Stand Dynamics of Dipterocarp Trees in Cambodia's Evergreen Forest and Management Implications — A Case Study in Sandan District, Kampong Thom [*1]—

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ABSTRACT

The purpose of this study was to explore the stand dynamics of dipterocarp species in evergreen forest as a basis for devising suitable management systems for Cambodia's forests. The data for this study were obtained from a two-year UNDP-funded forest inventory project in Sandan district of Kampong Thom province. A sample of 18 clusters located in evergreen forest were analyzed. Based on the average stand volume per hectare, this evergreen forest was further divided into poor (less than 200m^3), medium (200-300 m^3) and rich (greater than 300 m^3) forests. Dipterocarps contributed 50 m^3 (36%), 109 m^3 (43%) and 163 m^3 (53%) in poor, medium and rich forests, respectively. The dominant dipterocarps species were CHBG (*Dipterocarpus turbinatus*), CRMS (*Vatica astrotricha*) and PHDK (*Anisoptera glabra*).

To estimate the forest potential and allowable cut of dipterocarps stands, trees of DBH greater than 45cm were analyzed. Cambodia's silvicultural treatment prescribes that only 30% of stands are extracted on a selective felling cycle of 25-30 years. On the basis of this silvicultural treatment and management experience in Southeast Asia, the harvest potential of Cambodia's forest was estimated to vary from 20 m^3/ha (6 trees) to 54 m^3/ha (13 trees); approximately 65% of which was dipterocarps. These figures are more than double the current harvest rate of 10 m^3/ha. However, applying such a new management system might cause forest degradation if there is no long-term political commitment to management and research from the government and parties involved. Permanent and regular research on stand dynamics and other influential factors are required to ensure the sustainability of forest resources. Forest management can no longer be concerned solely with timber production; thus, harvesting and research in non-timber forest products should also be included in the management plan.

Keyword: Cambodia, dipterocarps, evergreen forest, forest management

INTRODUCTION

Tropical forests occupy only 7% of the Earth's land area, but they contain the majority (approximately 50-90%) of the Earth's species (WORLD PESOURCES INSTITUTE, 1989). Many functions of a tropical forest can be best met by careful natural forest management which is able to produce wood and other products with low inputs, provide a livelihood for people living in the forest and preserve ecological functions to a high degree (WEIDELT, 1996). Unfortunately, as a result of rapid development and fast growing population, the sustainability of tropical forests has been problematic in recent years. Although several attempts have been made to bring the forests under sustainable use and management, sustainability still remains dependent on the search for balance between the needs of present and future generations. Lack of knowledge of stand dynamics of different forest types might be one of the causes of mismanagement; hence the un-sustainability of use of the world's tropical forests today. Dipterocarps are dominant in tropical forests, and commercially important. Dipterocarp forests of Southeast Asia constitute a major and particularly valuable component of the world's tropical rain forests. The bulk of tropical timber comes from Dipterocarp ecosystems (CHOONG and ACHMADI, 1996).

Over the past 30 years of political instability, Cambodia's forests were left unmanaged and since then no forestry research has been done to improve the current forest management systems. Therefore, this study's purpose was to explore the stand dynamics of evergreen forest, focussing mainly on dipterocarp stands as a basis for devising suitable management systems for Cambodia's forests.

STUDY METHODS

Forest inventory

With the financial assistance of UNDP (United Nations Development Program), an executive agency of FAO, and a counterpart of the Department of Forestry and Wildlife, a two-year forest inventory project was initiated in 1995 and started operationally in January 1996. This inventory project covered 0.5 million ha of forests in Cambodia's two largest districts, Sandan and Santuk of Kampong Thom province.

Under this two-year inventory project, cluster sampling was chosen for practical reasons (DFW, 1998a). The clusters were set on 4 x 4-km grid lines (Fig. 2). Approximately 131 clusters were identified on the map for sampling; however, due to security and other reasons, only 66 clusters were successfully measured, of which 23 were located in evergreen, 36 in mixed, and 4 in deciduous forest, respectively. Only 18 of the 23 clusters in evergreen forest were analyzed. Each cluster contains 9 plots of 20 X 60m size; three plots in a line at equidistant intervals of 100m with 100m between the lines which are oriented to the north. All trees within DBH classes of 5-10, 10-30 and greater than 30cm were recorded in 0.01 ha, 0.04 ha and 0. 12 ha sample plots, respectively (Table 1).

Table 1: Recording procedure in each sample plot

Dimension of sample plots (m)	Area (ha)	DBH Classes (cm)
10x10	0.01	5-9.9
20X20	0.04	10-29.9
60X20	0.12	>30

Data analysis

The data for this study were made available by FAO's representative in Cambodia, with the approval of DFW.

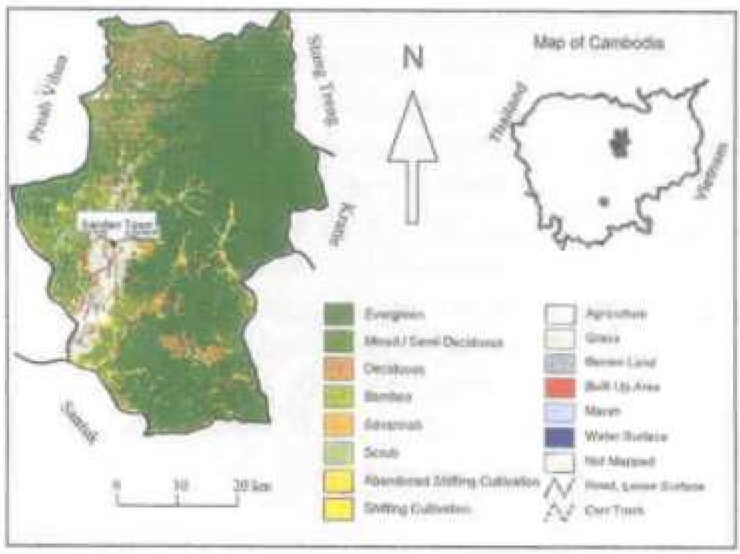

Fig. 1: Forest and land cover map of Sandan
Note: This map was prepared by DWF in 1997

As agreed in discussion with DFW, analysis based on a single cluster is not considered adequate to represent the whole forest. Thus, the authors analyzed data in 18 clusters, and took the average result of each plot by grouping into dipterocarps, non-dipterocarp, and unknown trees in order of diameter class of 5-9, 10-19, 20-

29, 30-39, 40-44, 45-49, 50-59, 60-69, and greater than 70cm. To estimate the harvest potential, the authors split the diameter class of 40-49cm into 40-45cm and 45-49cm due to the fact that the diameter limit for harvest of some trees is set at 45cm DBH. Dipterocarp trees were further classified into their genera and species for the stand dynamics study. In addition to these data, fieldwork was carried out between April and May 1999 to check some of the sampled clusters.

LITERATURE REVIEW OF DIPTEROCARPS

Dipterocarp trees generally are very dominant in the tropical forests and are now the major source of timber in Southeast Asia (CHOONG and ACHMADI, 1996). All dipterocarpaceae species are arborescent and tropical. The family type genus is the Asian *Dipterocarpus* Gaertn f. Dipterocarps are trees with alternate entire leaves and pentamerous flowers. The family Dipterocarpaceae *sensu stricto* is homogeneous and limited to Asia, while the Dipterocarpaceae *sensu lato* include three subfamilies: Dipterocarpoideae in Asia, Pakaraimoideae in South America; and Monotoideae in Africa and South America (MAURY-LECHON and CURTET, 1998). Consequently the family contains 15-17 genera or 470-580 species. In Cambodia alone there are 5 genera or 23 species of Dipterocarp trees. The 5 genera includes *Anisoptera* (1 species), *Dipterocarpus* (7 species), *Hopea* (5 species), *Shorea* (7 species) and *Vatica* (3 species) (Table 2). There are two major forest types in Cambodia - dryland and edaphic forests. Dipterocarps are the dominant species in all evergreen, mixed and deciduous forests of dryland forests.

Table 2: Tree Species of Dipterocarpaceae family in Cambodian forests

Scientific name	Local name	Species code	Commercial group
Anisoptera glabra	Phdeak	PHDK	
Dipterocarpus costatus	Chhieutiel Neandeng	CHND	Keruing
Dipterocarpus tuberculatus	Khlong	KHLG	Keruing
Dipterocarpus intricatus	Trac	TRAC	Keruing
Dipterocarpus alatus	Chhieutiel Tiek	CHTK	Keruing
Dipterocarpus dyeri	Chhieutiel Chgor	CHCG	Keruing
Dipterocarpus turbinatus	Chhieutiel Beng	CHBG	Keruing
Dipterocarpus obtusifolius	Tbeng	TBEG	Keruing
Hopea recopi	Chramas Tiek	CHMT	Merawan
Hopea ferrea	Korki Thmor	KKTM	Merawan
Hopea pierrei	Korki Ksach	KKKS	Merawan
Hopea odorata	Korki Masao	KKMS	Merawan
Hopea helferi	Korki Deck	KKDE	Merawan
Vatica astrotricha	Chramas	CRMS	Resak
Vatica philastreana	Tralat	TRLT	Resak
Vatica odorata	Chramas Tmor	CRTM	Resak
Shorea thorelli	Pchek Udom	PCUD	Meranti
Shorea siamensis	Ring Phnum	RIPM	Meranti
Shorea hypochra	Korki Pnorng	KKPN	Meranti
Shorea farinosa	Lumbior	LMBI	Meranti
Shorea obtusa	Pchek	PCEK	Meranti
Shorea vulgaris	Chor Chong	CHRH	Meranti
Shorea cochinchinnensis	Po Peil	PPEL	

OVERVIEW OF STUDY SITE

According to meteorological data, the provincial town of Kampong Thom's average rainfall was 1,305mrn and temperature 27.1°C between 1990 and 1993. Sandan is one of the seven districts of Kampong Thorn, containing 9 communes or 71 villages. Sandan has a population of 37,098 of whom 19,023 are female. Nearly 75% of the population are engaged in farming and forestry for their livelihood. Sandan (Fig. 1) has a total land area of 291,498ha, 89% of which is forested. Forest area has declined from 261,974ha in 1993 to 260,798ha in 1997. In terms of percentage, only 0.1% of the forest area has been converted to other forms of land use. By contrast, agricultural land has increased 488ha or 0. 04% per year over the same period (Table 3). The main economic development factors include logging, fishing and labor hire.

Table 3: Changes in land use in Sandan district

Type of land	**Area (1992-'93)**		**Area (1996-'97)**		**Change**	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest area	261,974	89.9	260,798	89.5	-1,176	-0.4
Evergreen dense	41,516	14.2	41,516	14.2	0	0.0
Evergreen disturbed	174,922	60.0	173,177	59.4	1,745	-0.6
Evergreen mosaic	5,986	2.0	6,775	2.3	789	0.3
Mixed dense	732	0.2	732	0.2	0	0.0
Mixed disturbed	7,332	2.5	7,287	2.5	-45	-0.0
Mixed mosaic	3,597	1.2	3,597	1.2	0	0.0
Deciduous	10,976	3.8	10,976	3.8	0	0.0
Deciduous mosaic	1,282	0.4	1,282	0.4	0	0.0
Forest regrowth	15,630	5.4	15,455	5.3	-176	-0.1
Non-wood	29,524	10.1	30,700	10.5	1,176	0.4
Wood/Shrub evergreen	3,809	1.3	3,659	1.3	-149	-0.0
Grassland	91	0.0	91	0.0	0	0.0
Wood/shrub dry	5,288	1.8	5,288	1.8	0	0.0
Mosaic of cropping (<30%)	2,682	0.9	3,471	1.2	790	0.3
Mosaic of cropping (>30%)	602	0.2	650	0.2	48	0.0
Agricultural land	16,930	5.8	17,417	6.0	488	0.2
Water surface	124	0.0	124	0.0	0	0.0
Total	291,498	100.0	291,498	100.0	0	0.0

Source: DFW (1998)

ANALYTICAL RESULTS

Before this two-year inventory project, evergreen forest in Sandan district had never been logged for any commercial purpose. Data used in this study were taken from 18 inventoried clusters (19.44ha). For all trees with DBH greater than 5cm, an average density of 1105.5 trees/ha and stand volume of 235.2m^3/ha were recorded. Within these totals, dipterocarps comprised 194.1 trees and 107.1m^3, non-dipterocarps 405.1 trees and 70.6m^3, and unknown species 506.3 trees and 57.4m^3 for density and stand volume, respectively (Table

4). Table 4 also shows that mean stand density and stand volume per hectare varied from 982.5 trees and 96.6m^3 (No. 1) to 1,075.7 trees and 210.9m^3 (No. 5), and to 1,290.4 trees and 300.1m^3 (No. 12). In order to allow more accurate evaluation, Sandan's evergreen forest was further classified into poor (stand volume less than 200m^3/ha), medium (stand volume between 200-300m^3/ha) and rich forest (stand volume greater than 300m^3/ha) (Fig. 2).

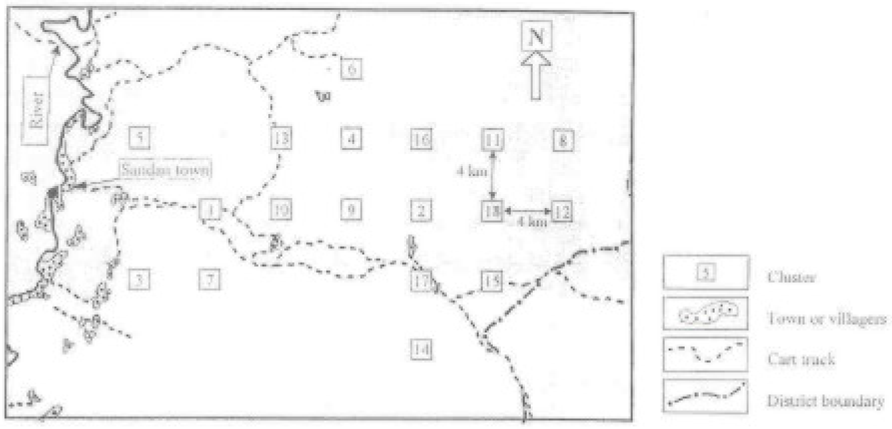

Fig 2: Map of inventoried clusters

Table 4: Mean stand density and volume per hectare in Sandan's evergreen forest (DBH --z 5cm)

Sample Cluster No.	Dipterocarps		Non-dipterocarp		Unknown		Total	
	Density (trees)	Volume (m^3)	Density (trees)	Volume (m^3)	Density (trees)	Volume (m^3)	Density (trees)	Volume (m^3)
Poor forest								
1	145.4	34.8	323.7	19.3	513.4	42.5	982.5	96.6
2	111.1	34.9	363.2	70.6	437.2	27.8	911.5	133.3
3	204.6	42.6	375.5	87.7	430.2	29.3	1010.3	159.6
4	70.6	87.1	387.6	40.8	397.1	31.3	855.3	159.2
Mean	132.9	49.9	362.5	54.6	444.5	32.7	939.9	137.2
Medium forest								
5	263.3	68.5	404.6	80.2	407.8	62.2	1075.7	210.9
6	190.7	79.7	401.2	67.0	635.9	79.2	1227.8	225.9
7	181.5	130.0	360.2	71.1	498.2	56.1	1039.9	257.2
8	192.1	106.6	318.9	74.5	613.6	78.5	1124.6	259.6
9	200.7	139.6	418.5	56.3	489.8	71.2	1109.0	267.1
10	216.4	99.2	511.4	114.3	497.6	67.2	1225.4	280.7
11	188.9	139.2	356.6	62.5	307.9	77.3	853.4	279.0
Mean	204.8	109.0	395.9	75.1	493.0	70.2	1093.7	254.3
Rich forest								
12	322.0	134.3	410.6	70.8	557.8	95.0	1290.4	300.1
13	145.4	169.6	478.2	56.0	611.1	76.4	1234.7	302.0
14	232.9	165.3	328.5	68.5	592.1	70.4	1153.5	304.2
15	193.5	129.7	354.4	126.5	562.3	51.0	1110.2	307.2
16	233.3	151.6	522.6	87.1	575.2	76.5	1331.1	315.2
17	317.6	183.8	586.8	96.0	469.2	41.1	1373.6	320.9
18	267.6	203.6	516.7	69.2	703.3	75.5	1487.6	348.3
Mean	244.6	162.6	456.8	82.0	581.6	69.4	1283.0	314.0
Mean (all)	194.1	107.1	405.1	70.6	506.3	57.5	1105.5	235.2

Poor forest

Poor forest comprised 4 of the total 18 clusters. On average per hectare, this forest has 939.9 trees and 137.2m^3, of which 132.9 trees (14.1%) and 49.9m^3 (36.3%) were Dipterocarps. Non-dipterocarps trees were 362.5 trees (38.6%) and 54.6 m^3 (39.8%), of which Myrtaceac, Ebanaceae and Caesalpinaceae were 12.8% and 9.8%, 6.4% and 2.0%, and 4.0% and 6.8% for stand density and stand volume, respectively (Table 5). Approximately 39.8% of total trees and 55.5% of stand volume for trees of DBH greater than 45cm belonged to the Dipterocarpaceae family (Table 5). The distribution of the stand volume across DBH classes clearly indicated that Dipterocarps mainly dominated the upper story and were therefore canopy and emergent trees.

Table 5: Mean stand density and stand volume per hectare of poor evergreen forest

Family	Total (DBH<45cm)				Total (DBH>=45cm)				Total (DBH >= 5 cm)			
	Density		Volume		Density		Volume		Density		Volume	
	trees	%	m^3	%	trees	%	m^3	%	trees	%	m^3	%
Dipterocarpaceae	125.7	13.6	11.8	17.2	7.2	39.8	38.1	55.5	132.9	14.1	49.9	36.3
Myrtaceae	119.7	13.0	11.6	16.9	0.9	5.2	1.8	2.7	120.6	12.8	13.5	9.8
Ebenaceae	60.0	6.5	2.8	4.1	0.0	0.0	0.0	0.0	60.0	6.4	2.8	2.0
Caesalpinaceae	36.1	3.9	5.5	8.0	1.6	9.0	3.9	5.6	37.7	4.0	9.4	6.8
Euphorbiaceae	33.1	3.6	3.4	5.0	0.5	2.5	0.8	1.2	33.6	3.6	4.3	3.1
Rosaceae	23.2	2.5	3.1	4.5	1.4	7.6	5.3	7.8	24.5	2.6	8.4	6.1
Rhizophoraceae	17.6	1.9	1.0	1.4	0.0	0.0	0.0	0.0	17.6	1.9	1.0	0.7
Sapotaceae	13.4	1.5	1.4	2.0	0.2	1.4	0.4	0.6	13.6	1.5	1.8	1.3
Hypericaceae	13.4	1.5	1.8	2.6	0.0	0.0	0.0	0.0	13.4	1.4	1.8	1.3
Crypteroniaceae	10.7	1.2	2.3	3.4	1.4	7.7	3.6	5.2	12.0	1.3	5.9	4.3
Meliaceae	9.0	1.0	0.5	0.7	0.0	0.0	0.0	0.0	9.0	1.0	0.5	0.3
Clusiaceae	5.1	0.6	0.3	0.5	0.5	2.5	1.0	1.4	5.6	0.6	1.3	0.9
Lauraceae	5.1	0.6	1.5	2.1	0.0	0.0	0.0	0.0	5.1	0.5	1.5	1.1
Sterculiaceae	3.9	0.4	0.5	0.8	0.2	1.3	0.9	1.4	4.2	0.4	1.5	1.1
Lythraceae	3.0	0.3	0.3	0.4	0.0	0.0	0.0	0.0	3.0	0.3	0.3	0.2
Fagaceae	2.1	0.2	0.2	0.3	0.0	0.0	0.0	0.0	2.1	0.2	0.2	0.2
Combretaceae	0.2	0.0	0.2	0.2	0.2	1.3	0.6	0.8	0.5	0.0	0.7	0.5
Unknown	440.5	47.8	20.5	29.8	3.9	21.8	12.3	17.8	444.5	47.3	32.7	23.9
Total	921.8	100	68.5	100	18.1	100	68.7	100	939.9	100	137.2	100

In the four clusters, six dipterocarp species were recorded: CHBG, CRMS, PHDK, LMBI, CHRH and TRAC. Since the last three (LMBI, CHRH and TRAC) are rare in this forest, they were grouped into OTHR (others) for analysis purposes. For DBH less than 45cm, 125.9 trees (stand density) and 1.8m^3 (stand volume) were recorded, of which CRMS, CHBG and PHDK comprised 108.6 trees (86.3%) and 8.1 m^3 (68.6%), 6.3 trees (5.0%) and 1.4 m^3 (11.9%), and 10.5 trees (8.3%) and 1.8 m^3 (15.3%), respectively, while OTHR covered the rest (Fig. 3). For DBH greater than 45cm, 7.1 trees and 38.1 m^3 were recorded, of which PHDK, CHBG and CRMS were 4.0 trees (56.3%) and 24.5 m^3 (64.3%), 2.7 trees (38%) and 12.4m^3 (35.2%), and 0 trees, respectively, and the rest was OTHR (Fig. 3). Based on Fig 3, it can be said that poor forest is comprised of three layers of dipterocarps-the upper layer (PHDK and CHBG), the middle layer (CRMS) and low layer (OTHR). The presence of TRAC here meant that this forest has been gradually converted to mixed and deciduous forests. In Cambodia, TRAC is usually found in deciduous forest.

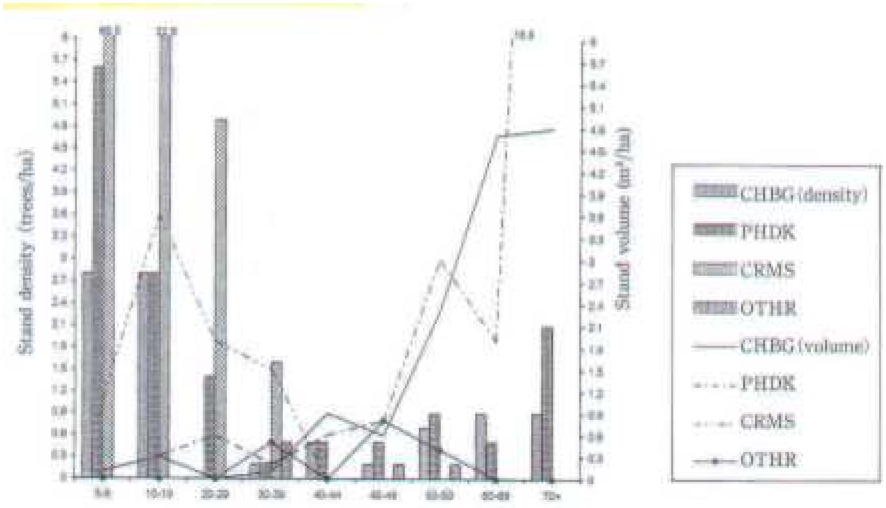

Fig. 3 Distribution of mean stand density and volume of dipterocarps in poor evergreen forest by DBH class

Medium forest

In the seven clusters, the average per hectare of stand density and stand volume recorded were 1,093.7 trees (DBH>=5cm) and 254.3m^3 of which dipterocarps, non-dipterocarps and unknown trees contributed 18.7% and 42.8%, 36.2% and 29.6%, and 45.1% and 27.6 for stand density and stand volume, respectively. Non-dipterocarps comprised Myrtaceae 118.3 trees (10.8%), Ebenaceae 102.8 trees (9.4%), Euphorbiaceae 64.3 trees (5.9%), etc. (Table 6). For stand density and stand volume of trees with DBH<45cm, dipterocarps comprised 188.7 trees (17.9%) and 22.4m^3 (21.2%), non-dipterocarps 384.8 trees (36.5%) and 42.0m^3 (39.9%) and unknown trees 483.5 trees (45.7%) and 41.2m^3 (39.0%), respectively (Table 6). For the DBH class greater than 45cm, the figures for mean stand density and stand volume of dipterocarps, non-dipterocarps and unknown trees, respectively, were 16.1 trees (43.9%) and 86.6m^3 (58.2%), 11.1 trees (30.2%) and 33.1m^3 (22.3%), and 9.5 trees (25.9%) and 29.0m^3 (19.5%) (Table 6). The larger the diameter, the more dominant were the dipterocarps.

Table 6: Mean stand density and volume per hectare of medium evergreen forest

Family	Total (DBH<45cm)				Total (DBH>=45cm)				Total (DBH>=5 cm)			
	Density		Volume		Density		Volume		Density		Volume	
	trees	%	m^3	%	trees	%	m^3	%	trees	%	m^3	%
Dipterocarpaceae	188.7	17.9	22.4	21.2	16.1	43.9	86.6	58,2	204.8	18.7	109.0	42.8
Myrtaceae	115.5	10.9	16.9	16.0	2.8	7.6	5.7	3.8	118.3	10.8	22.6	8.9
Ebenaceae	102.8	9.7	3.8	3.6	0.0	0.0	0.0	0.0	102.8	9.4	3.8	1.5
Euphorbiaceae	63.6	6.0	5.4	5.1	0.7	1.8	1.3	0.8	64.3	5.9	6.6	2.6
Caesalpinaceae	18.3	1.7	3.0	2.8	2.0	5.4	6.0	4.0	20.2	1.8	9.0	3.5
Clusiaceae	19.3	1.8	2.2	2.1	0.7	1.8	1.5	1.0	20.0	1.8	3.8	1.5
Meliaceae	18.0	1.7	1.0	0.9	0.0	0.0	0.0	0.0	18.0	1.6	1.0	0.4
Lauraceae	12.8	1.2	1.5	1.4	0.0	0.0	0.0	0.0	12.8	1.2	1.5	0.6
Sterculiaceae	7.3	0.7	1.2	1.1	0.9	2.5	6.7	4.5	8.2	0.8	7.8	3.1
Rosaceae	4.3	0.4	2.0	1.9	2.9	7.9	9.0	6.1	7.2	0.7	11.0	4.3
Crypteroniaceae	6.1	0.6	2.6	2.5	0.0	0.0	0.0	0.0	6.1	0.6	2.6	1.0
Rhizophoraceae	3.6	0.3	0.2	0.2	0.1	0.4	0.3	0.2	3.7	0.3	0.5	0.2
Hypericaceae	3.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0	3.6	0.3	0.1	0.0
Lythraceae	2.3	0.2	0.3	0.3	0.3	0.7	0.5	0.3	2.5	0.2	0.8	0.3
Sapotaccae	1.2	0.1	1.0	0.9	0.7	1.8	2.0	1.4	1.9	0.2	3.0	1.2
Verbenaceae	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	0.0
Ochanaceae	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	0.0
Moraceae	1.5	0.1	0.5	0.5	0.1	0.4	0.3	0.2	1.6	0.1	0.8	0.3
Combretaceae	0.8	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.8	0.1	0.3	0.1
Anacardiaceae	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.1	0.0
Fagaceae	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Unknown	483.5	45.7	41.2	39.0	9.5	25.9	29.0	19.5	493.0	45.1	70.2	27.6
Total	1,057	100	105.6	100	36.7	100	148.7	100	1,093.8	100	254.3	100

In the seven clusters, nine dipterocarp species were recorded, namely CHBG, CRMS, PHDK, CHRH, PPEL, KKKS, LMBI, TRAC and TRLT, with an average of 204.8 trees/ha and 109.0m^3/ha for stand density and stand volume. The last four species were grouped into OTHR (others) - With respects to stand density and stand volume (DBH<45 cm), CRMS, CHBG and PHDK comprised 137.8 trees (73.0%) and 13.3m^3 (59.2%), 8.5 trees (4.5%) and 3.6m^3 (16.0%), and 21.2 trees (11.2%) and 3.5m^3 (15.8%), respectively, while CHRH, PPEL and OTHR shared the rest. For DBH greater than 45 cm, CRMS was only 0.9 trees (5.7%) and 3.6m^3 (4.2%), PHDK and CHBG were 36.1% and 40.3%, and 49.3% and 50.8% for density and stand volume, respectively (Fig. 4).

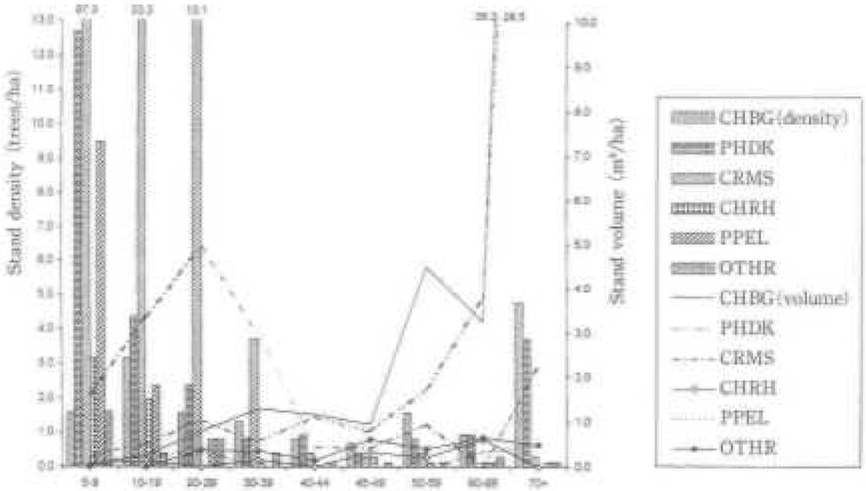

Fig. 4: Distribution of mean stand density and volume of dipterocarps in medium evergreen forest by DBH class

Rich forest

There were seven clusters of rich forest, with average stand density of 1,283.0 trees/ha and volume 314.0 m^3/ha for trees of DBH > 5cm. Of these, dipterocarps, non-dipterocarps and unknown trees contributed 244.6 trees (19.1%) and 165.7m^3 (52.8%) 456.8 trees 35.6%) and 73.1m^3 (23.2%), and 581.6 trees (45.3%) and 75.2m^3 (24.0%), respectively. Non-dipterocarps comprised Myrtaceae 176.3 trees (13.7%), Ebenaceae 102.1 trees (8.0%), Euphorbiaceae 47.0 trees (3.7%), etc (Table 7). In east Kalimantan, Indonesia, by comparison, an average stand volume of 402m^3/ha (DBH>10cm) was recorded (SIST and SARIDAN, 1998). On average per hectare for trees of DBH less than 45cm, Dipterocarps comprised 224.1 trees (18.0%) and 32.8m^3 (28.3%), non-dipterocarps were 477.4 trees (36.0%) and 43.3m^3 (36.5%), and unknown trees 572.1 trees (46.0%) and 40.8m^3 (35.2%), for mean stand density and stand volume, respectively (Table 7). For DBH class greater than 45cm, dipterocarps were 20.5 trees (52.0%) and 132.9m^3 (67.1%), non-dipterocarps 9.4 trees (23.8%) and 30.5m^3 (15.5%), and unknown trees 9.5 trees (24.2%) and 34.4m^3 (17.4%) for stand density and stand volume, respectively (Table 7).

Table 7: Mean stand density and volume per hectare of rich evergreen forest

Family	Total (DBH<45cm)				Total (DBH>=45cm)				Total (DBH>=5 cm)			
	Density		Volume		Density		Volume		Density		Volume	
	trees	%	m^3	%	trees	%	m^3	%	trees	%	m^3	%
Dipterocarpaceae	224.1	18.0	32.8	28.3	20.5	52.0	132.9	67.1	244.6	19.1	165.7	52.8
Myrtaceae	174.6	14.0	12.0	10.3	1.7	4.3	4.6	2.3	176.3	13.7	16.6	5.3
Ebenaccae	101.8	8.2	3.2	2.7	0.3	0.7	0.6	0.3	102.1	8.0	3.7	1.2
Euphorbiaceae	46.6	3.7	2.0	1.7	0.4	1.1	0.5	0.3	47.0	3.7	2.5	0.8
Clusiaceae	18.7	1.5	3.6	3.1	0.3	0.7	0.5	0.2	18.9	1.5	4.0	1.3
Lauraceae	16.8	1.4	1.0	0.9	0.0	0.0	0.0	0.0	16.8	1.3	1.0	0.3
Caesalpinaceae	13.6	1.1	3.3	2.8	2.1	5.4	9.1	4.6	15.7	1.2	12.3	3.9
Meliaceae	11.0	0.9	0.5	0.4	0.0	0.0	0.0	0.0	11.0	0.9	0.5	0.1
Crypteroniaceae	9.4	0.8	3.6	3.1	0.1	0.3	0.6	0.3	9.5	0.7	4.2	1.3
Rhizophoraccae	9.4	0.8	3.3	2.8	0.0	0.0	0.0	0.0	9.4	0.7	3.3	1.0
Sapotaceae	7.7	0.6	2.3	2.0	1.3	3.4	3.8	1.9	9.0	0.7	6.0	1.9
Anacardiaceae	8.5	0.7	0.7	0.6	0.0	0.0	0.0	0.0	8.5	0.7	0.7	0.2
Pagaceae	7.5	0.6	0.3	0.2	0.0	0.0	0.0	0.0	7.5	0.6	0.3	0.1
Sterculiaceae	6.3	0.5	2.1	1.8	1.1	2.7	5.0	2.5	7.4	0.6	7.1	2.2
Rosaceae	5.2	0.4	3.8	3.3	2.1	5.4	6.1	3.1	7.3	0.6	9.9	3.2
Mimosae	3.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	3.6	0.3	0.1	0.0
Moraceae	3.4	0.3	0.5	0.4	0.0	0.0	0.0	0.0	3.4	0.3	0.5	0.1
Lythraceae	2.5	0.2	0.2	0.2	0.0	0.0	0.0	0.0	2.5	0.2	0.2	0.1
Mimosaceae	0.5	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.5	0.0	0.2	0.1
Anonaceae	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Unknown	572.1	46.0	40.8	35.2	9.5	24.2	34.4	17.4	581.6	45.3	75.2	24.0
Total	1,243.6	100	116.1	100	39.4	100	198	100	1,283	100	314	100

From the detailed analysis of the seven clusters, six dipterocarps species were found: CHBG, CRMS, PHDK, CHRH and OTHR (KKTM and LMBI) with an average mean stand density and stand volume of 244.6 trees/ha and 165.7m^3/ha. For DBH less than 45cm, CRMS, CHBG and PHDK comprised 178.3 trees (79.6%) and 22.9m^3 (69.8%), 17.0 trees (7.6%) and 3,5m^3 (10. 7%), and 23.2 trees (10.4%) and 4.6m^3 (14.0%), respectively, while other species shared the rest (Fig. 5). For DBH greater than 45cm, CRMS, CHBG and PHDK were 0.6 trees (2.9%) and 1.9m^3 (1.4%), 10.2 trees (49.8%) and 65.8m^3 (49.5%), and 8.7 trees (42.4%) and 60.6m^3 (45.6%) respectively, and CHRH and OTHR shared the rest (Fig.5).

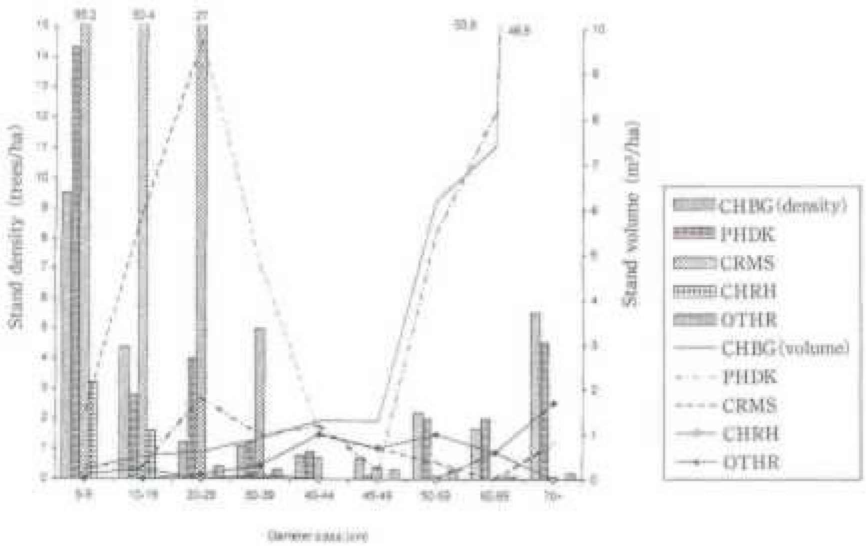

Fig. 5 Distribution of mean stand density and volume of dipterocarps in rich evergreen forest by DBH class

MANAGEMENT SYSTEMS IN SOME SELECTED COUNTRIES IN SOUTHEAST ASIA

Forest management in neighboring countries, Vietnam and Thailand

Forests in Vietnam are classified into three main types based on the stand volume per hectare, namely rich (more than 150m^3), medium (80-150m^3) and poor (less than 80m^3) forests. The harvest volume per hectare is 24 m^3/ha on average (VAN, 1999). Further information on forest management in Vietnam is not available at present.

A selective cutting cycle of 30 years is implemented in Thailand. With a mean annual increment of 1m^3/ha/year or 2% of standing volume (ITTO, 1994), the annual allowable cut per hectare is 30m^3 for evergreen and semi-evergreen forests, 80m^3 for dry mixed deciduous with teak and 45m^3 for those without teak, and 20m' for dry dipterocarp forest (FAO and UNEP, 1981). Evergreen forest is distributed through southern and eastern regions (near Cambodian border) where annual rainfall exceeds 2,000 mm, while semi-evergreen forests is distributed throughout the country where rainfall is around 1,000-2000mm/year (SUTTHISRINN, 1999).

Forest management in Malaysia

i) Malayan Uniform System (MUS)

Basically it is a system for converting the virgin tropical lowland rain forest to a more or less even-aged forest, containing a greater proportion of the commercial species. This is achieved by a clear-felling release of selected natural generation of varying ages, aided by systematic poison-girdling of defective and non-commercial species. This system has been successfully applied to the lowland dipterocarp forest, particularly in peninsular Malaysia. The cutting volume is set at 40m^3/ha of trees with DBH greater than 45cm.

ii) Selective Management System (SMS)

SMS was introduced in 1978, when it was found that MUS was not suitable for hill dipterocarp forest because of the comparatively more difficult terrain, uneven stocking, lack of natural regeneration before logging and uncertain seedling regeneration after logging (ITTO, 1994). SMS allows for more flexible timber harvesting regimes which are consistent with the need to safeguard the environment and at the same time to take advantage of the demands of the timber market. Under SMS the next cut is expected in 25-30 years after the first harvesting with an expected net economic outturn of 30-40m^3/ha enriched with dipterocarp species. The cutting limits prescribed for the group of dipterocarp species are that trees cut should not be less than 50cm

DBH, and for non-dipterocarp species not less than 45cm DBH, and the residual stocking should have at least 32 sound commercial trees per hectare.

Forest management in Indonesia

Until recently, no detailed data on growth rates of natural stands were available for Indonesia. For dipterocarp forests, estimates of 1-2m^3/ha/year in currently commercial species have been made. In such places as Sulawesi, Maluku and Irian Java, the commercial growth in the forests is assessed at less than 1m^3/ha/year (FAO and UNEP, 1981). There are two forest management systems in Indonesia: the Indonesian selective cutting sys- tem and Indonesian selective felling and replanting.

i) Indonesian selective cutting system (TPI)

Before 1988 this was the main management system which prescribed minimum cutting diameter according to forest type. Under TPI, concessionaires were required to contribute a deposit to a reforestation fund, which was refundable after they carried out the reforestation work prescribed. The system, however, was found to be impractical as only 10% of the concessionaires complied with the regeneration requirements on only 6% of the area logged. Simply, the cost for regeneration was much higher than the contribution to the reforestation fund. The TPI was then modified to require replanting, which is called Indonesian selective felling and replanting (TPTI). The TPTI was formulated to manage natural production forest with adequate young trees for regeneration.

ii) Indonesian selective felling and replanting (TPTI)

Under TPTI, forest concessionaires are required to manage their concession areas on a 35-year cutting cycle. Therefore, the annual allowable cut is based on this cutting cycle and the area given. Tree felling is bound by regulations on the minimum diameter to be cut and leaving behind a certain number of trees of certain diameter for future stock. Guidelines for TPTI which were prepared by the ministry of forestry required loggers to submit plans for inventory, road construction, felling, residual stand inventory and replanting, and protect 25 mother commercial species trees per hectare. On average, approximately 7-8 trees/ha were extracted (ITTO, 1994, Indonesia). In east Kalimantan under this system, dipterocarp forest is capable of growing about 1.3m^3/ha/year.

HARVEST POTENTIAL OF SANDAN'S EVERGREEN FOREST

Understanding the harvesting potential of a forest is a prime consideration for forest management and forest investment. As mentioned in Kim Phat (1999), in the selective cutting systems applied to Cambodian forests, harvesting intensity is expressed in terms of the volume of merchantable timber to be removed during each entry to the harvesting area or in terms of percentage of the standing merchantable volume to be removed. On the basis of a 30 year selective cutting cycle and Cambodian silviculture prescriptions under which only 30% of merchantable timber is removed (Decree 50), Sandan's harvest potential per hectare is 20.2m^3 (5.6 trees), 40.8m^3 (11.6 trees) and 54.3m^3 (12.7 trees) in poor, medium and rich evergreen forests, respectively (Table 8). The average harvest potential per hectare of all tree species for Sandan's evergreen forest is approximately 38.4m^3 (10.0 trees), of which 65.6% comes from dipterocarps.

Table 8: Harvest potential per hectare of Sandan's evergreen forest

Species	Poor forest		Medium forest		Rich forest		Average	
	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)
CHBG	1.8	9.5	5.7	38.6	7.3	58.3	4.9	35.5
PHDK	4.0	24.5	5.8	34.9	8.7	60.6	6.2	40.0
CRMS	1.6	1.5	5.0	7.0	6.3	7.6	4.3	5.4
OTHR	$^{(P)}$0.4	$^{(P)}$1.2	$^{(M)}$1.4	$^{(M)}$4.1	$^{(R)}$1.0	$^{(R)}$4.6	0.9	3.3
Subtotal	7.8	36.7	18.0	84.5	23.3	131.1	16.4	84.1
30% cut	2.3	11.0	5.4	25.4	7.0	39.3	4.9	25.2
Non-dipterocarp	6.9	18.3	11.1	22.3	9.3	15.5	9.1	18.7
Unknown	3.9	12.3	9.5	29.0	9.5	34.4	7.6	25.2
Subtotal	10.8	30.6	20.6	51.2	18.9	49.9	16.8	43.9
30% cut	3.2	9.2	6.2	15.4	5.7	15.0	5.0	13.2
Grand total	18.6	67.3	38.6	135.7	42.2	181.0	33.1	128.0
30% cut	5.6	20.2	11.6	40.8	12.7	54.3	10.0	38.4

Note: The diameter limits for harvest:
CHBG>=60cm,
PHDK>=45,
CRMS>=30,
OTHR (assumed for all) >= 45cm,
non-dipterocarps and unknown (assumed) >=45cm
OTHR$^{(P)}$: LMBI, CHRH, TRAC

OTHR$^{(M)}$: CHRH, PPEL, KKKS, LMBI, TRAC and TRLT
OTHR$^{(R)}$: CHRH, KKTM, LMBI

DISCUSSION AND CONCLUSION

The analysis of the structure of the Sandan's evergreen forest shows wide variations in both stand density and stand volume (Table5, 6 and 7). On average for stand density, 1,105.5 trees (235.2m^3/ha) were recorded; of which dipterocarps represented 17.3%. After the dipterocarps, other major species were Myrtaceae (12.5%), Ebenaceae (7.9%) and Euphorbiceae (4.4%).

The structure of poor evergreen forest is not much different from those of medium and rich evergreen forests. The difference is in quantity; as poor evergreen forest has been repeatedly logged over recent years. Poor evergreen forest should be designated as forest reserve for at least 30 years. Firewood, however, should be allowed to be extracted because about 100% of Cambodia's villagers depend mainly on firewood for cooking energy.

On a selective cutting cycle of 30 years, the harvest potential of medium and rich evergreen forests theoretically varies from 40.8m^3/ha to 54.3m^3/ha. However, due to the fact that there is no information on the growth rate of Sandan's evergreen forests and a number of unknown trees are not commercial species, the annual allowable cut (ACC) should be set at 40 m^3/ha (based on assumption of growth rate of 0.56% of total stand volume). This figure is more or less the same as in Malaysia and Thailand. Forests in Vietnam were widely destroyed during the Vietnam War; thus their ACC must be less than that of evergreen forest in Cambodia.

The most likely species to be harvested are CHBG, PHDK and CRMS. Since unknown trees still represent a big proportion of the forest, any further study on such trees should be encouraged. The Cambodian government is still short of funds and human resources to reforest and properly manage the forests, and only logging companies have such resources. Thus, a selecting felling and replanting system as implemented in Indonesia should be introduced to Cambodia.

Forest management can no longer be concerned solely with timber production. The values of non-wood forest products are frequently overlooked, yet locally they may be much more important than wood products, and their production may be the key to involving people in participatory forest management. Non-wood forest products should be an integral part of the survival and development strategy for the continuing well-being of man, livestock and native flora and fauna (WICKENS, 1994).

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