Perhutani (State Owned Forest Company), of Unit I, Central Java. Afterwards, plantation forest in Java Island, increased by two units, namely Unit II of East Java, and Unit III of West Java. Although at the beginning, only teaks were planted, due to the increasing silvicultural expertise of the Dutch forester at that time, other species beside teak were also planted, such as pine, mahogany, agathis, etc. Up to present, the number of timber species planted in the area of Perum Perhutani in Java Island is approximately 20 species. Total area of plantation forest occurring in Java Island is estimated as 2 millions ha. The use of those timber species is mainly for construction wood.

After the beginning of the development of Industrial Plantation Forest (HTI) outside of the Java Island, namely since the Fourth Five Year Development period of Indonesia (PELITA IV); there is at present 4.5 million ha of HTI (Industrial Plantation Forest) which has been developed. The utilization pattern of this Industrial Plantation Forest (HTI) can be categorized into three categories namely:

- HTI for fiber production
- HTI for construction wood
- HTI for energy wood and non wood forest products

In the HTI for fiber wood, the species planted are mostly those of fast growing species, such as acacia, moluccan sau, mangium. eucalyptus, yemane (gmelina) etc, whereas for construction wood, species which are frequently planted are mahogany, pine, meranti and mangium.

Although the two types of plantation forest, they need different system of harvesting, due to consideration of forest structure, management system, location and socio-cultural background of the community around the forest.

6.2.2 Systematics of harvesting system of plantation forest in Indonesia

On the basis of silvicultural system used in the development of plantation forest, harvesting systems of plantation forest in Java Island and outside the island of Java, are the same, namely clear cutting. For plantation forest in Java Island, clear cutting with natural and artificial regeneration is employed, whereas most of the Industrial Plantation Forests outside Java employ clear cutting with artificial regeneration.

Harvesting operation with clear cutting system is very efficient and economical, because equipments, workers and activities are centered in one location, namely harvesting area. Efforts to search the trees to be cut and other further works, are not needed. This is the phenomenon which distinguish harvesting system in plantation forest with that of natural forest.

In principle, timber harvesting can be divided into three main steps, namely tree felling, short distance wood transportation (skidding) and long distance wood transportation. In each step, there are several activities, for instance, tree felling is accompanied by cutting of branches, twigs and tops, and bucking. Also, in skidding activities, there are also sub activities such as loading and unloading.

Harvesting of wood in several locations of Perum Perhutani (State Owned Forest Company) comprise approximately 10 systems of wood harvesting. Those harvesting system are categorized on the basis of method and mode of skidding. Based on degree of mechanization, the wood harvesting system in plantation forest can be categorized into two degrees of mechanization, namely manual system and semi mechanical system:

a. Manual System

Manual system is a series of harvesting activities which use human power in its step activity. In this wood harvesting system, delimbing, debranching and bucking are conducted with conventional cutting apparatus (hand saw and axe) and sometimes chain saw. Loading and unloading are conducted by human labour with the aid of simple tools. Also, for skidding activities, human and animal powers are employed. This manual system of forest harvesting is identical with that employed in Perum Perhutani. Harvesting systems which are categorized into this system are wood hauling system by human, skidding by human (cart system, sulky system and geletrek system), skidding by animal, gravitation system, and cable system.

b. Semi Mechanical System

Semi mechanical harvesting system is characterized by the limited use of human power, and several steps harvesting activities which usually uses human power, employs mechanical power instead. Tree felling activities can be conducted with semi mechanical apparatus, such as felling machine or chain saw. Delimbing, debranching and bucking are usually still conducted with chain saw. Other activities such as loading, unloading and skidding are conducted with machine power. This system is used in the harvesting of Industrial Plantation Forest. Harvesting systems included in this harvesting system group are forwarder system, feller buncher system and cable system, and skidding system with Unimog.

Timber harvesting system in Indonesian Plantation Forest has not practical the full mechanized system which uses harvester and modern skyline cable system. Technology level of cable system used in Indonesia is still very low, and even one of the employed cable system does not use yarder.

The use of harvester in modern cable system in harvesting of plantation forest in Indonesia is still at the trial stage.

Systematics of wood harvesting systems and its use in Indonesian Plantation Forest is summarized in Table 6.6.

Table 6.6. Systematics of wood harvesting system and its use in plantation forest of Indonesia

No	Harvesting system	Uses			
		Small diameter (< 30 cm)	**Large diameter (> 30 cm)**	**Flat**	**Moderate - Steep**
1	Perum Perhutani (Manual)				
	a) Hauling by human	x	x	x	-
	b) Skidding by human	x	X	x	-
	c) Skidding by animal	x	x	x	-
	d) Gravity system	x	x	-	x
	e) Cable system	x	x	-	x
2	HTI (Semi Mechanical)				
	a) Forwarder system	x	-	x	-
	b) Feller system	x	-	x	-

6.2.3 Harvesting system in Perum Perhutani

Timber harvesting system employed in the area of Perum Perhutani is dominated by manual harvesting system, employing human or animal power. The choice of this system is in accordance with socio-economic condition of the community around the forest, although in terms of technical or ergonomical point of view is not so humane. This system is used due to several considerations which among other things the phenomenon that sufficient labour with cheap level of wage is available around the forest; low level of investment needed; the opportunity to utilize draft animal which is used to plow rice field during planting season, for skidding; and the phenomenon that timber harvesting is the main livelihood for some people.

6.2.3.1 Tree felling and bucking

In the beginning, tree felling by Perum Perhutani used simple tools such as axes and hand saw operated by two people. Delimbing and debranching also uses the same equipment, whereas bucking use two men hand saw or bow saw. However, due to technological development and improvement of the logger's skill, tree felling activity and sub activities within it, are all conducted with chain saw, both in logging of small diameter trees and large diameter trees.

Logging is usually conducted by one group of loggers which consist of one operator and one assistant. Average working hours is 7 hours per day. Productivity of logging is affected very much by tree species, size (diameter), topography, and logger's skill. Table 6.7 present data on productivity of tree felling using hand saw for two tree species.

Table 6.7 Data on productivity of tree felling using hand saw for two tree species

Description	Tree species	
	Teak	Mollucan sau
1. Tree diameter (cm)	67.50	21.00
2. Volume (m^3/tree)	3.49	0.58
3. Number of wood segments per tree	22.00	7.00
4. Working duration of tree felling (minute)	205.29	5.91
5. Productivity (m^3/day/group)	7.03	4.12

6.2.3.2 Skidding and loading

6.2.3.2.1 Hauling with human power

Timber harvesting system with hauling using human power is used in small diameter tree harvesting, especially in thinning operation at all enterprise classes and in clear cutting of several wood species such as mollucan sau and acacia. Diameter of trees produced is on the average below 30 cm and the round wood segments have length between 1 – 2 m. In the implementation, one or two wood stems are lifted on the shoulder by a worker and handled from tree felling site to log yard. Productivity of hauling system with human power depends very much on skidding distance and volume of the handled timber. Average productivity of hauling with human power is 0.7 m^3 hm/hour.

Hauling system with human power is also used in clear cutting at the end of the rotation. Length of wood segment produced is the same with that of small diameter wood. In this system, 4 workers hauls the wood on the shoulder by using simple hauling equipment. Distance in this manual hauling of large wood is usually not more than 50 m. Productivity of manual hauling of large wood is around 1.2 m^3/hour. Equipments used in this system are among other things chain saw and apparatus to haul wood on shoulders.

6.2.3.2.2 Skidding by human

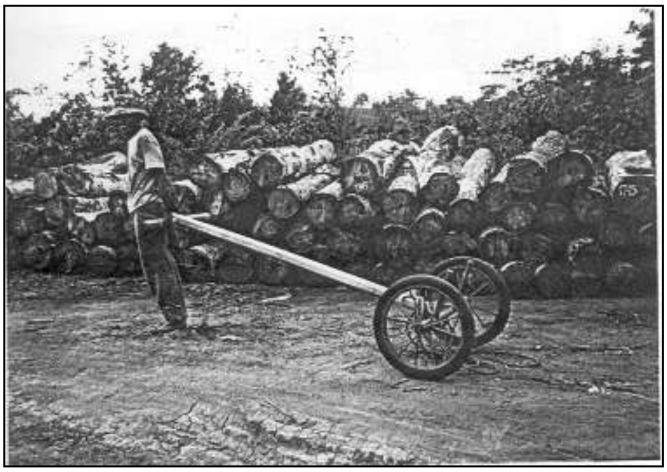
6.2.3.2.2.1 Hand sulky

This simple equipment is used to skid small diameter wood on level terrain. Timber harvesting of *Acacia mangium* and mollucan sau (sengon) in KPH (Forest Management District) Bogor, of West Java, uses this equipment. Large end of the load is put on the axis, whereas the small end is put on the ground. Volume of transported logs can reach 0.2 m^3 per trip. Productivity of skidding using this method is presented in Table 6.8.

Table 6.8 Variables and skidding productivity using hand sulky

No	Variables	Magnitude
1	Stem diameter (cm)	26.62
2	Wood volume (m^3/trip)	0.11
3	Skidding distance (hm)	0.871
4	Slope (%)	4
5	Productivity (m^3/hour)	1.60

Skidding tool in the form of hand sulky is made form wood and use tyre wheel with diameter of 60 cm. At midpoint under the axis, round wood pole with diameter of 6 cm, and length of 2 m is installed. This equipment is operated by one person. However, working safety is ensured more if two persons are operating, where one person acts as operator and the other as assistant. Figure 6.1 shows the hand sulky as skidding tool.



Courtesy : Nurialita, 2000.

Figure 6.1. Skidding of pine wood with hand sulky

6.2.3.2.2.2 Two wheeled cart

Timber skidding with two wheeled cart is frequently used in timber harvesting of agathis, rasamala, pine and mahogany in the area of Perum Perhutani Unit III West Java which has terrain ranging from moderate to steep terrain. Skidding in this system requires pathway with width of 1 – 2 m which connects felling site and log yard.

The carts used are made by the workers themselves. The cart is made from wood and uses wooden wheel or tyre wheels. Wooden wheel has diameter of 20 – 30 cm and its surface is lined with rubber from used tyre. On the other hand, tyre wheel has diameter of 30 cm. Cart frame is made from iron with wooden base. The axis is iron with length of 85 cm and diameter of 4 cm. This equipment is operated by two persons. In field operation, wood is placed longitudinally on the cart base with center of the wood is in coincidence with the center of the cart, so that the load is balance. On the front end of the wood, iron nail with diameter of 1 cm is nailed. This nail is connected with rope in double arrangement. With the aid of a piece of pole and bamboo inserted in doubly arranged rope, two workers then lift the front end of the wood and haul it (Figure 6.2).

Courtesy : Yazid, 1997.

Figure 6.2 Wood skidding using two wheeled cart

Number of logs skidded, varies depending on the diameter size. For log with diameter of more than 30 cm, only one log is transported, whereas for log with diameter of less than 30 cm, two or three logs are transported. Average productivity of skidding with this two wheeled cart is 0.4024 m^3/hour with average skidding distance of 450 m.

6.2.3.2.3 Animal system

Animal species which is usually used in timber harvesting in plantation forest in Java Island is cattle. Skidding with cattle power is only used in teak harvesting, especially in the area of Perum Perhutani Unit I Central Java, and Unit II East Java. Because cattle is not so resistant to heat from the sun light, the use of cattle power in wood skidding is maximally 3 hours per day.

In skidding operation, a pair of cattle is controlled by one person using several aid apparatus. Aid apparatus is among other things cattle assembler, chain and slide. Cattle assembler is made from wood and function as controller of the animal. Chain is used to haul the skidded wood, whereas the slide function to position one end of the wood. One end of the skidded wood is tied to the assembler, and the other end is put on the slide.

Ability of a pair of cattle to skid wood at average distance of 500 m for 4 working hours per day is around 4.5 m^3. For greater skidding distance (1,000 m), productivity is smaller, namely only 1.8 m^3 per day.

6.2.3.2.4 Gravity system

Wood skidding system which utilize gravitation force in Indonesia is called geletrek system. Geletrek is a simple equipment made from bamboo or rattan (Figure 6.3). This equipment function to steer the wheel when the wood is skidded down the hill (slope up to 20%). This equipment is operated during harvesting of pine wood in several KPH’s (Forest Management Unit) in Central Java which have topography ranging from moderate to steep. Geletrek is operated by one person. Skidding productivity using geletrek is shown in Table 6.9.

Table 6.9 Productivity of wood skidding using geletrek

Variables	Geletrek
Wood volume (m^3/trip)	0.18
Skidding distance (hm)	1
Slope (%)	6.69
Productivity (m^3/hour)	1.70

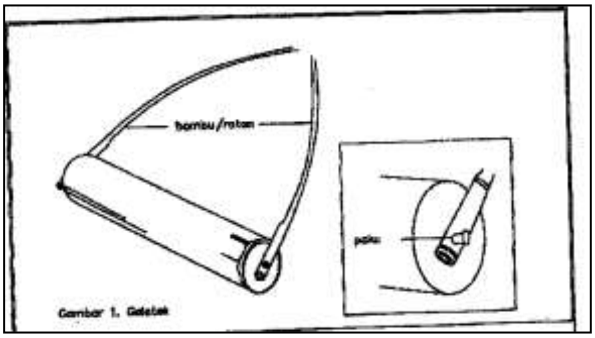


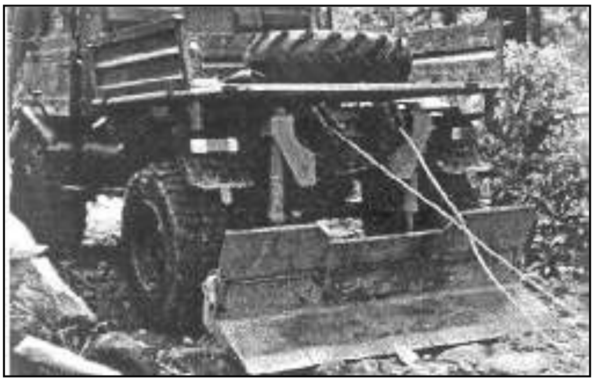
Figure 6.3 Geletek

6.2.3.2.5 Cable system

6.2.3.2.5.1 Mono cable

Wood skidding with mono cable system in Indonesian Plantation Forest is used in timber harvesting in steep area, such as in several KPH in West Java which have rough topography. This cable system is the most simple of cable system, because it does not need spar tree. The equipment used is in the form of winch installed on Unimog, both in front and in the rear. This vehicle has multiple functions namely as transportation means and as power source for winch. Type of vehicle used in the harvesting of pine wood in KPH of Majalengka, West Java is Unimog U900. The power of the machine is 84 HP (62 KW). Length of cable used can reach 100 m with pulling capacity of 4020 kg (8130 N).

The species of wood skidded is pine. Length of wood segment to be skidded is 1.5 m, with stem volume of 0.73 m^3 per trip, and number of stem per trip is 7 stems. Slope of the terrain is between 33% - 87%. Average productivity of wood skidding using Unimog is 8.77 m^3 per hour with average skidding distance of 20 m. Skidding productivity using Unimog 406 is 3.39 m^3 per hour with average skidding distance of 75 m.



Courtesy : Syarifudin, 2002.

Figure 6.4 Winch installed in the rear of Unimog

6.2.3.2.5.2 Gravity cable system

This cable system is categorized as skyline cable system. Gravity force cable system is a cable system which does not use power machine (yarder). This cable system uses wire stretched from the upper slope to lower slope. Both ends of the wire are tied on spar tree. To tie the log which is skidded down, a wire is used and the load is hooked on wood or branch of wood which function as load carrier. This cable system is also accompanied by simple brake.

Each wood which will be skidded down is lifted on a platform. Both ends of the logs are tied with chain or hook, to the cart and lifted to the main cable so that the carriage wheel attaches above the cable. Cable without end is clamped at the foot of the carriage. At the same time, in the lower slope, empty carriage is installed at the second cable. During the loading and installation of empty carriage, brake should be tightened so that the load does not slide freely downward. During the sliding of the log, brake is loosened so that the load slide downward and the empty carriage is pulled upward.

This cable system has been used in the harvesting of pine wood and other non teak species planted in mountainous area such as KPH Lawu Ds (East Java), KPH Sukabumi (West Java) and KPH Pekalongan. This system require a team which minimally comprise 6 – 7 persons. Average skidding distance is 250 m. Average productivity of this system is 1.73 m^3 per hour with average skidding distance of 75 m. Table 6.10 presents information on productivity of wood skidding at several different degrees of slope.

Table 6.10 Productivity of wood skidding with gravity cable system at four slopes

Slope (%)	Productivity	
	(m^3/hour)	(m^3/day)
10	1.356	9.945
15	2.156	15.091
20	1.709	11.963
25	1.777	12.442

6.2.3.2.5.3 Skyline cable system

This skyline cable system is a cable system which uses power mover (yarder). As in most skyline cable system, this system require at least 2 spar trees. Cable system which is used in the harvesting of plantation forest in Java Island is a cable system using yarder which is designed by Center for Research and Development of Forest Products, Bogor (Yarder P3HH20).

Equipment used in this cable system are among other things diesel machine Jiandong with power of 20 HP made in RRC as a motor. This machine is engineered by transmission system, cable drum, and brake system so that this equipment can be used to pull and loosen cable which is loaded with logs.

This cable system has been used in the harvesting of pine wood at several KPH's in the West Java Perum Perhutani (Unit III). This system is designed to extract wood assortment with diameter of 20 – 40 cm and length of 1 – 2 m. Average productivity of this system is 13.72 m^3 per day or 1.69 per hour with average skidding distance of 110 m.

6.2.3.3 Loading and unloading

Loading and unloading of wood in the area of Perhutani is generally using traditional system. This activity is conducted by group comprising 6 – 20 workers. This loading and unloading system is used not only for small diameter wood, but also for large diameter wood. Although this system has low productivity and very dangerous for the worker, this system is still used up to now.

Equipment used in this traditional loading and unloading system consist of ender-ender, tulak, rami rope, and lever metal stick. Ender-ender is wooden poles which possesses length of 4 – 6 m, and diameter of 18 – 20 cm which function as a bridge for wood which will be lifted to the truck. Tulak is a round metal measuring 2 m in length and diameter of 4 – 10 cm which function as a lever and pushes the wood to enter the truck. Rami rope function to assist in pulling the wood above the truck from other side. The diameter of rope used, is usually 3 m with length up to 20 m. The lever metal stick serve as a lever and used to arrange the position of the log on board of the truck.

6.2.3.4 Wood transportation

Wood transportation, including skidding, is a very important stage of forest harvesting because it require a biggest item of cost. Cost in this stage is estimated as 70% from the whole cost of forest harvesting. This cost is used mainly for investment in the procurement, construction and maintenance of transportation infrastructure such as road, railroad, bridge, and vehicles. Mode of transportation in the area of Perum Perhutani is by using truck and locomotor.

6.2.3.4.1 Wood transportation using truck

Mode of wood transportation with trucks is used in plantation forest harvesting, both in Java and in Industrial Plantation Forest (IPF) outside Java. Difference in the mode of transportation of this two kinds of plantation forest is in terms of size and capacity of the truck.

In the plantation forest of Java Island (Perum Perhutani), trucks with smaller transporting capacity are used. Small trucks which are frequently used in highway, are those commonly used in wood transportation in Perum Perhutani. This truck is known with wheel arrangement of 6 x 4, which imply that total number of wheel is 6, whereas the number of motor wheel is 4, with two axis. The power of this truck is between 100 – 135 PK (Horse Power) which is able to haul load up to 8 tonnes. Average load of wood transportation using truck in Perum Perhutani, ranges between 3 – 4 m^3/truck with speed of 35 – 40 km per hour.

From the point of view of truck ownership, truck used in wood transportation is categorized into owned by Perum Perhutani or owned by other parties. In wood transportation in Perhutani, private companies which transport wood, uses trucks with various trade marks (brands) such as Themes Traider, Chevrolet, Desoto, Ford, Fuso, and Zill. On the other hand, trucks possessed by Perhutani have trade mark (brand) Mercedes 911 or Mercedes 808. These official trucks are used in turns form one KPH to other KPH. Transportation distances with trucks at several large KPH's such as KPH Cepu, Randublatung, Bojonegoro, and Jatirogo are less than 20 km.

6.2.3.4.2 Wood transportation using loco motor

Mode of wood transportation, firstly used for wood harvesting in the area of Perum Perhutani is the use of cikar, pushed lorry, and loco motor. The use of cikar and pushed lorry is at present, not existing anymore, whereas wood transportation using loco motor is still used up to this time in KPH Cepu, but with minor role as compared to transportation using truck.

Locomotive which function as hauler is moved by steam power obtained from the burning of fuel wood. This loco motor is produced by one machine industry in Germany (Berliner Maschinenbau) in the year 1928. The number of remaining loco motor which are still functional is three units. Up to now, beside serving as wood transportation means, this loco motor is also used in forest recreation services. This locomotive has the capacity to haul carriages with load up to 65 m^3 for maximum distance of 20 km and 45 m^3 for maximum distance of 40 km. Maximum number of carriage in a series is 12 units. Estimate of the amount of fuel needed in the form of fire wood is 7.2 sm. Loco motor operator usually number to 5 persons comprising 1 machinist, 1 fire crew (stoker) and 3 brake handler.

6.2.4 Harvesting system in Industrial Plantation Forest

6.2.4.1 Tree felling and bucking

Tree felling in HTI is conducted with chainsaw or feller. However, most HTI uses chainsaw as tree felling tool, especially small HTI. On the other hand, large HTI

uses also feller, as well as chainsaw. Activities of delimbing, debranching topping, and bucking are still using chainsaw.
Chainsaw used in tree felling in HTI has machine power between 5 – 8 HP. Productivity of tree felling with chainsaw for trees with diameter under 25 cm is 43 trees per hour. Tree felling worker group has two jobs namely tree felling and bucking, and collecting (stacking) the products in the side of forwarder skidding road. This stacking of wood is conducted manually. Several trade marks (brands) of chainsaw frequently used in HTI is STIHL, Husquarna, and ECO.

Second equipment for tree felling in HTI is feller buncher. Feller buncher is a mobile wood cutting equipment and constitute an excavator model with high wide car body, complemented with disc save head which function to hold and cut tree stems. Feller buncher is operated with two purposes, namely as feller and as a means to stack logging products (buncher). As a transportation facility, feller buncher is only suitable for short distance transportation. Logging products which amount to 2 to 4 trees are transported with this equipment from tree felling site to skidding road, log yard or roadside. The use of this equipment in wood harvesting of plantation forest is still relatively recent.

HTI companies in Indonesia which have used feller buncher in its activities are among other things HTI Arara Abadi in Riau, HTI Riau Andalan Pulp and Paper, and several HTI's in Kalimantan. Model's which have been used have the power of 168 HP and 153 HP. Several brands of feller buncher which have been used in Indonesia are Bell feller buncher, Timbco buncher, and Caterpillar.

Productivity of tree felling using this equipment ranges between 72 – 170 trees per hour. Tree diameter which have been cut, vary between 8 cm up to 40 cm. Productivity of tree felling with average diameter of 25 cm ranges between 34 m^3/hour – 37m^3/hour. The use of feller buncher is suitable for terrain with slope of 10% – 35%.

6.2.4.2 Wood skidding

6.2.4.2.1 Forwarder system

Wood skidding with forwarder in Indonesia is conducted during harvesting of HTI outside Java Island. The brands of forwarder which have been used in Indonesia are Timberjack 610 and Anoa. Anoa is a forwarder which is designed by Indonesian worker in a factory of heavy machinery, Trakindo. This wood skidding machine is suitable for trees with diameter of 10 – 50 cm and large area of harvest, because the cost of skidding operation with forwarder is very expensive. Length of wood segment generally consist of 2 sizes. For trees with diameter > 20 cm, the length is 4.0 – 4.2 m whereas for trees with diameter of 10 – 19 cm, the length is 1.4 – 3.5 m. HTI company in Indonesia which has operated this equipment is among other things PT. Musi Hutan Persada which is located in Sumatera.

Figure 6.5 Short distance wood transportation and wood loading using forwarder in one HTI in Sumatera

Wood harvesting using forwarder system, has the following sequence :

1. Tree felling using chainsaw
2. Bucking and debranching using chainsaw
3. Wood gathering (bunching) at the side of skidding road
4. Wood skidding from the pile of wood on the road side to log yard

Harvesting with forwarder system can be done by a tree feller, 2 to 4 helpers who move the wood from the stump to road side, and a forwarder operator. Tree felling productivity is 1.76 m^3 per hour or 12.32 m^3 per day (1 working day = 7 hours). Productivity of skidding ranges between 182.42 m^3 per day – 190.40 m^3 per day.

6.2.4.3 Loading and unloading

From the technical and ergonomical point of view, loading and unloading of wood in HTI is better than those in plantation forest of Perum Perhutani. Equipment used in HTI is designed in accordance with modern technological development of wood harvesting. Wood skidding equipment used in the harvesting of HTI, such as forwarder, possesses its own loader. Loader in forwarder can execute loading and unloading in log yard, and loading to long distance transportation vehicle. Beside that, wood loading and unloading to and from truck in HTI can be conducted with special equipment to load and unload, namely grapple loader or loader mounted on a truck.

Figure 6.6 Wood loading and unloading using grapple loader

6.2.4.4 Wood transportation

6.2.4.4.1 Wood transportation with truck

Transportation vehicle used in the harvesting of HTI is variable enough. Generally, vehicle to transport pulp wood ranges from flat bed truck with gross weight of 4 tonnes up to trailer truck with gross weight of 65 tonnes. Large HTI companies generally use truck with large size and capacity, whereas small HTI companies tend to use truck with capacity of 1.5 to 2 tonnes which are able to transport load up to 6.5 tonnes.

Figure 6.10 Truck for transporting logs in HTI

6.2.4.4.2 Wood transportation with loco motor

This wood transportation with lorry is not used in the wood harvesting in HTI. However, loco motor is used transporting wood pulp from log yard to processing factory.

6.3 Economics of forest plantation establishment

6.3.1 Feasibility study and investment analysis: Case study of Barito Pacific Group Companies (*Acacia mangium*)

A feasibility study was done in 1992, which included an attempt to quantify the profitability of the project. Before the study was done, the Ministry of Forestry issued a permit to set up a trial plantation over 50.000 ha, for a period of five years starting 1n 1989. Generally there are two groups in developing a plantation forest, namely costs incurred during the establishment period, and costs incurred during the harvesting period.

Establishment cost were Rp 2,147,683 per hectare (equivalent to US $ 1,058). This covered:

1) Planning overhead cost
2) Nursery protection (the pest and disease)
3) Land preparation interest during construction
4) Planting amortization
5) Maintenance infrastructure development and maintenance

6) Estimated harvesting costs, up to the miligate, were Rp 20,500/m^3 (US $ 10,1) and cover the following items
7) Construction of logging roads extraction
8) Maintenance of logging roads loading and unloading
9) Felling transport

Assumptions that were made for the financial analysis included:

a. The rotation length for the selected species is 8 years
b. Amortization method is straight line
c. Deposit interest for the equity is 11%
d. Inflation rate is 9%
e. Commercial interest rate on the reforestation fund is 11%
f. Planted area is 193,500 ha
g. The area harvested each year is 21,500 ha
h. The yield of pulpwood at age eight years is 200 m^3/ha
i. The selling price of the log is Rp 60,000/m^3 (US $ 29,6/m^3)
j. Assessment was calculated based on cash flow for 17 years

Based on these assumptions the analysis showed that the project would yield an internal rate of return (IRR) of 14.12% which higher than the composite interest of 10.07%. Sensitivity analysis showed that the project would still be feasible with the following conditions:

a. Log price decreases by 8%
b. Production decreases by 12%
c. Production cost increase by 8%
d. A combination of selling price and production both decrease by 5%
e. A combination of selling price decreases by 4% and production cost rises by 4%
f. A combination of production decreases by 5% and, and production cost rises by 5%.

6.3.2 Case: Feasibility study of development of HTI *(Acacia mangium, Gmelina arborea, Eucalyptus deglupta)* by PT. Kertas Basuki Rachmat (December 1996)

Feasibility Study of company to express a competent company or its don't in executing visible development from level of NPV, BCR, and IRR. Level of NPV, BCR, and this IRR is later; then compared to by criterion: if IRR>I, NPV>0, and BCR>1, hence the company competent to execute development HTI.

Enterprising HTI Pulp PT Paper Basuki Rachmat of composite rate of interest level 11,21% owning value NPV of equal to Rp 40,- billion, BCR of equal to 1,106 and IRR of equal to 13,52%, seemly mount BCR, NPV, and IRR hence the enterprising HTI PT Paper Basuki Rachmat and development of pursuant to competent financial analysis be achieved.

6.3.3 Case: Feasibility study of development of HTI *(Paraserianthes falcataria)* PT Ceria Karya Pranawa (March 1996)

By virtue of projection of current of cash can be conducted by analysis of financial with method of discounted cash flow. Some assumption in analysis of this financial:

1. Duration analyze once the period plant plus harvest (twice cycle) in this case 16 year (t0 - t16). Year of preparation and seedbed of crop started by one year of before cultivation (t0). Development of cycle crop of I (t0 - t8), year seldom (t5), and the year start crop after cycling 8 year (t9 - t16).
2. Inflation rate for input and out put relative is equal, so that the price (market price) input and also output is constant price.
3. Rate of interest used in analysis is rate of interest deliberated of according to proportion of capital source. Pursuant to capital structure, and assumption that opportunity cost of capital equity of equal to 17.5% (deposit rate), Fund of Reboisasi of equal to 0%, and DR with flower of equal to 17.5%, hence flower (discount rate) what is used for the calculation Assess Clean Nowadays (NPV) and also Ratio Manfaat-Biaya (B/C) [of] equal to 12%. Calculation analyzes eligibility of financial presented at Table 6.11.

Table 6.11 Result of Financial Analysis of Activity of HTI in PT Ceria Karya Pranawa

Interest Rate	12%	15%	18%	23%
NPV	35,089,806,598	13,571,885,464	-1,040,165,091	-15,786,558,494
Total Acceptance Disconto	127,518,342,902	94,949,856,007	71,616,574,306	45,968,295,872
Total Expenditure Disconto	92,428,536,304	81,377,970,543	72,656,739,398	61,754,854,366
Benefit Cost Ratio	1.38	1.17	0.99	0.74
Internal Rate of Return (%) = 17.79				

6.3.4 Case: Financial feasibility of development HTI *(Acacia mangium, Gmelina arborea)* PT Sinar Alam Lestari (March 1995)

Pursuant to projection of current of cash can be conducted by analysis of financial with method of discounted cash flow. Some assumption in financial analysis :

1. Duration analyze once the period plant plus harvest (twice cycle) in this case 16 year (t0 - t16). Year of preparation and seedbed of crop started by 1 year of before cultivation (t0). Development of cycle crop of I (t0 - t8), year seldom (t5), and the year start crop after cycling 8 year (t9 - t16).
2. Inflation rate for input and output relative is of equal, so that the price (market price) input and also output is constant price.
3. Rate of interest used in analysis is rate of interest of deliberated according to capital source proportion. Pursuant to capital structure and assumption that opportunity cost of capital equity of equal to 14% (deposit rate). interest free Fund DR equal to 0% and DR of deposit interest of equal to 12%, for a while capital composition is 36.33% (equity) : 32.17% (interest free DR : 31.5% (DR deposit interest), hence flower (discount rate) what is used for enumeration NPV of and also BCR of equal to 9%.

Result of calculation analyze eligibility financial enterprising HTI with type and mount certain management is designed at wide of areas 144.000 competent ha executed by financial, where NPV > 0 (Rp 31.72 billion), BCR > 1 (1.10) and IRR

(16.54%) is higher the than boundary IRR value which can be accepted. While calculation result analyze pure eligibility financial enterprising HTI PT SAL show is improper executed by financial, where value NPV < 0 (Rp – 39.99 billion), BCR < 1 (0.898), value IRR < used rate of interest (17%). Composite rate of interest 17% this reckoned from by a capital equity PT SAL flower of equal to 14% with by investment expense of equal to 66% and commercial capital rate/ bank loan equal to 18% from 34% required total cost.

Comparison of cost, capital structure, analyze balance, projection of money stream, and analyze financial, and also eligibility of financial of executor of development of HTI PT SAL by joint and presented by pure PT SAL of tables of following :

Table 6.12 Comparison Executor of Development of HTI PT SAL

No	Breakdown of	Executor of Development of HTI PT SAL	
		Joint	**PT SAL**
1	Total cost of development HTI (t0-t8)	Rp. 201.70 billion	Rp 201.70 billion
2	Capital structure	1. Equity (PT SAL and PMP) : 36.33% 2. Interest free DR : 32.17% 3. DR deposit interest : 31.50	1. Equity PT SAL : 34% 2. Commercial bank loan : 66 %
3	Profit analyze	cumulative profit balance start year 12th Rp 142,34 billion	negative cumulative profit Rp 118.24 billion.
4	Cash flow	Positive start year 5th to the last year of is effort (t16)	Start year 5th to 9th, year 10th and 16th negative cumulative.
5	Financial analyze	NPV = Rp.31,32 billion BCR = 1.101 IRR = 16.54% i = 9 %	NPV = Rp-39.99 billion BCR = 0.898 IRR = negative i = 17%
6	Financial feasibility	Competent	Improver

6.3.5 Prospect for timber plantation development

Prospects for timber plantation development and investment opportunities depend on the market for the product. According to the data of the Ministry of Trade and Industries for 7 commodities for export, plywood and sawn timber are decreasing at 2 – 6% per year, but pulp product is increasing around 20% per year. This indicates that the forest product prospective is developing especially timber plantations for pulpwood product.

6.3.6 The problems of timber plantation

1) High risk and uncertainty: Timber plantation development is very risky and uncertain because it involves many people, it needs a lot of funding and it takes a long time to develop. Finding solutions to the problems has a high priority especially for large scale timber plantations.
2) Legal aspect of area and land tenure: Large-scale plantation need large areas of land, and the land must be available for a long period of time. In Indonesia, it is difficult to find large areas of land that are not being used, and where the availability of the land can be assured for a long period. Most of the people live in rural areas, and depend on farming, fishing, hunting, and other rural activities for their subsistence.
3) Shifting cultivation: the activities of local people in and around the forest put pressure on forest land through shifting cultivation and fire.
4) Deforestation and forest fire: Forest fire is a big problem in Indonesia, which, together with shifting cultivation and logging operations causes deforestation. Deforestation in Indonesia is about 900,000 – 1.2 million hectares per year. In the last decade, this has increased to nearly 1.6 million hectares per year. Forest damage occurs not only in natural forests but also in plantation forest.
5) Soil quality: Generally the tropical rain forest is a fragile ecosystem with soil of marginal quality.

6.3.7 Discussion

Plantation forest development in Indonesia has may constraints. The investment risk in plantation forests can be attributed to the in security and high risk due to long-term land-used conflicts.

The development of plantation forest has requirements that are becoming more difficult to accomplish. For example, for pulp logs the area should be about 300,000 ha, this size is difficult to be achieved in the condition of "clear and clear".

Establishment size of plantation forest of 30,000 - 50,000 ha in a continuous area is also difficult due to community pressures on the forest land. These pressures create on going conflicts.

Investors are not yet interested in establishment of plantation forests for fuel wood due to low selling price and expensive production and transportation costs. In the words, revenues do not cover the total production costs.

On the other hand, investors for plantation forest should be encouraged in order to rehabilitate degraded bare land, create employment and sustain the environment.

Future trends such as exports of sawn timber and plywood have been decreased between 2 – 6%, whereas pulp export has been increased up to 20%. Therefore plantation forest establishment should be focused for pulp production, with beneficial output from 7 years rotation (short term), quick reinvestments and fast growth because of silvicultural system.

Analysis suggests that a plantation of under 10,000 ha is inefficient except for short rotation (7 year) and pulp logs. Plantation forest for construction wood needs a time frame of more than 30 years and minimal business scale of 30,000 ha.

The main problems of plantation forests are social conflicts, land security and markets for plantation forest products. The main problems should be acknowledged for potential investors in plantation forest business.

Solutions for successful establishment of plantation forest are as follows:

1) Legal concerns and security of plantation forest concessionaires.
2) Infertile soil of plantation forest, which therefore, needs technology inputs.
3) The availability of good quality seeds.
4) Management, organization, and professional human resources, capital investment.
5) Adequate capital investment.
6) Available industry and markets absorbing plantation forest products.
7) Social conflict should be controlled to minimal level.