Management of mixed forest in Cambodia — A case study in Sandan district, Kampong Thom[(a)]—

[1]Nophea KIMPHAT, [2]Sophanarith KIM, [3]Syphan OUK, [4]Yuji UOZUMI and [4]Tatsuhito UEKI

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[1]Doctoral Program in Agricultural Science, United Graduate School of Agricultural Science, Gifu University/ Laboratory in Shinshu University. 8304 Minamiminowa, Kamiina, Nagano 399-4598
[2]Research Student, Department of Forest Science, Faculty of Agriculture, Shinshu University
[3]Department of Forestry and Wildlife, Phnom Penh, Cambodia
[4]Department of Forest Science, Faculty of Agriculture, Shinshu University

Summary. Exploitation of forests without utilizing information on harvest potential has resulted in mismanagement and deforestation worldwide, particularly in Southeast Asia. The purpose of this report is to provide the comprehensive information on harvest potential of Cambodia's mixed forest, which can be used as a strong foundation for sound forest management in Cambodia.

Analysis of 20 inventoried clusters showed that, on average, the stocking of Sandan's mixed forest was 695 trees/ha and 168 m^3/ha for stand density and stand volume, respectively. Of 168 m^3, dipterocarp, non-dipterocarp and unknowns shared 37%, 37% and 26%, respectively. On a selective felling of 30 years, Sandan's mixed forest can potentially provide 28 m^3/ha or 8 trees/ha, of which dipterocarp species represents 40% of the trees to be harvested. This figure is more or less the same to those in Thailand and Vietnam. Sound forest management requires the proper zoning of the forest area to be harvested and to be set aside from harvesting. Research on vegetation and wood utilization of non-dipterocarp and unknown trees should be encouraged since the majority of local people still depend mainly on them for cooking energy, food, medicine and other customary uses. Strong and long-term political commitment to research is always required to ensure the long-term sustainability of natural resources as whole for the benefit of future generations.

Key words : Cambodia, mixed forest, dipterocarps, harvest potential and forest management

1. Introduction

Forestry has played a major role in the rapid economic expansion of Southeast Asian countries over the past half century. It will continue to do so in the foreseeable future[7]. Because there has been a great demand for wood at the time when effective forest management was yet to take place, deforestation and forest degradation of natural forests have accelerated in many tropical countries of the region. The area of forest in Southeast Asia decreased from 217.2 million ha in 1990 to 202.6 million ha in 1995 with the annual rate of change being -1.4%[4)7)]. It is essential to bring these forests under sustainable use and management.

Forest degradation in natural tropical forests is due mainly to unsustainably high harvesting levels carried out without the utilizing information on stand dynamics and the harvest potential the forest can provide. Therefore, the aim of this paper is to provide comprehensive information on harvest potential of Cambodia's mixed forest, which can be used as a strong foundation for sound forest management in Cambodia. Since approximately 80% of commercial wood of Southeast Asian countries come from dipterocarps[2)], dipterocarp stands are a particular focus in this report.

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2. Study method

The data used for this study was taken from the latest forest inventory conducted in 1996 by the Department of Forestry and Wildlife of Cambodia in cooperated with FAO. Totally, twenty inventoried clusters or 21.6 ha (each cluster contains 9 plots of 20 x 60 m in size) were analyzed. With the aid of various statistical tools, the authors grouped the tree species into dipterocarps, non-dipterocarp and unknown species in the order of DBH (Diameter at Breast Height) classes of 5-9 cm, 10-29 cm, 30-44 cm, 45-59 cm and 60 cm, or greater, for evaluation purpose. Then, trees of Dipterocarpaceae were analyzed by species and DBH classes as above. The DBH were classified in accordance with silvicultural system in Cambodia, that some trees have their DBH fall within 30 cm, 45 cm, 50 cm and 60 cm. Based on the forest management in Malaysia[5], trees of non-dipterocarp and unknown species were assumed to be extractable at diameter of 45 cm and above. The species code of four capital letters is designated for every individual species for forest management purpose.

3. Overview of Sandan

Cambodia has a total forest cover of 10.6 million ha or 59% of the country's total land area in 1997. Having a total area of 1.4 million ha or 13% of the total forest area, mixed forest refers to forests of deciduous and evergreen species, where evergreen species represent from 50-80% of the stand[10]. Sandan district, a study site, is one of the seven districts of Kampong Thom province. Sandan is bordered by Preah Vihear province to the west, Stung Treng province to the north and east, Kratie province to the east, and Santuk district to the south (Fig. 1). It consists of nine communes or 71 villages. Forest covers 260,798 ha or 89% of the provincial area, of which 11,616 ha is mixed forest. Approximately 75% of 37,098 persons of Sandan's population engage in farming and forestry for their livelihood[3]. The main economic activities include logging, fishing and labor renting.

4. Analytical Results

4.1 Mean stem density and stand volume in

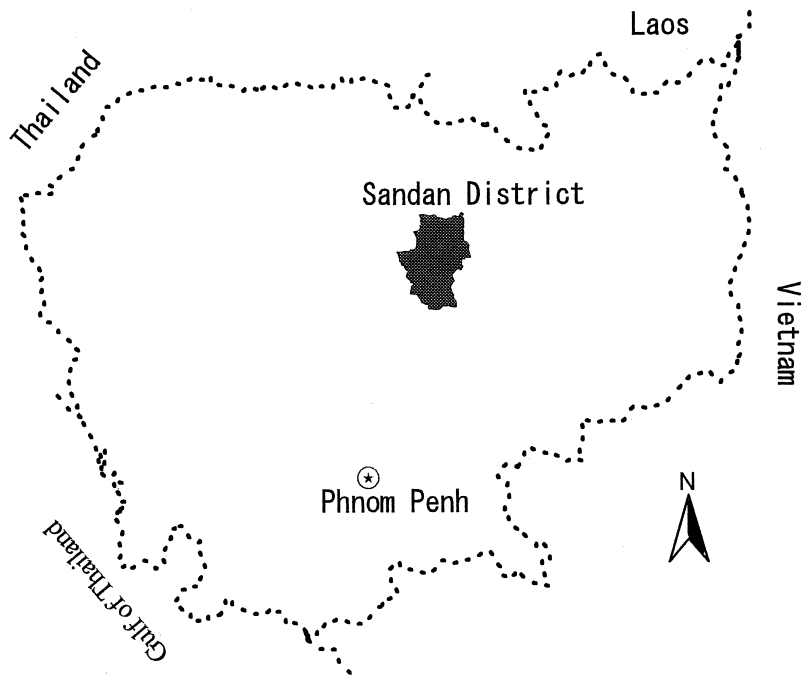

Fig. 1 Location map of Sanclan District
Note : Map not to scale

Table 1 Stem density and stand volume distribution in Sandan's mixed forest

Cluster No.	Dipterocarps		Non-dipterocarp		Unknown		Total	
	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)
	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)
1	2.0	11.3	48.5	7.6	108.3	4.7	158.8	23.6
2	1.0	0.8	327.0	23.0	345.4	16.9	673.4	40.7
3	0.9	17.9	53.8	31.1	10.3	4.9	65.0	53.9
4	162.9	23.3	442.6	58.3	240.4	16.6	845.9	98.2
5	46.0	18.5	310.1	80.2	210.9	22.6	567.0	121.3
6	304.1	112.6	172.2	22.0	79.6	16.2	555.9	150.8
7	130.6	76.3	269.2	38.5	83.3	26.2	483.1	141.0
8	250.6	78.3	315.1	74.8	220.7	40.3	786.4	193.4
9	93.7	66.1	302.3	63.3	214.8	39.2	610.8	168.6
10	7.4	55.3	178.6	58.1	150.5	57.6	336.5	171.0
11	55.6	48.6	286.4	81.7	341.3	40.8	683.3	171.1
12	261.6	93.3	560.0	66.9	398.5	49.7	1220.1	209.9
13	116.6	63.1	362.7	87.5	471.3	60.9	950.6	211.5
14	260.6	85.1	211.6	76.8	659.6	70.3	1131.8	232.2
15	9.2	31.5	362.1	84.6	440.2	90.2	811.5	206.3
16	108.3	75.4	122.7	76.3	167.7	65.5	398.7	217.2
17	54.6	33.2	357.4	100.9	415.1	80.3	827.1	214.4
18	192.5	67.2	219.4	109.3	345.4	40.6	757.3	217.1
19	163.8	149.3	407.5	59.0	350.2	46.6	921.5	254.9
20	252.7	131.2	462.9	55.3	398.9	75.2	1114.5	261.7
Mean (all)	**123.7**	**61.9**	**288.6**	**62.8**	**282.6**	**43.3**	**695.0**	**167.9**
STDEV	102.4	40.3	133.3	27.1	161.3	25.4	309.0	69.3
Percentage (%)	17.8	36.9	41.5	37.4	40.7	25.8	100.0	100.0

Note : STDEV refers to Standard Deviation

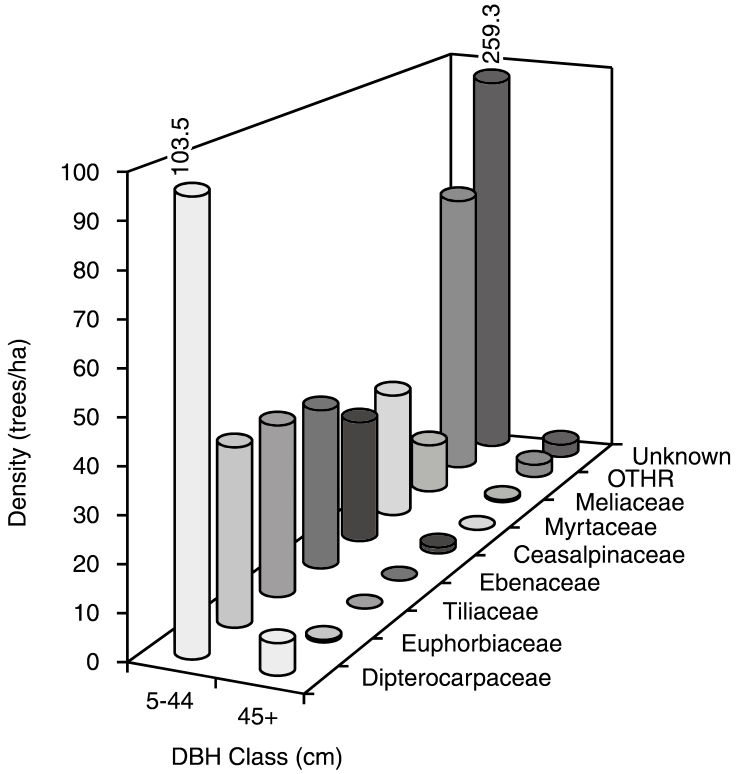

Fig. 2 Stem clensity distribution by family in Sandan's mixecl forest

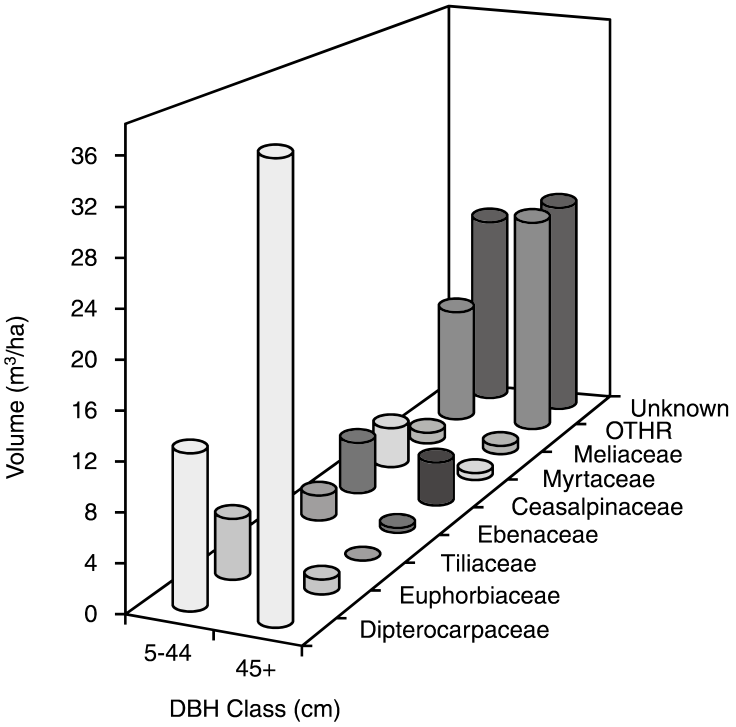

Fig. 3 Stand volume distribution by family in Sandan's mixecl forest
Note: OTHR in Fig. 2 and Fig. 3 includes Lauraceae. Lythraceae. Cusiaceae, Rosaceae, Stereuliaceae, Rhizophoraceae, Crypteroniaceae, Hypericaceae, Sapotaceae. Podocarpaceae, Myristicaceae, Combretaceae, Anacardiaceae, Fagaceac, Bombaceae, Moraceae, Loganiaeeae, Anonaceac, Mimosaceac, Rubiaceae, Papilionaceae, Arecaceae

mixed forest

Over the twenty inventoried clusters in Sandan's mixed forest, on average, 695.0 trees and 167.9 m^3/ha were recorded for stand density and stand volume, respectively. In terms of stand density, dipterocarp, non-dipterocarp and unknown trees shared 123.7 trees/ha (17.8%), 288.6 trees/ha (41.5%), and 282.6 trees/ha (40.7%), respectively. In terms of stand volume, dipterocarp, non-dipterocarp and unknown trees shared 61.9 m^3/ha (36.9%), 62.8 m^3/ha (37.4%) and 43.3 m^3/ha (25.8%), respectively (Table 1). Table 1 also shows that stem density and stand volume in Sandan's mixed forest range from 158.8 trees/ha and 23.6 m^3/ha (cluster No. 1) to 65.0 trees/ha and 53.9 m^3/ha (cluster No. 3) to 1114.5 trees/ha and 261.7 m^3/ha (cluster No. 20), respectively. These figures indicate that logging activities had taken place before forest inventory was conducted.

Stand distribution varies significantly by families. Among 288.6 trees and 62.8 m^3 of non-dipterocarp species, 28 tree families were recorded, of which trees of the families of Euphorbiaceae, Tiliaceae, Ebenaceae, Caesalpinaceae, Myrtaceae and Meliaceae were dominant. In terms of stem density in Sandan's mixed forest, trees of non-dipterocarp and unknown species can be seen when DBH smaller than 45 cm. These trees almost disappear when DBH greater than 45 cm (Fig. 2). In terms of stand volume, trees of dipterocarp species are slightly dominant when DBH smaller than 45; they become highly dominant when DBH greater than 45 cm, followed by Euphorbiaceae, Caesalpinaceae (Fig. 3), suggesting that trees of non-dipterocarp and unknown species should be extracted earlier than those of dipterocarp species, otherwise they will naturally die.

4.2 Species richness of Dipterocarpaceae

Dipterocarp are very important species in tropical forests. They represent approximately 80% of commercial timber from tropical forests. Forest

planning requires realizable data and that, it is necessary to study into species richness in Sandan's mixed forest. Of 123.7 trees of dipterocarp species in Table 1, thirteen individual species were found, namely PHDK (*Anisoptera glabra*), CHBG (*Dipterocarpus costatus/turbinatus*), CRMS (*Vatica astrotricha*), CHRH (*Shorea vulgaris*), PCEK (*Shorea obtusa*), KHLG (*Dipterocarpus tuberculatus*), KKMS (*Hopea odorata*), KKTM (*Hopea heferei*), LMBI (*Shorea farinosa*), PPEL (*Shorea cochinchinnensis*), TBEG (*Dipterocarpus obtusifolius*) and TRAC (*Dipterocarpus intricatus*). For convenient purpose, the last seven species were grouped to OTHR (others). For DBH less than 45 cm, CRMS and PHDK were dominant, followed by CHBG and PCEK in terms of stem density and stand volume. For DBH greater than 45 cm, PHDK and CHBG were dominant followed by CHRH (Fig. 4 and Fig. 5). These figures suggest that the mortality rates of PHDK and CHBG are high compared to other dipterocarp species in Sandan's mixed forest.

5. Harvest Potentials in Sandan's mixed forest

One of the crucial factors for sustainable management of forest resources is to harvest products at a rate the forest can provide. Until recently, Cambodia has had no information on stand dynamics and the harvest potential of forests, which are the basis of sound forest management. Based on the results of analysis, and in respect to diameter limits of harvest for individual tree species in Cambodia (30% of mature stands are subject to extract), the potentially extractable portion for Sandan's mixed forest is 7.9 trees/ha or 27.8 m^3/ha. In percentage terms, dipterocarp, non-dipterocarp and unknown species shared 48.2% and 49.2%, 30.8% and 29.4%, and 7.9% and 27.8% for stem density and stand volume to be harvested, respectively (Table 2). PHDK and CHBG are the major species to be harvested.

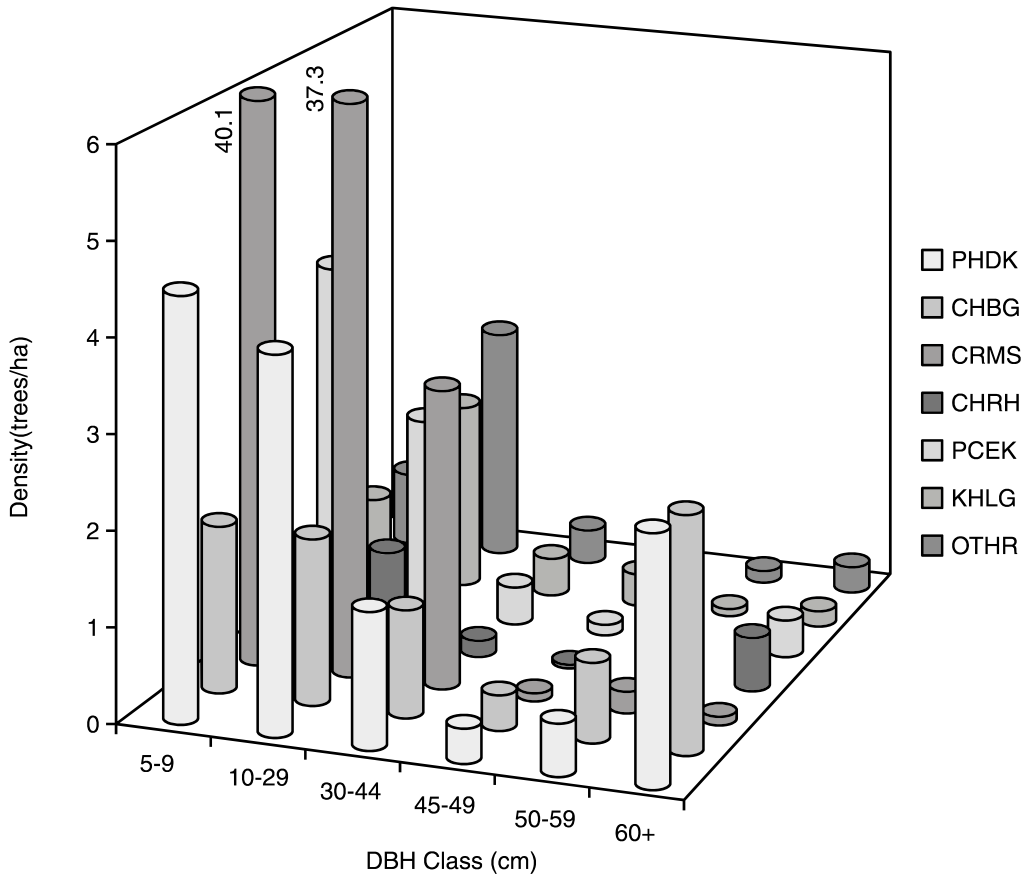

Fig. 4 Stand distribution of dipterocarp species in Sandan's mixed foresi

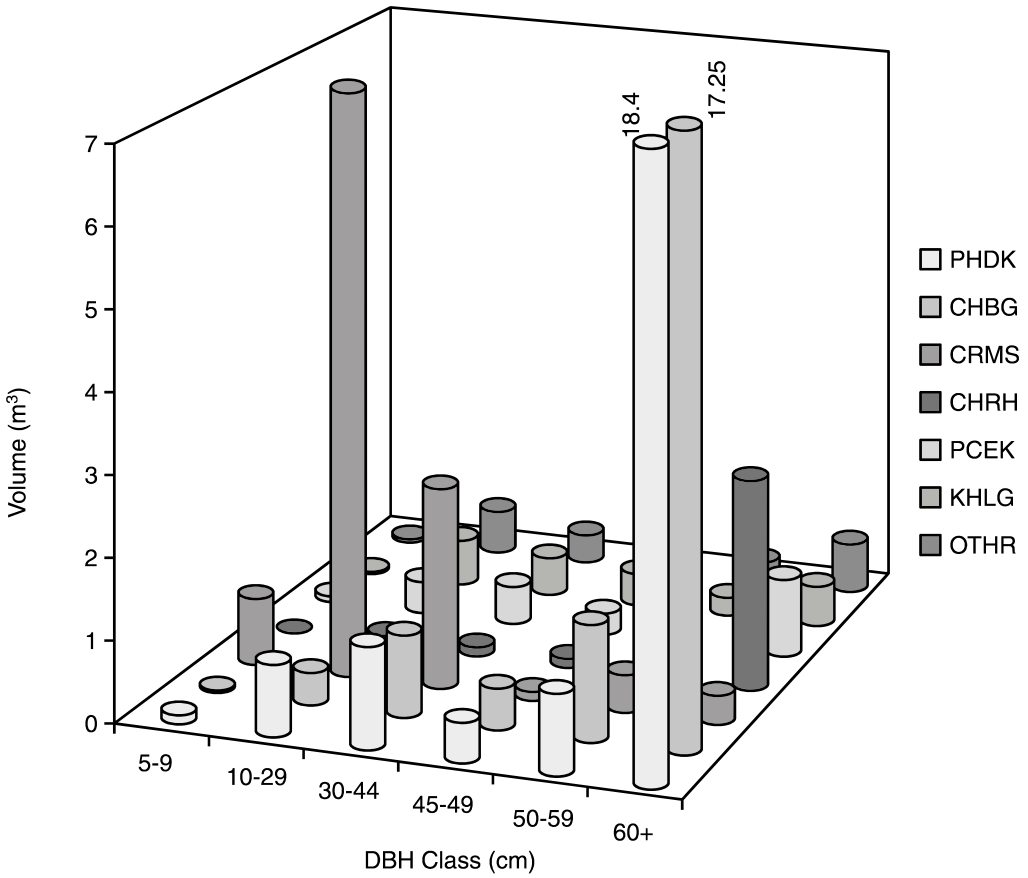

Fig. 5 Volume distribution of dipterocarp species in Sandan's mixed forest

Table 2 harvest potentials of mixed forest in Sandan district

Tree Species	Mature trees for harvest		30% Extraction	
	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)
PHDK	4.9	19.8	1.5	5.9
CHBG	3.1	17.3	0.9	5.2
CRMS	3.2	3.0	1.0	0.9
CHRH	0.4	2.5	0.1	0.8
PCEK	0.5	1.5	0.2	0.5
KHLG	0.3	0.6	0.1	0.2
OTHR	0.4	0.9	0.1	0.3
Subtotal	12.8	45.6	3.8	13.7
Percentage(%)	48.5	49.2	48.6	49.2
Euphorbiaceae	0.7	1.1	0.2	0.3
Ebenaceae	0.3	0.4	0.1	0.1
Caesalpinaceae	1.3	4.1	0.4	1.2
Myrtaceae	0.3	0.6	0.1	0.2
Meliaceae	0.4	0.8	0.1	0.2
OTHIR	5.1	20.2	1.5	6.1
Subtotal	8.1	27.2	2.43	8.16
Percentage (%)	30.7	29.3	30.8	29.4
Unknown	5.5	19.9	1.7	6.0
Percentage (%)	20.8	21.5	20.6	21.4
Total	26.4	92.7	7.9	27.8
Percentage (%)	100	100	100	100

Note : Diameter limits for harvest of individual species : PHDK 45 cm. CHBG 60 cm. CRMS 30 cm, CHRH 60 cm, PCEK 45 cm, KHLG 50 cm, OTHIR, non-dipterocarp and unknown species are assumed at 45 cm.

Table 3 Equation models for volume computation

Types of Equations	Equation Models
One entry equations	1. $V=a+bD^2$
	2. $V=a+bD+cD^2$ (*1)
Double entry equations (*2)	1. $V=a+bD^2H$
	2. $V=a+b\ \sqrt{D^2H+c(D^2H)}$

Where
- a, b and c are parameters
-D : tree diameter measured at 1.3 m above ground,
-H : tree height measured until first main branch.
-V : tree volume
Note :
-(*1) Only this equation was drawn for easily looking at D axis
-(*2) were not tested for this study

Table4 Regression statistics for one-entry volume table for volume estimation in mixed forest

Regression Statistics	Dipterocarp	Non-dipterocarp	Unknown
Intercept (a)	0.208571	0.061429	0.0438
D Variablel (b)	-2.55171	-0.95665	-0.86984
D Variable 2 (c)	11.61898	7.854577	8.229845
Multiple R	0.9670	0.9921	0.9420
R Square	0.9352	0.9843	0.8873
Adjusted R Square	0.9344	0.9841	0.8854
Standard Error	1.2647	0.0753	0.1022
Observations	180	180	120

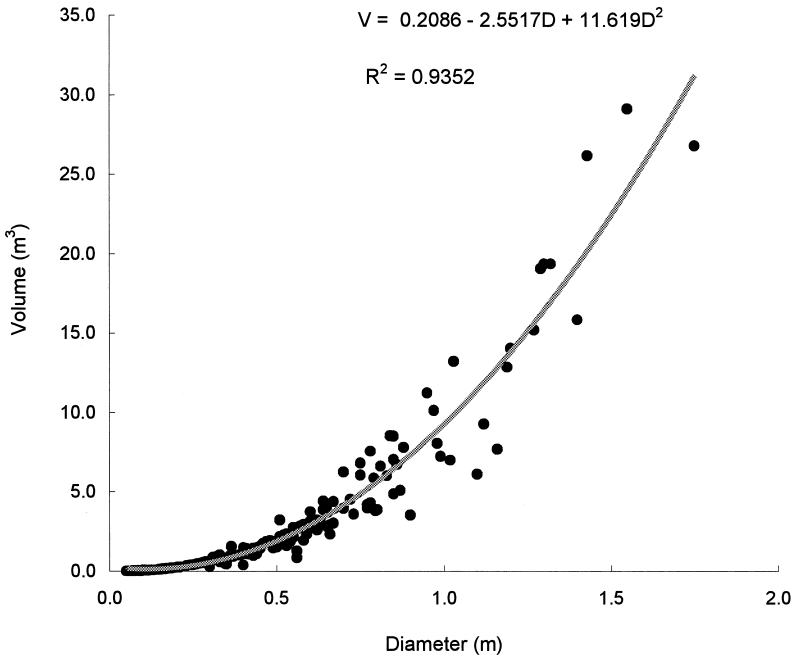

Fig. 6 Volume estimation with one-entry volume table for dipterocarp species

6. Preliminary study on volume equations for volume estimation

Volume equations accelerate the forest inventory process by reducing time and expense required for forest inventory. Unfortunately, no such study or research report exist in Cambodia, except an undergraduate thesis on "stand volume for commercial dipterocarp species in Rattanakiri province" forest was written in 1994 in north-eastern part of Cambodia.

There are two kinds of volume equations used

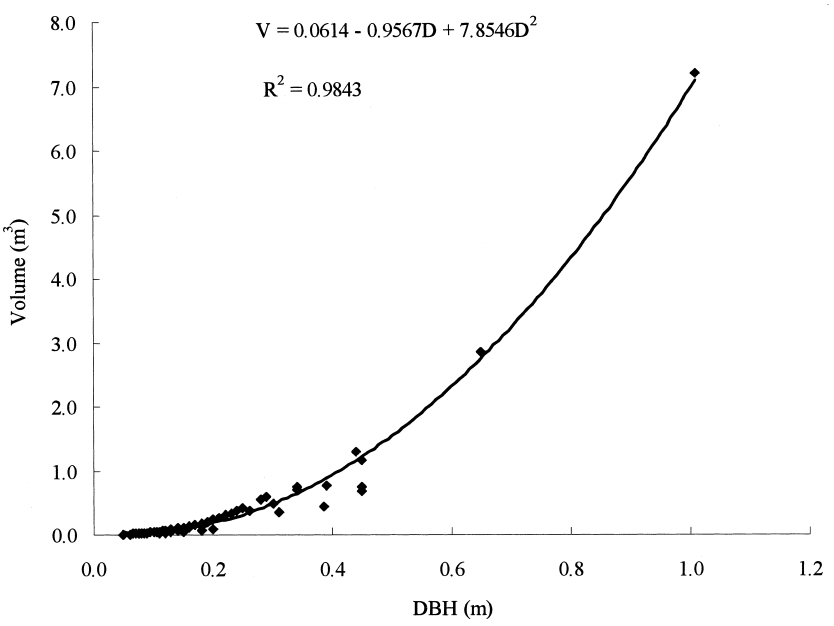

Fig. 7 Volume estimation with one-entry volume table for non-dipterocarp species

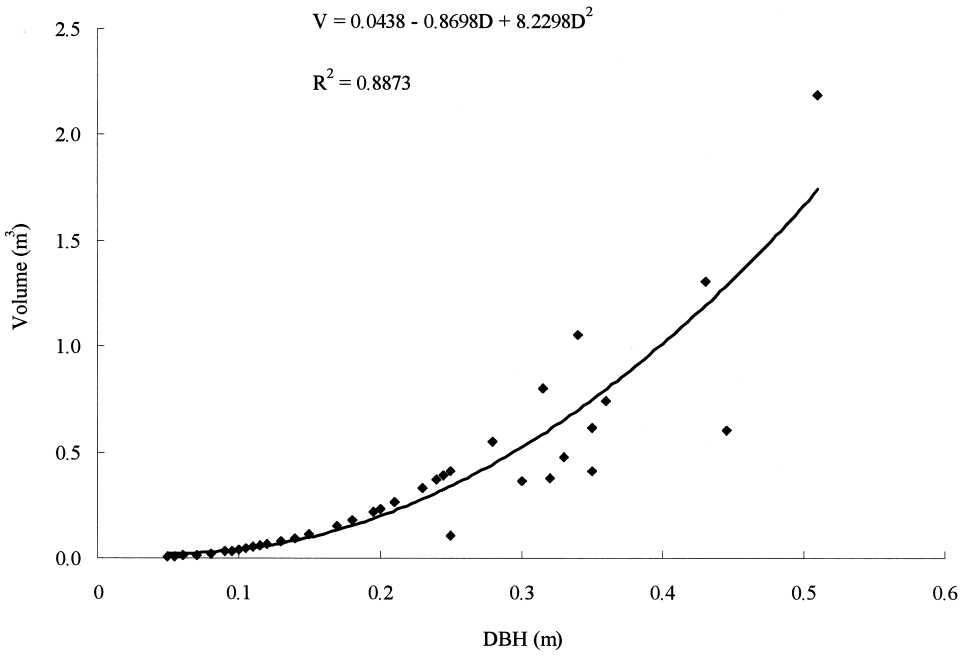

Fig. 8 Volume estimation with one-entry volume table for unknown species

for volume estimation in tropical forests (Table 3) : the single entry or one-entry equations giving the relationship between the volume and the diameter, and the double entry equations giving the volume derived from diameter and the height. These correlations are calculated by regressions from the records of the trees sampled. The equations with two variables (diameter and height) enable a better accuracy in the assessment of the volume but its major drawback is the difficulty to measure easily and with accuracy the height of the trees in the field[1]. For this reason, the single entry equations for dipterocarp, non-dipterocarp and unknown species were studied in this report.

To construct the volume equations, 180 trees each of dipterocarp and non-dipterocarp species, and 120 trees of unknown species were used. Using the regression method available in Mi-

crosoft Excel, the analysis results were presented in table 4. Thus, the volume equations for volume estimation of dipterocarp, non-dipterocarp and unknown species are $V_1 = 0.2086 - 2.5517D + 11.6190D^2$ (Fig. 6), $V_2 = 0.0614 - 0.9567D + 7.8546\ D^2$ (Fig. 7) and $V_3 = 0.0438 - 0.8698D + 8.2298D^2$ (Fig. 8), respectively. According to these equations, one meter of DBH gives the volume estimation of 9.3 m^3, 6.9 m^3 and 7.4 m^3 for of dipterocarp, non-dipterocarp and unknown species, respectively.

7. Discussion and Conclusion

The stand density and stand volume of Sandan's mixed forest is 695.0 trees and 167.9 m^3/ha, respectively. Of these figures, dipterocarp, non-dipterocarp and unknown species shared 17.8% and 36.9%, 41.5% and 37.4%, and 40.7% and 25.8% for stand density and stand volume, respectively. The dipterocarp species of PHDK, CHBG, CHRH, CRMS and LMBI are dominant followed the species of families of Lythraceae, Sterculiaceae, Euphorbiaceae, Caesalpiniaceae and Ebenaceae.

Theoretically, the extractable volume of Sandan's mixed forest is approximately 27.8 m^3/ha (7.9 trees). The extractable volume in Southeast Asia is between 30-40 m^3 in Malaysia, around 35 m^3 in Thailand[4] and around 24 m^3 in Vietnam[11]. Due to the lack of information on growth and other influent factors, the authors recommend that only 25 m^3 or 14.9% of the total stocking be extracted on a selective felling of 30 years cycle pending the new information become available. Because of the big variations in the inventoried clusters, suggested that some parts of mixed forest in Sandan were logged, they might be gradually converted to shrub or other form of forest if immediate action is not taking place. Thus, this forest should be designated as forest reserve for at least 30-60 years, while, in the meantime, enrichment planting of commercial species (mainly dipterocarp species) should be implemented. Study on wood utilization and other values of non-dipterocarp and unknown trees should encouraged since these species are likely to play a vital role in sustainable use and management of the present and future forest resources.

For the present and future forest inventory, the volume equations for volume estimation of $V_1 = 0.2086 - 2.5517D + 11.6190D^2$ (dipterocarp), $V_2 = 0.0614 - 0.9567D + 7.8546\ D^2$ (non-dipetrocarp) and $V_3 = 0.0438 - 0.8698D + 8.2298D^2$ (unknown) should be used as to save time and other forms of expenses. However, they should be revised when the latest data become available. Study on two-entry volume table should also be encouraged. To obtain the best realizable results for volume table construction, all sampled trees should be measured every two meters along the bole using modern research tools e.g. the Relascope of Bitterlich or virtually cut out the bole into several sections of equal length, to measure its diameter in the middle of the section at a given height and to total the volume of all these sections. Sustainable forest management need up-to-date and realizable data to help prepare a economically feasible, socially viable and environmentally acceptable management plan.

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カンボジアにおける混交林経営に関する研究
―サンダン地方を事例として―

Nophea KIMPHAT[1]・ Sophanarith KIM[2]・ Syphan OUK[3]・ 奥住侑司[2]・植木達人[2]

[1]岐阜大学大学院連合農学研究科
[2]信州大学農学部森林科学科
[3]カンボジア林業・野生動物部

要 約

林分及び伐採可能な木材情報が分からず，世界中の森林経営，特に東南アジアの森林経営は失敗している。本研究はカンボジアにおける混交林の林分及び伐採可能な蓄積を見出すこと共に適切な森林経営を見出すことを目的としている。

20クラスターからの調査データを解析した。その林分の DBH 5 cm 以上平均密度は695本/ha で，平均蓄積は168m^3/ha である。平均密度の約37%づつはフタバガキ樹種と非フタバガキ樹種で，26%は不明樹種ですある。伐採率30%及び回帰年30年間の択伐より，サンダンにおける混交林の伐採可能な蓄積は約28m^3/ha（8本/ha）で示した。この中にフタバガキ科は40%，その他は非フタバガキと不明樹種である。この伐採量は隣国のベトナムとタイの伐採量と同じくらいである。持続可能な森林経営を達成するために，生産林や保護林などゾーニングする必要がある。非木材，薪，食料や自然薬などは農村人々に対して，とても大切なものなので，非フタバガキや不明樹種の利用方法などについても引き続き研究の必要がある。その上，長期持続可能な林森林経営を得るために，長期安定な政治及び行政からの森林経営への約束が必要と考えられる。

キーワード：カンボジア，混交林，フタバガキ科，伐採可能な量，森林経営