Management of Mixed Deciduous Forest in Central Cambodia-A Case Study in Sandan District[a]

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Abstract

Cambodia was one of the most heavily forested countries in the world, but a large proportion of forest has been destroyed as a result of wars and political instability over the past 30 years. Forest management in Cambodia has been difficult due to the lack of information on scientific research. It is believed that one of the key points to ensure the sustainable management of the forests is to understand their population dynamics. The aim of this paper is to provide useful information on the population dynamics of Cambodia's deciduous forest, as a basis for management decision making.

Having approximately 50% evergreen tree species, mixed deciduous forest is managed for commercial and non-commercial wood production on a 25-30 years selective felling cycle. Under the national forest inventory project, four clusters were established in Sandan's deciduous forest, containing 36plots or 4.32ha of forest. Statistical analysis showed that the average density was 626 trees/ha, of which dipterocarp, non-dipterocarp and unknown trees were 57 trees, 339 trees and 230trees, respectively. In percentage terms by families, 11% of total trees were from the family Lyrthraceae; followed by 9% the family of Dipterocarpaceae ; and 36% of unknown and minor families. The average stand volume per hectare was 178m^3, of which approximately 66% were those of trees with diameters greater than 45cm. On a felling cycle of 30years, the mean annual allowable harvest volume theoretically was 35 m^3/ha, 8% of which came from dipterocarp trees. Based on forest management experiences in other Southeast Asian countries, 30m^3/ha is recommended to extract pending the data on growth rate becomes available.

There is a need to firmly protect the forests from repeated encroachments so that the residual stands can naturally regenerate and reach the harvestable size over a period of 30 years. While enrichment planting of commercial species is required, further vegetation research is also needed since the proportion of unknown trees is still high. All these trees will produce additional wood for the present and future needs. In addition, political will and the cooperation of all parties involved are, in priority, required to ensure long-term sustainable management of the forest resources.

Key word: Cambodia ; dipterocarps ; harvest potential ; selective felling ; sustainable forest management

1. Introduction

Sustainable forest management has been a core forestry issue over recent years as we are in the millenium facing new challenge of global warming. Many countries are trying to bring forest resources under sustainable management, but their success has been less than expected. The lack of information on stand dynamics and harvest potential of forests has contributed to the mismanagement of forest resources

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today. The aim of this paper is to provide useful information on the population dynamics of Cambodia's mixed deciduous forest, as a basis for management decision making.

Forests of Southeast Asian countries declined from 217.2 million ha in 1990 to 202.6 million ha in 1995 with an annual change of −1.4 percent[5]. As consequences of wars, Cambodia's forests in particular have been destroyed and left unmanaged until recent years. Forest resources have sharply declined from 12.7 million ha in 1973 to 10.6 million ha in 1997[11], and they will no longer be a source of wood for the needs in the present and future uses unless immediate action is taken. Sufficient knowledge on forest structures can enable effective action.

2. Study Method

The data of this study was taken from the forest inventory conducted in Sandan district, Kampong Thom Province. Forest inventory was conducted in Sandan in 1996 with UNDP/FAO (United Nations Development Program/Food and Agricultural Organization of the United Nations) funding and technical assistance. Cluster sampling method was used, each cluster contains nine plots of 0.12 ha size (20×60m). Due to security problems, only four clusters were successfully inventoried in Sandan's deciduous forest. All trees with DBH of 5-9 cm, 10-29 cm and greater than 30 cm were recorded in 0.01 ha, 0.04 ha and 0.12 ha, respectively. All recorded trees were classified to regeneration (5-9 and 10-29 cm), immature (30-39 and 40-44 cm) and mature (45-59 cm and greater than 60 cm) classes in the orders of dipterocarp, non-dipterocarp and unknown trees, respectively. Stand density, basal area and volume per hectare were derived from equation (1) below. Due to the fact that diameter limits for harvest of many trees fall within 45 cm, the diameter limit of dipterocarp, non-dipterocarp and unknown trees suitable for extraction were assumed at 45 cm or greater.

$S = T/A$ (1)

Where

S : stand density or basal area or volume in each DBH class (trees/ha or m^2/ha or m^3/ha)

T : total trees or basal area or volumes recorded in A-sized plot (trees or m^3)

A : area of inventoried plot (ha)

3. Cambodia's Deciduous Forest and its Silvicultural Treatment

In 1997, Cambodia has a total forest cover of 10.59 million ha or 58% of the country's total land area[3]. It declined from 11.3 million ha in 1992. The major forest types in Cambodia include dryland (evergreen, mixed, and deciduous) and edaphic forests (mangrove and flooded). Since mangrove and flooded forests were designated as protected areas ; logging activity in these forests is prohibited[10]. Evergreen, mixed and deciduous forests cover 4.1 million ha (38.7%), 1.4 million (13.2%) ha and 4.0 million ha (38.3%), respectively (Table 1). Although all forests in Cambodia are state-owned forests, they are managed under concession agreements. Until recently, 4.8 million ha of forests was granted to 25 forest concessions[7].

Deciduous forests refer to multistory forests consisting of less than 50% trees of evergreen species. According to species distribution and natural conditions, deciduous forest is divided to mixed and dry deciduous forest[1]. The dry deciduous forest is characterized by five major species, namely *Dipterocarpus obtusifolius* (local name : Tbeng, code : TBEG), *Dipterocarpus intricatus* (local name : Trac, code : TRAC), *Shorea siamensis* (local name : Ring Phnom, code : RIPM) and *Dipterocarpus tuberculatus* (local name : Khlong, code : KHLG) of Dipterocarpaceae, and *Terminalia tomentosa* of Combretaceae. If these mentioned species are not found, that deciduous forest is considered as mixed deciduous forest. A selective cutting system of 25-30 years cycle is applied to mixed deciduous forest, and so are to evergreen and mixed forests. Approximately 30% of the mature stands (usually DBH greater than 45cm) are extracted, the residuals function as mother trees for natural regeneration, and they will be extracted in the next 25

Table 1 Forest cover in Cambodia (1997)

No	Name	Land area	
		(ha)	(%)
I	Dryland forest	10,158,942	96.0
	Evergreen forest	4,094,029	38.7
	Mixed forest	1,394,436	13.2
	Deciduous forest	4,052,231	38.3
	Regrowth forest	544,778	5.1
	Plantation forest	73,468	0.7
II	Edaphic forest	428,465	4.0
	Flooded forest	351,205	3.3
	Mangrove forest	77,260	0.7
I + II	Forests	10,587,407	100.0

Source : DFW (1998 a)

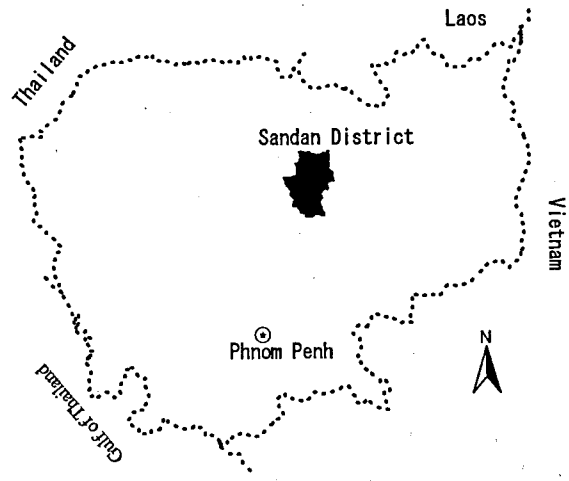

Fig. 1 Location map of Sandan District
Note : Map not to scale

Table 2 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 : DEW (1998 b)

-30years. A clear cutting of 12-15 yearscyela is applied to dry deciduous forest and, generally, it generates through coppicing. The forest is managed for pole and fuelwood production[9]. This report deals with mixed deciduous forest only.

4. An Overview of Study Site, Sandan

Sandan is one of the seven districts of Kampong Thom, consisting of 9 communes or 71 villages. Sandan has a population of 37,098 persons of whom 19,023 persons are female. Nearly 75% of the population are engaged in farming and forestry. The average temperature is estimated at 27.1°C and the annual rainfall exceeds 1300 mm. Sandan (Fig. 1) has a total land area of 291,498 ha, 89% of which is forested. Forest area has declined from 261,974 ha in 1993 to 260,798 ha in 1997. Evergreen, mixed and deciduous forests cover 222,424 ha, 11,661 ha and 12,258 ha, respectively (Table 2). The main economic development factors include logging, fishing and labor renting[4].

5. Analytical Results

5.1. Density, Basal Area and Standing Volume

Data from four inventoried clusters were utilized for this study. Mean tree density, basal area and standing volume is Sandan's mixed deciduous forest were 621.5 trees/ha, 32.0 m^2/ha and 179.2 m^3/ha, respectively (Table 3). The figure of stand volume per hectare is almost three times bigger than that of Cambodia's dry deciduous forest, which was recorded at 60 m^3/ha[11]. Over these four inventoried clusters, 26 tree families were identified. The family of lythraceae was the dominant taxon contributing about 11.0% of the total tree density (mean of 69.0 trees/ha), 47.6% of the total basal area (mean of 15.4 m^2/ha), and 42.9% of the total standing volume (mean of 76.5 m^3/ha). The family of Dipterocarpaceae was the second dominant taxon contributing 8.2% of the total density (51.2 trees/ha), 8.1% of the total basal area (2.6m^2/ha), and 10.9% of the total standing volume (19.4 m^3/ha) (Table 4). Unidentified trees (unknown) represented 36.8% (230.3 trees/ha), 16.9% (5.5 m^2/ha) and 16.5% (29.4 m^3/ha) for density, basal area and volume, respectively. The larger standard deviations than the means of the family Dipterocarpaceae in all DBH classes suggested that the family Dipterocarpaceae was not well distributed in Sandan's mixed deciduous forest. Because illegal logging frequently occurred in the area, we concluded that trees of dipterocarpaceae in some clusters of the four inventoried clusters had been logged before the inventory took place.

5.2. Stand Density, Basal Area and Volume of Dipterocarpaceae

Trees of dipterocarps are a very important source of wood and non-wood products in tropical forests. Approximately 80% of the commercial species in tropical forests belong to dipterocarp group[2], and in Cambodia, about 77% of commercial wood come from dipterocarp species[12]. It was believed that sustainable management of dipterocarp forest leads to the sustainability of the whole tropical forests. Therefore, the authors analyzed into species of dipterocarpaceae family. There are five genera or twenty -three species of dipterocarps found in Cambodia, namely *Anisoptera* (1 species), *Dipterocarpus* (7 species), *Hopea* (5 species), *Shorea* (7 species) and *Vatica* (3 species). However, in Sandan's deciduous mixed forest, only five species were found. The amount of 57.2 trees (Table 3 and Table 4) consisted of CHBG (local name : Chhietiel Bieng/Bankoung, scientific name : *Dipterocarpus turbinatus* or *costatus*) 17.6 trees, TRAC 16.8 trees and PPEL (local name : Popel, scientific name : *Hopea recopi*) 11.7 trees, CRMS (local name : Chramas, scientific name : *Vatica astrostricha*) 6.3 trees and CHRH (local name : Chor Chong, scientific name : *Shorea vulgaris*) 4.8 trees. For DBH class of less than 30 cm, TRAC, CHBG and PPEL were dominant, and CHBG became dominant when DBH class greater than 30 cm (Fig. 2). In terms of basal area, out of 2.6 m^2/ha in table 3-4, (Fig. 3), CHBG, TRAC, CRMS, CHRH and PPEL shared 62.9%, 15.5%,

Table 3 Mean stem density (MSD), mean basal area (MBA) and mean stand volume (MSV) in Sandan's mixed deciduous forest (four clusters)

Stocking	DBH Class (cm)					Total
	5-9	10-29	30-44	45-59	60+	
MSD (all species)	327.8	210.4	30.3	22.0	31.0	621.5
STDEV (all species)	69.4	15.5	19.2	12.4	18.9	112.3
MSD (Dipt.)	25.0	18.8	3.0	2.1	2.3	51.2
STDEV (Dipt.)	19.0	21.3	2.8	3.1	2.2	37.6
MBA (all species)	1.1	5.2	3.1	4.4	18.3	32.0
STDEV (all species)	0.5	1.0	2.0	2.4	11.7	15.4
MBA (Dipt.)	0.1	0.5	0.3	0.4	1.3	2.6
STDEV (Dipt.)	0.1	0.5	0.3	0.6	1.5	2.5
MSV (all species)	5.4	36.1	16.0	25.0	96.7	179.2
STDEV (all species)	1.0	9.6	11.8	16.2	56.2	78.7
MSV (Dipt.)	0.4	2.4	2.9	1.0	8.8	15.5
STDEV (Dipt.)	0.4	3.4	3.4	1.2	10.9	14.6

Note: The units used are trees/ha, m^2/ha and m^3/ha for MSD, MBA and MSV, respectively. STDEV is Standard Deviation.

Table 4 Stem density, basal area and stand volume by family in Sandan's mixed evergreen forest

Fanuly	Density		Basal Area		Standing Volume	
	(trees/ha)	(%)	(m^2/ha)	(%)	(m^3/ha)	(%)
Lythraceae	69.0	11.0	15.4	47.6	76.5	42.9
Dipterocarpaceae	57.2	9.1	2.6	8.1	19.4	10.9
Tiliaceae	31.3	5.0	1.7	5.2	7.7	4.3
Combretaceae	23.2	3.7	0.9	2.8	5.2	2.9
Ebenaceae	26.4	4.2	0.8	2.3	4.8	2.7
Myrtaceae	41.7	6.7	0.7	2.3	3.8	2.1
Caesalpinaceae	19.7	3.1	0.7	2.1	5.2	2.9
Bombaceae	6.5	1.0	0.7	2.0	4.1	2.3
Mimosaceae	14.1	2.3	0.7	2.0	4.2	2.4
Euphorbiaceae	13.2	2.1	0.6	1.9	4.0	2.3
Rosaceae	19.0	3.0	0.6	1.8	3.6	2.0
Anacardiaceae	4.9	0.8	0.4	1.1	2.2	1.2
Lauraceae	4.4	0.7	0.3	0.9	1.9	1.1
Hypericaceae	10.9	1.7	0.1	0.4	0.7	0.4
Moraceae	5.3	0.9	0.1	0.4	0.8	0.5
Sapotaceae	10.7	1.7	0.1	0.4	0.9	0.5
Clusiaceae	19.5	3.1	0.1	0.3	0.5	0.3
Verbenaceae	6.7	1.1	0.1	0.3	1.3	0.8
Crypteroniaceae	0.5	0.1	0.1	0.3	0.6	0.3
Rubiaceae	0.9	0.1	0.1	0.2	0.3	0.2
Loganiaceae	3.0	0.5	0.1	0.2	0.3	0.2
Papilionaceae	2.1	0.3	0.1	0.2	0.5	0.3
Fagaceae	1.4	0.2	0.0	0.1	0.1	0.1
Datiscaceae	0.7	0.1	0.0	0.0	0.1	0.0
Meliaceae	1.4	0.2	0.0	0.0	0.1	0.0
Rhizophoraceae	2.8	0.4	0.0	0.0	0.1	0.0
Unknown	230.3	36.8	5.5	16.9	29.4	16.5
Total	626.4	100.0	32.4	100.0	178.1	100.0

Note: Unknown species refer to tree species that were unable to identify during forest inventory

5.1%, 5.1% and 5.1%, respectively. According to basal area, TRAC was dominant for DBH class less than 30 cm, CHBG became dominant when DBH is greater than 30 cm. In terms of stand volume, on average of 19.4 m³ (Table 3 and Table 4), CHBG, TRAC, CRMS, CHRH and PPEL shared 69.6%, 11.9%, 7.7%, 6.2% and 4.6%, respectively. For DBH class less than 30 cm, it clearly showed that PPEL and TRAC were dominant, and CHBG became dominant when DBH is greater than 45 cm (Fig. 4). In general, the more increase in diameter, trees of CHRH, CRMS, PPEL and TRAC gradually disappear while those of CHBG still remains.

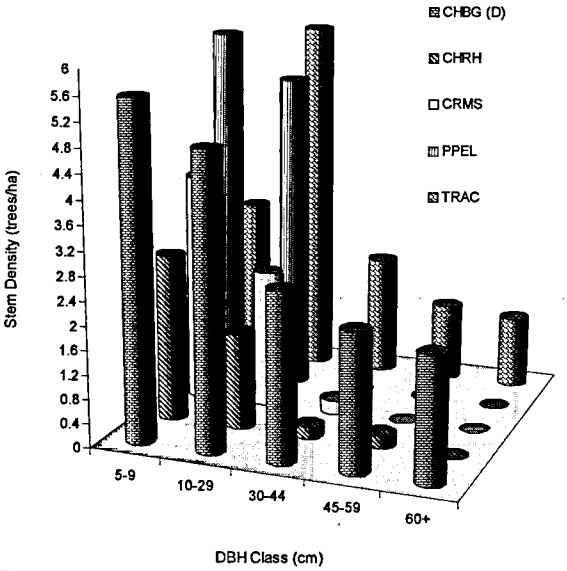

Fig. 2 Distribution of stem density of dipterocarps by DBH class in Sandan's mixed deciduous forest

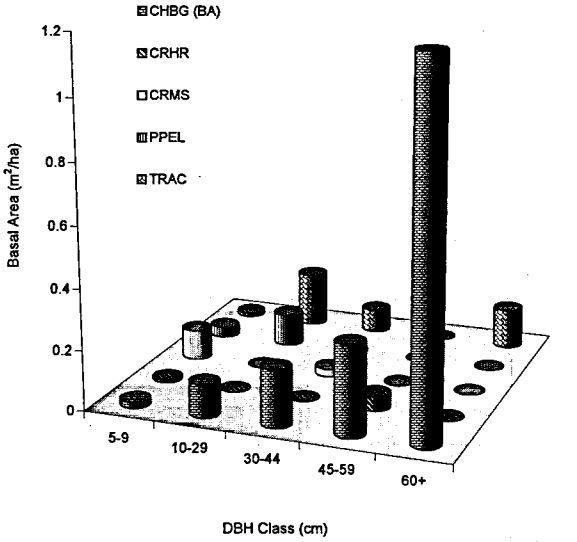

Fig. 3 Distribution of basal area of dipterocarps by DBH class in Sandan's mixed deciduous forest

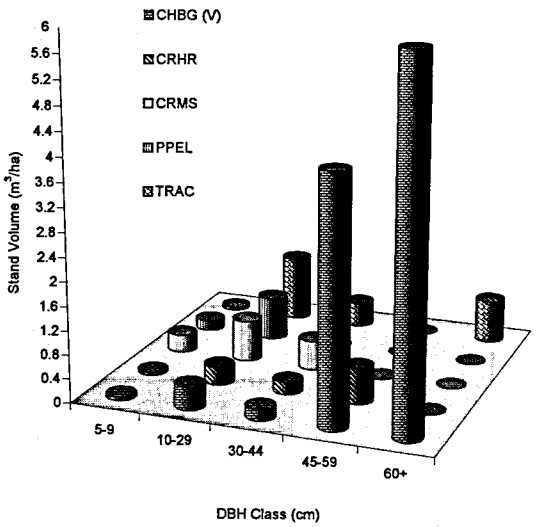

Fig. 4 Distribution of stand volume of dipterocarps by DBH class in Sandan's mixed deciduous forest

6. Harvest Potentials of Cambodia's Mixed Deciduous Forest

Sustainable forest management requires the availability of relevant information, particularly on the products that a forest can provide on a sustainable basis. Thus, the harvest potentials of Sandan's deciduous forest are the topic discussed in this section. Based on the assumption made in "study method" section, all trees with DBH greater than 45 cm were analyzed. Stand volume (DBH>45 cm) of all trees was 117.1 m³/ha (52.4 trees), of which 9.8 m³ (4.4 trees), 94.2 m³ (42.5 trees) and 13.1 m³ (5.5 trees) were from

dipterocarp, non-dipterocarp and unknown trees, respectively (Table 5). For dipterocarps alone, trees of CHBG were the major species to be logged, followed by TRAC and CHRH. Because CRMS and PPEL were not found, the extraction of such species must had been done before the inventory. Based on silvicultural treatment for mixed deciduous forest (selective felling of 30 years cycle and 30% extraction rate), Sandan's mixed deciduous forest can potentially provide 35.1 m^3/ha or 15.7 trees/ha. Of this figure, Dipterocarp, non-dipterocarp and unknown species share 2.9 m^3 (8.3%). 28.3 m^3 (80.6%) and 3.9 m^3 (11.1%), respectively (Table 5).

7. Discussion and Conclusion

On average, stand density, basal area and stand volume of mixed deciduous forest were 626.4 trees/ha, 32.4 m^2/ha and 178.1 m^3/ha, respectively. Lythraceae was the first dominant family with stem density, basal area and stand volume of 69.0 trees/ha (11.0%), 15.4 m^2/ha (47.6%) and 76.5 m^3/ha (42.9%), respectively. Dipterocarpaceae was the second dominant family, contributing 8.2% of the total stem density, 8.1% of the total basal area and 10.9% of the total stand volume. Only five species of Dipterocarpaceae were found in Sandan's mixed deciduous forest. They were CHBG, TRAC, CHRH, CRMS and PPEL. The existence of TRAC indicated that the mixed deciduous forest in Sandan is in the transition from mixed to dry deciduous forest. Enrichment planting of commercial species (mainly dipterocarp species) is required to avoid such transition.

Forest exploitation is a key issue to ensure whether the forest products be extracted on a sustainable

Table 5 Harvest potential in Sandan's mixed deciduous forest

DBH Class(cm)	45-59		60+		Total	
Tree Species	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)
Dipterocarps						
CHGB	1.4	0.8	1.7	8.1	3.1	8.9
TRAC	0.4	0.1	0.6	0.7	1.0	0.8
CHRH	0.3	0.1	0.0	0.0	0.3	0.1
CRMS	0.0	0.0	0.0	0.0	0.0	0.0
PPEL	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	2.1	1.0	2.3	8.8	4.4	9.8
30%cut	0.6	0.3	0.7	2.6	1.3	2.9
Non-dipterocarps						
Lythraceae	7.4	6.8	20.8	63.8	28.2	70.6
Myrtaceae	0.7	2.4	0.2	2.3	0.9	4.7
Tiliaceae	2.3	0.5	1.4	1.9	3.7	2.4
Ebenaceae	0.7	0.9	0.0	0.7	0.7	1.6
Combretaceae	0.5	0.7	0.9	0.0	1.4	0.7
Caesalpinaceae	0.7	1.3	0.2	0.5	0.9	1.8
Clusiaceae	0.0	0.2	0.0	3.2	0.0	3.4
Rosaceae	0.9	0.9	0.0	0.3	0.9	1.2
Mimosaceae	1.2	0.7	0.2	0.6	1.4	1.3
Euphorbiaceae	0.9	1.1	0.2	0.0	1.1	1.1
Others	1.9	2.0	1.4	3.4	3.3	5.4
Subtotal	17.2	17.5	25.3	76.7	42.5	94.2
30%cut	5.2	5.3	7.6	23.0	12.8	28.3
Unknown	2.3	2.4	3.2	10.7	5.5	13.1
30%cut	0.7	0.7	1.0	3.2	1.7	3.9
Total	21.6	20.9	30.8	96.2	52.4	117.1
Total 30%cut	6.5	6.3	9.2	28.9	15.7	35.1

Note: All trees within DBH greater than 45 cm were assumed to be extractable.

basis. To provide the best estimate of the forest products to be extracted, the information on growth is required. However, since this information is still not available in Cambodia, the authors provide a conclusion on harvest potential of Sandan's mixed deciduous forest based on analytical results, and a standard management system based on the management experiences of other Southeast Asian countries. Theoretically, Sandan's mixed deciduous forest can potentially produce 35.1 m^3/ha. In Vietnam, forests are classified as poor (less than 80 m^3), medium (80-150 m^3) and rich (more than 150 m^3) on the basis of growing stock per hectare, and the harvesting regime is 24 m^3/ha[12]. Thailand manages the forests on a 30 years selective felling cycle with harvesting regimes varying from 20-80 m^3/ha[6][8]. Malaysia manages the forests on a 25-30 years selective felling cycle with harvesting regimes of 30-40 m^3 /ha/year[8]. Based these management practices, the authors recommend that Sandan's mixed deciduous forest be extracted at 30m^3/ha on a selective felling of 30 years cycle for the first 5 years until information on growth and mortality rates become available. Unknown species share 36.8%, 16.9% and 16.5% of stem density, basal area and stand volume, respectively. This demonstrates a need to identify and study the names and potential utilization of these trees that will in turn provide more commercial wood. Approximately 92% of Cambodian population depend on fuelwood for daily cooking energy, and the unknown species are the important source for them in the present and future.

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