ISSN: 2449-1780 Vol. 3 (2), pp. 059-071, August, 2015

http://www.globalscienceresearchjournals.org/

Global Journal of Wood Science, Forestry and Wildlife

Full Length Research Paper

Assessment on the species composition and stand structure of three different mixed deciduous forest types in Alaungdaw Kathapa National Park

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Accepted 26 August, 2015

Much research has not been done on mixed deciduous forests in Myanmar. It is necessary to adopt suitable silvicultural operations to improve systematic and sustainable management of the mixed deciduous forests. In addition to this, the research aims to focus adequate information on the species composition and stand structure of the three different mixed deciduous forests in Alaungdaw Kathapa National Park. In each forest type, (1) ha plot was established and further divided into (8) subplots of 50 m x 25 m. The diameters at breast height (dbh) - 1.3 m above ground and heights of all the standing trees were measured and the data were analysed by Statistica software. The results show that Verbenaceae, Ulmaceae, Combretaceae, Mimosaceae families are found in all three different mixed deciduous forests having the larger number of species. The frequency class value and diversity indices and the species were more or less equally abundant as the value of evenness, E (%) closed to 1.0. The number of larger diameter classes in dry upper mixed deciduous forest is more than the rest two forests; the diameter class (201-250 cm) possesses the highest percentage of relative basal area in all three different mixed deciduous forests. The lesser number of highest trees are occurred in the lower mixed deciduous forest and gave a better regression coefficient and shape for all tree species of the three different mixed deciduous forest's height curve. In order to conserve the Alaungdaw Kathapa National Park sustainably, strict policies and sustainable conservation plans such as gap and line enrichment planting should be implemented.

Key words: Diversity Indices, Enrichment Planting, Evennes, Height Curve, Statistica Software,

INTRODUCTION

Myanmar is endowed with a rich diversity of habitat types arising largely from its unusual ecological diversity. About 47% of the country's total land area is still covered with natural forests. Myanmar has been protecting and conserving its diverse biological resources on a sustainable basis. In Myanmar, Reserved Forests (RFs), protected public forests (PPFs) and protected areas (PAs) constitute as PFE. Myanmar Forest Policy aims to

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constitute 30% of the total country's area as RF and PPF while 10% as PAS in long run. Up to May 2015, the area of RF and PPF reaches to 24.80% of the total country's area and PAS is 6.67%.

Myanmar has 39 PAS and all make vital contributions to the conservation of the world's natural and cultural resources. Wildlife sanctuary, national park, botanical garden are situated under the management of the Protected Areas System. The Myanmar Forest Policy seeks to extend the Protected Area System (PAS) by gazetting 5 % of the total and of the country from 6.67 % at present to10 % in the long run.

There are seven ASEAN heritage parks in Myanmar; Khakaborazi National Park, Indawgyi Lake Wildlife sanctuary, Alaungdaw Kathapa National Park, In lay Lake Wildlife Sanctuary, Meinmahla Kyun Wildlife Sanctuary, Lampi Marine National Park and Natma Taung National Park.The Alaungdaw Kathapa National Park covers a range of vegetation types. These include moist upper mixed deciduous forests up to 1,400 m, dry upper mixed deciduous forests, lower mixed deciduous forests, dry Indaing forest and some pine forests on higher ridges. The National Park harbours a wealth of large mammals including elephant, leopard, clouded leopard, black bear, gaur, banteng, sambar, barking deer, serow, goral, wild boar, wild dog and primates. 77 reptile species and 240 butterfly species, 168 birds species have also been recorded in the Park. The Park offers excellent opportunities for study and recreation including worship at the place where Alungdaw Shinmahar Kathapa has been enshrined. More than 100,000 pilgrims annually visit to the Alungdaw Kathapa Shrine. Therefore, the sustainability of the forest resources of the different forest types in the national park is of crucial important as well as species composition and stand structure is unavoidably desirable.

Problem Statement

Mixed deciduous forests are not only valued for timber but also important sources of non-timber forest products (NTFPs) and biodiversity conservation in Myanmar. Much research hasn't been done on mixed deciduous forests in the country. It is necessary to adopt suitable silvicultural operations to improve systematic and sustainable management of the Mixed Deciduous Forests. In addition to this, the researcher should have adequate information on the species composition and stand structure of forests. As a consequence, enhancement on management and conservation of the forests in the country could be improved. In order to manage Myanmar forest sustainably, it is radically needed to know not only the important species like *Tectona grandis* L.f. (teak), *Xylia xylocarpa* (Roxb.) Taub. (pyinkado), and *Pterocarpus macrocarpus* Kurz but also other lesser-known species. The lesser-known species may be imperative in the life of forest communities and floristic composition of the forest (Kermode, 1964).

In this research, efforts will be completed to achieve the followings;

- Assessment on tree species composition of the Dry Upper Mixed Decidious Forest (DUMD), Moist Upper Mixed Deciduous(MUMD) Forest and Lower Mixed Deciduous(LMD) Forest.
- Investigation on the stand structure of the DUMD Forest, MUMD Forest and LMD Forest..

MATERIALS AND METHODS

Study Area

Alaungdaw Kathapa National Park is situated between 22 ˚5´ N and 94˚ 26´ East in Yinmabin Township, Sagaing region. Alaungdaw Kathapa National Park was established as a protected area in 1981 and opened as a National Park in 1989. The Park covers an area of about 1,403 km^2 and it is situated in the Mingin and Kani townships, Sagaing Region. It comprises the Patolon reserved forests and two thirds of the adjoining Taungdwin reserved forests. The series of the parallel ridges are major features of the areas and are characterized by fairly steep escarpments on the eastern face and moderate slopes on the west. The area has a monsoon climate but is sheltered to some extent from the full effect of the South-West monsoon by the western Chin Hill. The soil is generally a sandy loan with varying proportion of sand (Oo. N., T., 2006).

Methodology

A field survey was carried out in the Dry Upper mixed decidious forest, Moist upper mixed deciduous forest and Lower mixed deciduous forest with subjective sampling. The three temporary sample plots were selected only in places where stocking was full for each forest types in the Alaungdaw Kathapa National park. In each forest type, (1) ha plot was established and further divided into (8) subplots of 50 m x 25 m. The diameters (greater than 5cm) at breast height (dbh) - 1.3 m above ground and heights of all the standing trees were measured using diameter tape and clinometer respectively.

Species Diversity (Simpson Diversity and Shannon Diversity Indices)

SIMPSON's Index (D)

SIMPSON's Index or dominance measures gave the probability of any two individuals drawn at random from an

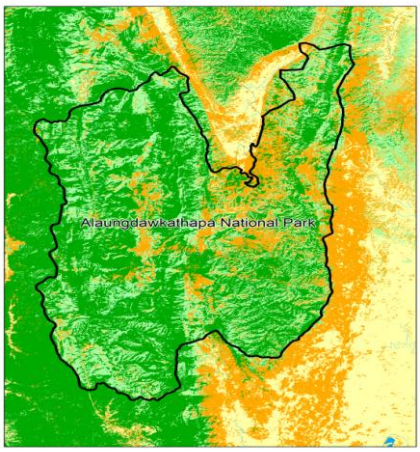

Figure 1: Study area

infinitely large community belonging to different species (Magurran, 1988). The formula measuring the heterogeneity index in this study is as follows:

where; n_i = number of individuals in the *i*-th species

k = number of species

N = total number of individuals (all species)

$$D = \frac{\sum_{i=1}^{k} n_i \cdot (n_i - 1)}{N \cdot (N - 1)}$$

SHANNON Index (H')

The SHANNON Index (H') expresses the information content per individual within an infinite population (Peet, 1974) and is estimated by

$$H' = -\sum_{i=1}^{k} p_i \cdot \ln p_i$$

where; p_i = proportional abundance of the *i*-th species

k = number of species

In this study, the expected value (H') was calculated as follows (quoted in Brodbeck, 2004):

$$H' = \sum_{i=1}^{k} \frac{n_i}{N} \cdot \ln \frac{n_i}{N}$$

where; n_i = the number of individuals in the *i*-th speices

N = the total number of individuals

The maximum diversity (H_{max}) could be found if all species were of equal abundance. That implies those means $H' = H_{max} = \ln k$ where ln *k* is the total number of species. Species evenness can be measured by the ratio of observed diversity to maximum diversity (Magurran, 1988). The following formula was used to find out the measure of evenness (Brodbeck, 2004).

where; E [%] = evennes

H' = observed diversity according to SHANNON

H_{max} = maximum possible diversity

$$E\,[\%] = \frac{H'}{\ln H_{max}} \cdot 100$$

E is constrained between 0 and 1.0. The value 1.0 represents a situation in which all species are equally abundant.

Importance Value Index (IVI)

Importance Value Indxe for each species is calculated by adding up relative dominance, relative abundance and relative frequency. Mathematically, it can be expressed as follows:

IVI=R.A+R.F+R.BA

Where

Relative abundance (R.A) = percentage of each species on total stem number per hectare

Relative frequency (R.F) = percentage of each species contribution to the sum of absolute frequency

Relative Dominance (R.D) = percentage of each species's basal area on sum of basal area of all species.

Relative basal area (R.B.A) stands for the dominance of the species.

$$R.B.A = \frac{Total.\ basal\ area\ of\ a\ given\ species}{Sum\ of\ total\ basal\ area\ of\ all\ species} * 100$$

RESULTS AND DISCUSSION

Tree Composition

In the DUMD forest, a total of 272 trees belonging to 10 families were recorded in 1 ha plot. Family Ulmaceae (62 trees) is represented by the largest number of trees followed by Verbenaceae (44 trees) and Mimosaceae (40 trees). A total of 276 trees belonging to 10 families were recorded in 1 ha plot of the MUMD forest. Family Fabaceae (50 trees) is represented by the largest number of trees followed by Sapindaceae (34 trees) and Verbenaceae (24 trees).In LMD forest, a total of 154 trees belonging to 10 families were recorded. Table 1 shows species composition and density in 1 ha plot of the three different mixed deciduous forests in the Alaungdaw Kathapa National Park.

Species Area Relationship (Species area curve)

The species area curve is the best criteria for determination of the minimum study area. It can be described with the number of species in relation to the size of the area. It was drawn to explain that a representative sample of the species composition was obtained by the sample plots. Cain (1959) and Lamprecht (1986) recommended that a sample plot can be considered

Table 1: The (10) largest family of the DUMD Forest, MUMD Forest and LMD Forest in accordance with the number of species, trees with dbh ≥ 5 cm and height ≥ 1.3 m.

DUMD Forest Family	No of trees	MUMD Forest Family	No of trees	LMD Forest Family	No of trees
Euphorbiaceae	10	Fabaceae	10	Rutaceae	2
Juglandaceae	12	Celastraceae	14	Chloranthaceae	2
Dipterocarpaceae	16	Combretaceae	18	Rhamnaceae	2
Lythraceae	18	Dipterocarpaceae	18	Combretaceae	4
Anacardiaceae	22	Euphorbiaceae	18	Euphorbiaceae	8
Combretaceae	24	Apocynaceae	24	Mimosaceae	10
Apocynaceae	24	Ulmaceae	28	Ulmaceae	18
Mimosaceae	40	Mimosaceae	40	Verbenaceae	24
Verbenaceae	44	Sapindaceae	50	Sapindaceae	34
Ulmaceae	62	Verbenaceae	56	Fabaceae	50
Total	272		276		154

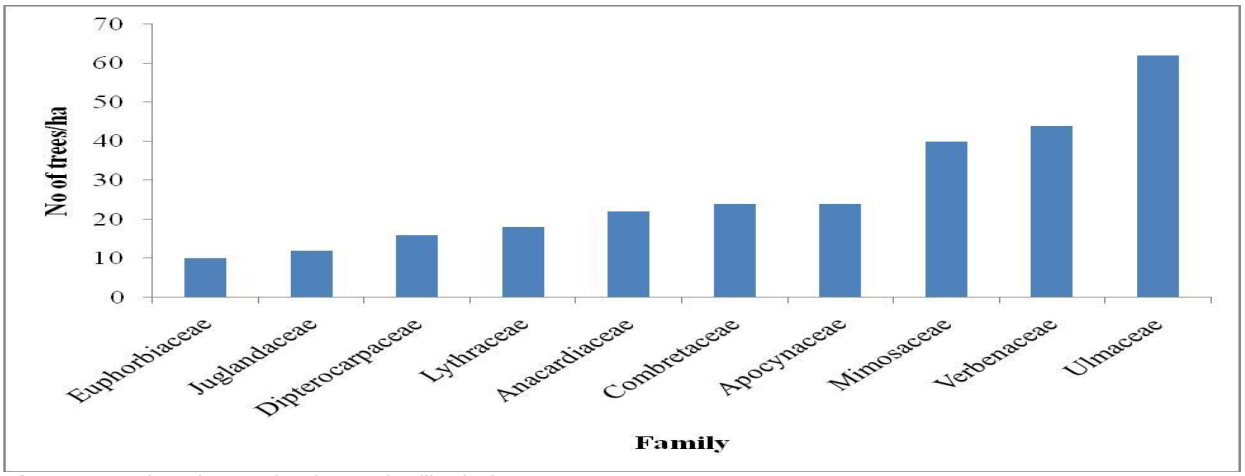

Figure 2: Number of trees of 10 largest families in the DUMD Forest

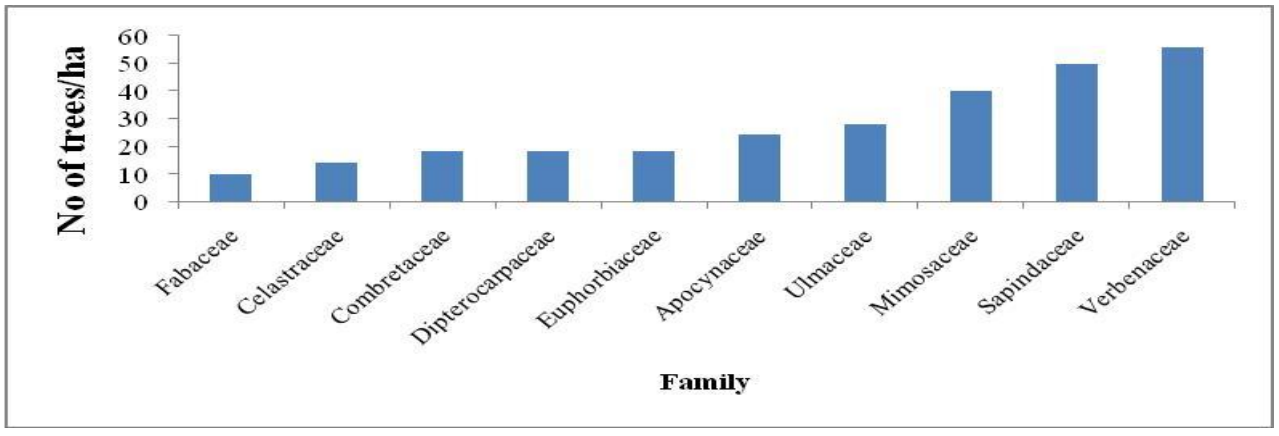

Figure 3: Number of trees of 10 largest families in the MUMD Forest

as a representative when an enlargement of the sample area by 10% results in a species number less than 10%. In this study, the minimum study was based on such procedure in order to be supposed that the sample area is adequate as a minimum representative area for the study. The relationship between the number of species and area of the DUMD forest, MUMD forest and LMD forests are shown in Figure 4.

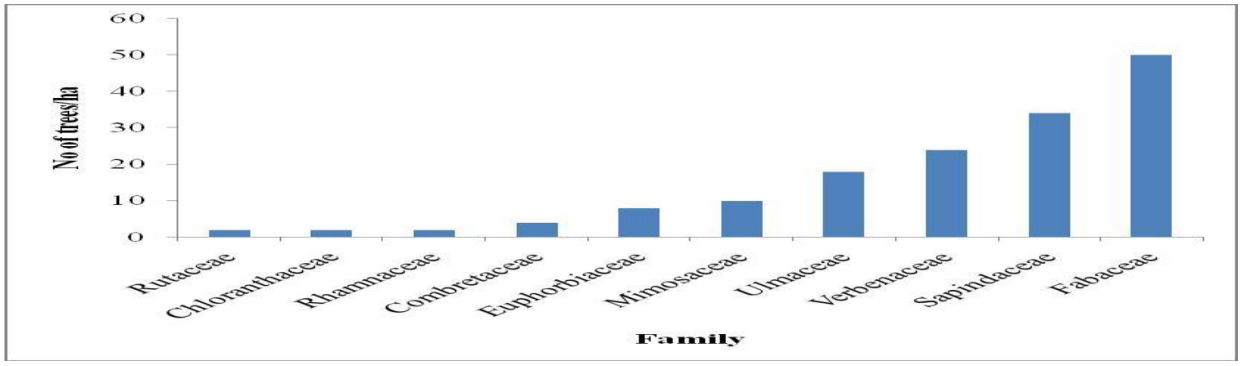

Figure 4: Number of trees of 10 largest families in the LMD Forest

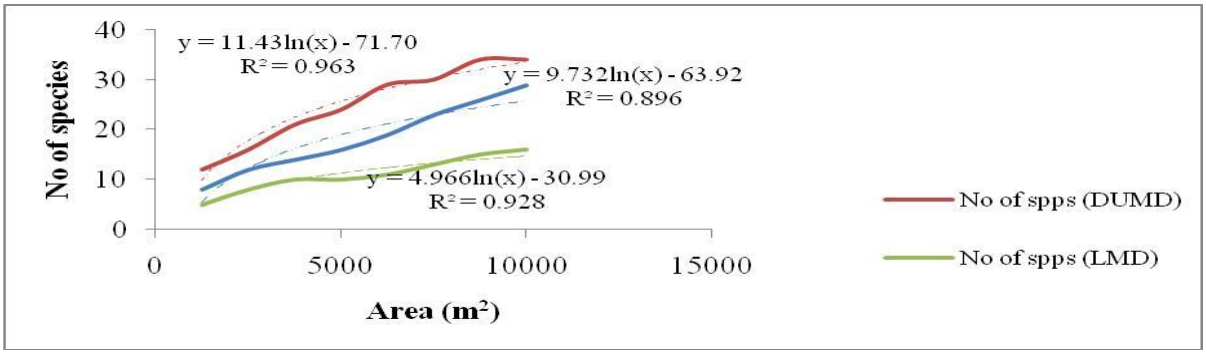

Figure 5: Species area curve of the three different mixed deciduous forests.

The species area curve describes species diversity in relation to increasing size of area. For all curves, all trees having with diameter at breast height equal and greater than 5 cm DBH show a high number of species per unit area. The curve shows that the number of species is highest in DUMD forest and followed by MUMD forest and LMD forest.

Species Richness

The number of species per unit area is used to measure the species richness and diversity in individual forest communities. The species richness is commonly expressed the number of species (tree species over a specified minimum diameter at breast height) per hectare which is also mentioned as species density. In forest vegatation analysis, the number of tree species over 5 cm diameter at breast height (dbh) is commonly quoted. Due to the result of the study, 34 species/ ha were found in DUMD forest, 29 species /ha in MUMD forest and 16species /ha in LMD forest.

Species Diversity and Evenness

Species diversity is the number of different species in a particular area (species richness) weighed by some measure of abundance such as number of individuals or biomass (Harrison *et al*., 2004). According to Magurran (1988), species diversity consists of two components, namely variety and relative abundance of species. A typical species rich ecosystem has many rare species and a few individuals represented in their high numbers (Lu, 1999).

The species frequency distributions of the DUMD forest, MUMD forest and LMD forests are shown in Figure 5.
4 species (5.26 % of total individuals) occupied only one individual each in the DUMD forest whereas 9 species (0.07 % of total individuals) with only one individual in the MUMD forest and 5 species (5.88% of total individuals) with only one individual in the LMD forest.

In the DUMD forest, Teak (*Tectona grandis*) was found to be the most abundant species followed by Pyinkado (*Xylia xylocarpa*), Taukkyant (*Terminalia crenulata*). In the MUMD forest, Teak (*Tectona grandis*) was found to be the most abundant species followed by Gyo (*Schleichera oleosa*), Pyinkado (*Xylia xylocarpa*), Kabaung (*Celtis cinnamomea*) and Lathtoke (*Holarrhena pubescens)* etc. In the LMD forest, Gyo (*Schleichera oleosa*) was found to be the most abundant species followed by Padauk (*Pterocarpus macrocarpus*), Teak (*Tectona grandis*), Yindaik (*Dalbergia maymyensis*),Kabaung (*Celtis cinnamomea*) etc. *Tectona grandis* and *Xylia xylocarpa* are the most valuable species in Myanmar.

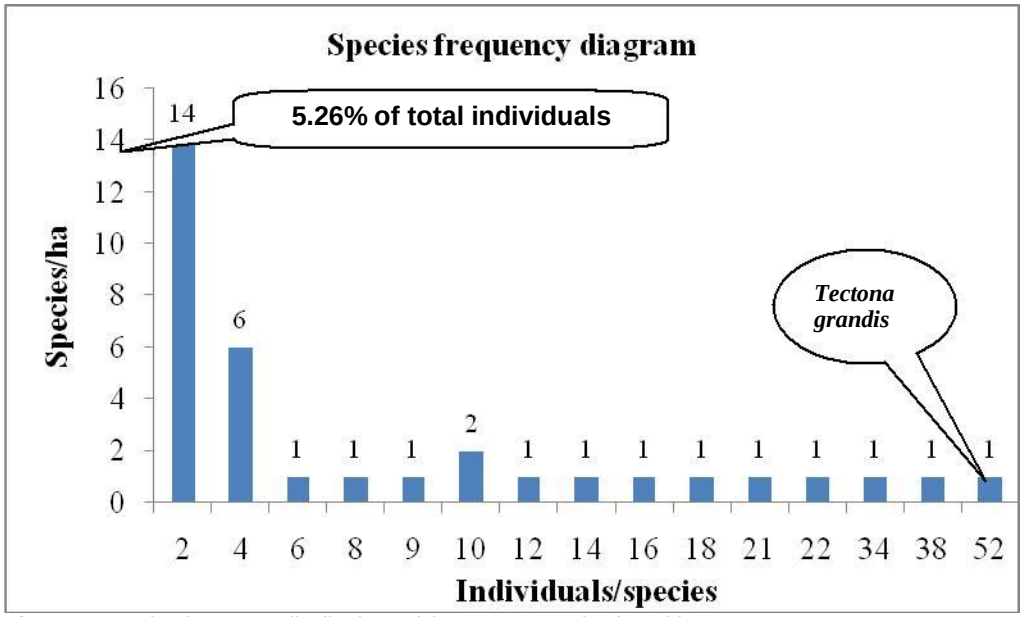

Figure 6: Species frequency distributions of the Dry Upper Mixed Deciduous Forest.

Table 2: Tree species diversity in the DUMD forest, MUMD forest and LMD forests of the Alaungdaw Kathapha (all tree species dbh ≥ 5 cm and height ≥ 1.3 m)

Forest	Number of trees (per ha)	Number of species (per ha)	*D*	(*1-D*)	(H')	H_{max}	(E) (%)
Dry mixed deciduous forest	322	34	0.07	0.92	2.97	9.75	84.09
Moist Upper mixed deciduous forest	319	29	0.09	0.90	2.75	8.57	81.52
Lower mixed deciduous forest	162	16	0.12	0.88	2.32	6.09	83.79

Table 3 : The dominance, abundance, frequency and importance value index (IVI) for 10 most important species of the DUMD forest.

No	Species	Scientific name	Abundance (N/ha)	Dominance (m^2/ha)	Frequency	IVI
1	Gyo	*Schleichera oleosa*	9	0.49	62.5	9.50
2	Htauk-kyant	*Terminalia crenulata*	22	4.21	50	19.88
3	Ingyin	*Shorea siamensis*	17	0.77	50	11.22
4	Kyun	*Tectona grandis*	52	21.24	100	69.01
5	Padauk	*Pterocarpus macrocarpus*	8	1.06	37.5	8.05
6	Pyinkado	*Xylia xylocarpa*	38	4.53	75	27.50
7	Tha pyae	*Eugenia bracteolate*	2	0.72	12.5	3.26
8	Thityah	*Schima wallichii*	4	0.17	12.5	2.68
9	Yon	*Anogeissus acuminate*	14	0.77	37.5	9.16
10	Zaungbale	*Lagerstroemia villosa*	10	1.12	37.5	8.75
11	Other species		172	12.50		130.99
	Total		348	47.57		300

Table 4: The dominance, abundance, frequency and importance value index (IVI) for 10 most important species of the MUMD forest

No	Species	Scientific name	Abundance (N/ha)	Dominance (m^2/ha)	Frequency	IVI
1	Gyo	*Schleichera oleosa*	51	3.91	100	33.70
2	Htaukkyant	*Terminalia crenulata*	12	2.35	62.5	14.65
3	Ingyin	*Shorea siamensis*	2	0.06	12.5	1.98
4	Kyun	*Tectona grandis*	56	21.70	87.5	69.67
5	Padauk	*Pterocarpus macrocarpus*	2	0.12	12.5	2.10
6	Pyinkado	*Xylia xylocarpa*	36	5.80	87.5	31.54
7	Thit pagan	*Dalbergia lanceolaria*	2	0.25	12.5	2.36
8	Thin Win	*Millettia pendula*	6	0.22	37.5	6.02
9	Yon	*Anogeissus acuminate*	6	1.44	37.5	8.47
10	Zaungbale	*Lagerstroemia villosa*	4	0.24	12.5	2.58
11	Others		146	13.84		126.56
	Total		323	49.91		300

Table 5: The dominance, abundance, frequency and importance value index (IVI) for 10 most important species of the LMD forest.

No	Species	Scientific name	Abundance (N/ha)	Dominance (m^2/ha)	Frequency	IVI
1	Binga	*Mitragyna diversifolia*	4	0.01	12.5	4.66
2	Gyo	*Schleichera oleosa*	34	9.34	87.5	52.82
3	Htauk-kyant	*Terminalia crenulata*	4	3.22	25	12.55
4	Kyun	*Tectona grandis*	24	17.22	62.5	56.31
5	Nabe	*Lannea coromandelica*	2	1.63	12.5	6.32
6	Padauk	*Pterocarpus macrocarpus*	26	15.76	100	61.47
7	Pyinkado	*Xylia xylocarpa*	10	5.30	37.5	22.11
8	Thetyin-gyi	*Croton oblongifolius*	4	0.09	25	6.97
9	Thit-pagan	*Dalbergia lanceolaria*	6	0.89	37.5	11.81
10	Yindaik	*Dalbergia maymyensis*	18	0.12	37.5	17.84
11	Other species		30	2.65		47.15
	Total		162	56.22		300

In the DUMD forest, Teak (*Tectona grandis*) was found to be the most abundant species followed by Pyinkado (*Xylia xylocarpa*), Taukkyant (*Terminalia crenulata*). In the Moist Upper Mixed Deciduous forest, Teak (*Tectona grandis*) was found to be the most abundant species followed by Gyo (*Schleichera oleosa*), Pyinkado (*Xylia xylocarpa*), Kabaung (*Celtis cinnamomea*) and Lathtoke (*Holarrhena pubescens)* etc. In the LMD forest, Gyo (*Schleichera oleosa*) was found to be the most abundant species followed by Padauk (*Pterocarpus macrocarpus*), Teak (*Tectona grandis*), Yindaik (*Dalbergia maymyensis*),Kabaung (*Celtis cinnamomea*) etc. *Tectona grandis* and *Xylia xylocarpa* are the most valuable species in Myanmar.

Species Diversity (Simpson Diversity and Shannon Diversity Indices)

Diversity indices are better measure of the species diversity of a forest than the species density and mixture ration and more informative than species counts alone

Table 6: The total number of trees (≥ 5cm) in the three different mixed deciduous forests with respect to DBH classes.

DBH Classes	Dry Upper Mixed Deciduous Forest		Moist Upper Mixed Deciduous Forest		Lower Mixed Deciduous Forest	
	BA/ha (m^2)	Trees/ha	BA/ha (m^2)	Trees/ha	BA/ha (m^2)	Trees/ha
≥50	11.69	217	9.59	187	2.81	86
51-100	17.46	46	21.29	46	6.69	12
101-150	36.11	26	26.90	23	17.02	13
151-200	66.54	27	41.72	17	36.80	14
201-250	79.80	19	156.80	40	111.95	29
251-300	66.64	11	33.26	6	34.28	8
Total	297.85	348	322.23	323	224.98	162

(Diversity indices are better measure of the species diversity of a forest than the species density and mixture ration and more informative than species counts alone (Weidelt, 2000). According to Magurran (1998), species diversity is often expressed by two indices, namely, Shannon index (H´), Evenness (E%) and Simpson's index (D). Shannon diversity index places more weight on the rare species while Simpson's diversity index emphasis on the common species (Weidelt, 200).It is generally accepted that both indices give appropriate measures of diversity and provide different insights into the diversity of the forest. Number of trees, species density and diversity indices and the evenness of the DUMD forest, MUMD forest and LMD forests are compared in Table 2.

Based on the results of the SHANNON Index (H') and SIMPSON's Index (*D*), all three forests had a high heterogeneity of rare species and a high diversity of common species. This is because the value of $\boldsymbol{H'}$ was high and the value of ***D*** was very small. In all study sites, the species were almost equally abundant as the percentage of evenness **E** (%) was close to 1.0. Generally the indices ***D***, $\boldsymbol{H'}$, $\boldsymbol{H_{max}}$ and Evenness did not show any marked differences between the three different forests although the DUMD has larger species than the rest two forests.

Importance Vale Index (IVI)

SSilvicultural Importance Value Indxe is the most well known indicator to generalize the analytical results of individual forest surveys in order to gain a quick overview and to make immediate comparison between different surveys. On the other hand, the ecological significance of a species can be compared by IVI in a given type (Lamprecht, 1989). It is noted that the best known is the Importance-Value-Index (IVI) of Curtis and McIntosh (Lamprecht, 1989). Importance Value Index for each species is calculated by adding up relative dominance, relative abundance and relative frequency.

The dominance, abundance, frequency and importance value index (IVI) for 10 most important species of the DUMD forest, MUMD forest and LMD forest are described in Table 3-5.

In the DUMD forest, the most abundant species in the investigated stand is *Tectona grandis* and it also possess the greatest IVI value followed by *Xylia xylocarpa* and are also found to be the largest in the stand. According to the IVI values of two most abundant species, associated type of the investigated stand may be recognized as *Tectona grandis* and *Xylia xylocarpa..*

In the DUMD forests, regarding the species composition, the most abundant species in the investigated stand is *Tectona grandis* and it also possess the greatest IVI value followed by *Xylia xylocarpa*, *Schleichera oleosa.*

In the LMD forests, regarding the species composition, the most abundant species in the investigated stand is *Schleichera oleosa* and it also possess the greatest IVI value followed by *Pterocarpus macrocarpus* and *Tectona grandis* and are also found to be the largest in the stand. According to the IVI values of two most abundant species, associated type of the investigated stand may be

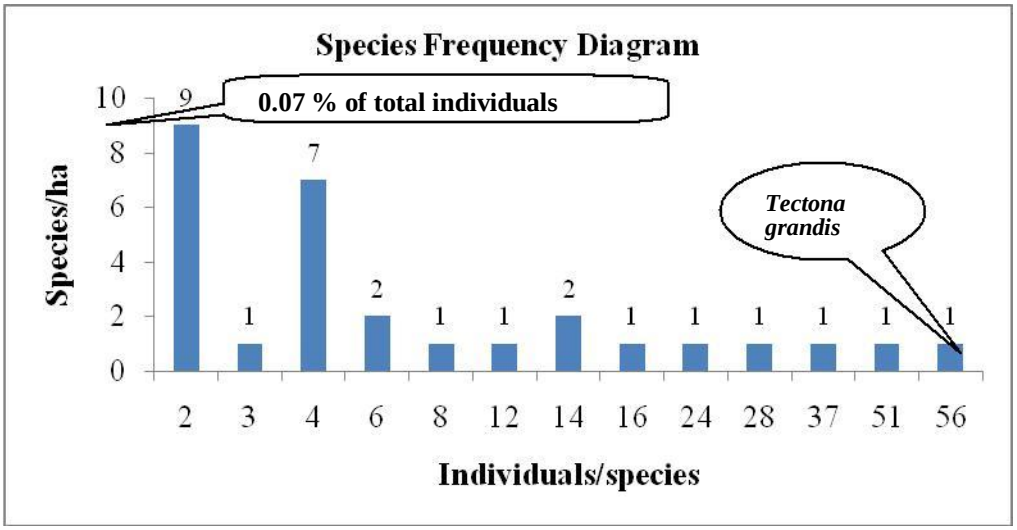

Figure 7: Species frequency distributions of the Moist Upper Mixed Deciduous Forest

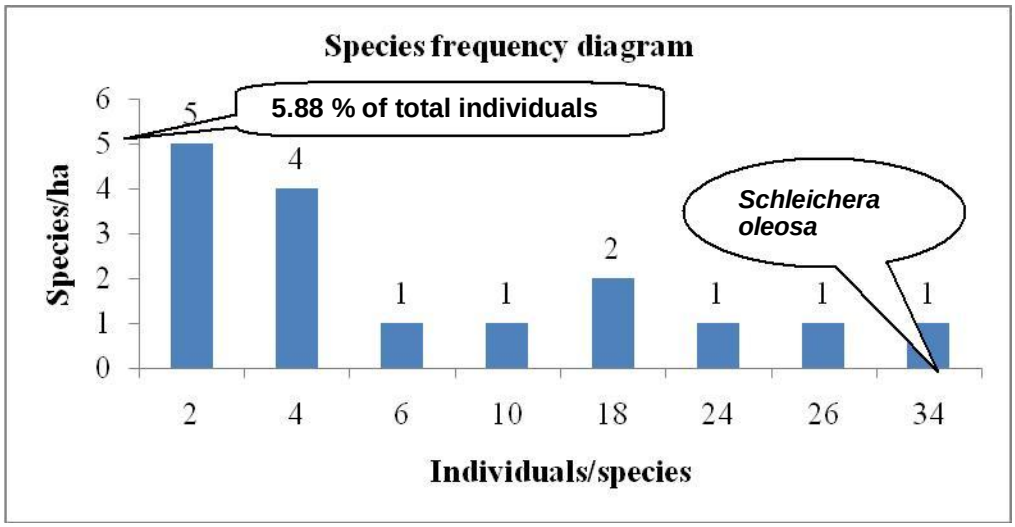

Figure 8: Species frequency distributions of the LMD Forest

recognized as *Schleichera oleosa* and *Pterocarpus macrocarpus..*

Stand Structure

Horizontal Structure

In the DUMD forest, MUMD forest and LMD forests, there were 348 trees/ha, 323 trees/ha and 162 trees/ha respectively. According to the result, it showed that the individual trees accumulated in the lower diameter classes. The total number of trees (≥ 5cm) with respect to DBH classes is shown in Table 6.

The relative abundance-diameter distribution diagram and relative basal area-diameter distribution diagram of the DUMD forest, MUMD forest and LMD forest of the park are shown in Figure 9 and 10 respectively in order to compare the stand conditions of the three different forest types

As shown in Figure 9 and 10, in terms of relative abundance-diameter distribution is not much different for all three different mixed deciduous forest. The number of small diameter classes of the three different mixed deciduous forests is more or less the same. But the number of larger diameter classes in DUMD forests is more than the rest two forests. Figure 10 shows that the diameter class (201-250 cm) possesses the highest percentage of relative basal area in all three different mixed deciduous forests.

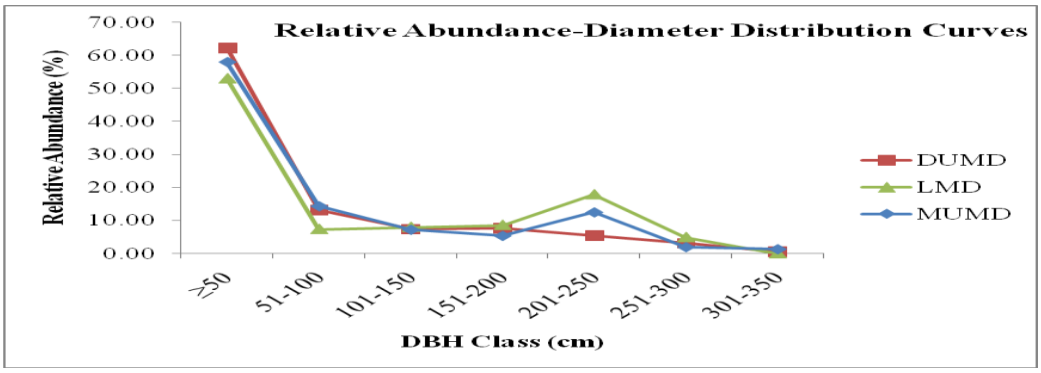

Figure 9: Relative abundance-diameter distribution of the three different mixed deciduous forests in the park

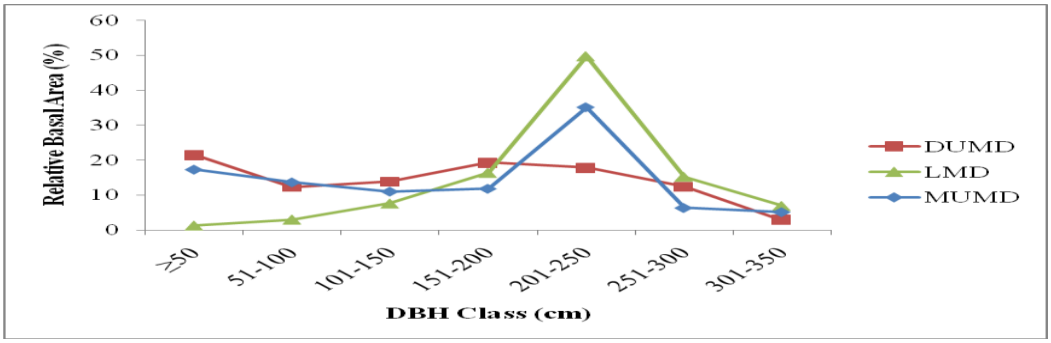

Figure 10: Relative basal area-diameter distribution of the three different mixed deciduous forests in the park

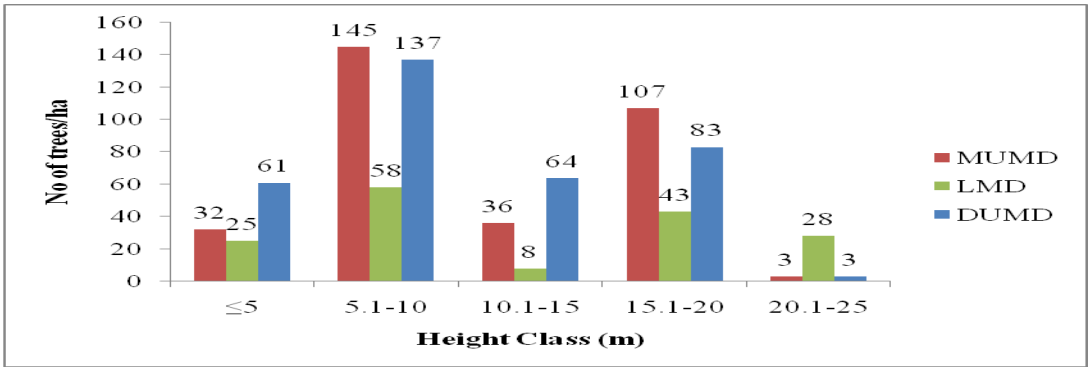

Figure 11: Vertical distribution of trees in the study area by Height class (Total sample area =1 ha) for each forest type

Vertical Stand Structure

Individual tree by height class of the three different mixed deciduous forest types are given in Figure 10. In all three types of forests, the numbers of trees are largest in the class between 5.1-10 m. followed by 15.1-20 m height class. The number of trees is the least in the height class 20.1-25 m. In general, the lesser number of highest trees are occurred in the LMD forest.

Stand Height Curve

A stand height curve presents the correlation between tree height and tree diameter or basal area. It is used to

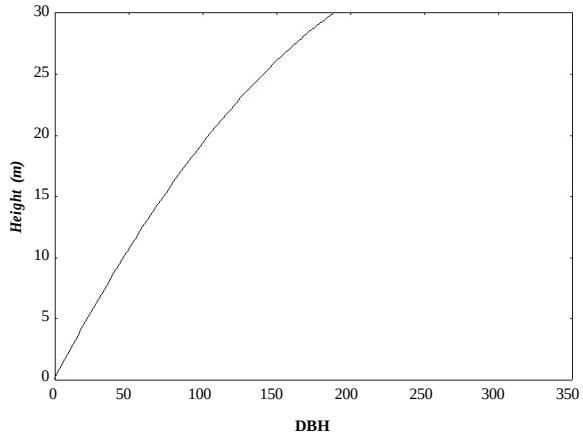

Figure 12: Diameter-Height curves of DUMD Forest.

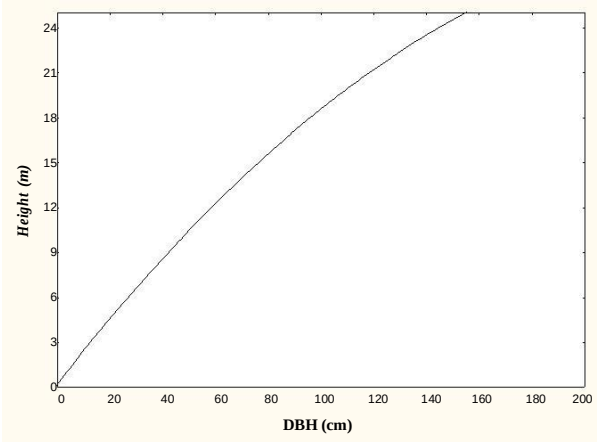

Figure 13: Diameter-Height curves of MUMD Forest.

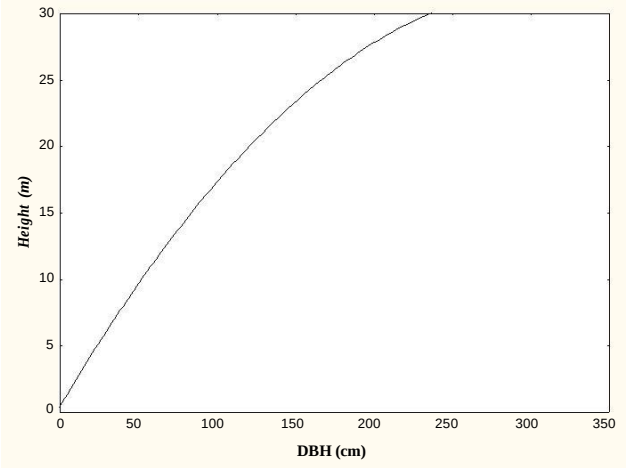

Figure 14: Diameter-Height curves of LMD Forest.

predict the height of trees from their measured dbh. This is because it is difficult to measure stem height in natural forest especially in rain forests. Among various height curve functions, the following functions were tested to get the best fit with the collected data of the three different mixed deciduous forests.

Table 7: Parameters and r^2 of diameter-height relationship (Van Laar and Akca (1997) fitted model.

Forest Types	Parameters a	B	R^2
DUMD	0.18244	-0.00044	0.79
MUMD	0.20701	-0.00054	0.91
LMD	0.19959	-0.00050	.93

1. Prodan-equation: $$h = 1.3 + \frac{d^2}{A + B \cdot d + C \cdot d^2}$$

2. Petterson-equation: $$h = 1.3 + \left(\frac{d}{A + B \cdot d} \right)^2$$

3. Van Laar and Akca $h = 1.3 + (a*DBH + b*DBH^{\wedge 2})$

The The height curve is eventually derived from the functions but is the only best fitting to the observed data, as it is monotone and should increase with dbh increase (Laar and AkÇa, 1997). Selection of the regression function was based on the shapes and trends of the curves within the range of measured diameters and the statistical parameters. The statistical parameters were the coefficient of determination (R^2) and the regression coefficient (R) (Kramer and AkÇa 1995; Lappi, 1997; Richter, 1998).

In this study, the height curves were drawn with a data set of all trees species ≥ 5 cm dbh of one hectare area in each forest type. The height curves are valid up to the maximum observed dbh. The test showed that the Van Laar and Akca (1997) gave a better regression coefficient and shape for all tree species of the three different mixed deciduous forest's height curve.

The slope of curves should be looked at when height curves are studied. This is because they express the relative growth of diameter and height. Height reflects the quality of the site (climate, soil, and exposition) but silvicultural treatment can scarcely influence the growth of tree height. Loetsch *et al*., (1973) mentioned that on good sites, height curves show relatively steep and higher maximum heights while height curves of poorer sites rise much more slowly and maximum heights are lower. Brodbeck (2004) stated that height curves give steep slope in young stands due to the greatest of the early stage growth height while lower gradient are obtained in old stands due to slow growth of height with age. Finally the curves reach constant level at the highest diameters.

In this study, all of the height curves, however, did not follow those trends because the height increased with increasing diameter. The observed height curves for the three different mixed deciduous forests are shown in Figure 12-14 and the respective parameter values are also expressed in Table 7.

CONCLUSIONS AND RECOMMENDATIONS

The structure and composition of the forest can be different depending on the elevation, climatic condition and other environmental factors. The appropriate management systems should be adopted based on the nature of forests in order to manage different kinds of forests scientifically and sustainably. To investigate the appropriate management system, firstly the basic information of stand structure, composition of the forest is of vital importance. For this purpose, this study was carried out in the mixed deciduous forests in the Alaungdaw Kathapa National Park. More research with mixed deciduous forest of Myanmar is paramount important. The Alaungdaw Kathapa National Park is a historical famous Buddhist pilgrimage site in Myanmar so that a lot of foreigners visit throughout the year and many outsiders are encroached around the National Park to earn by selling food and NTFPs. As a consequence, timber and NTFPs have been extracted illegally from the Alaungdaw Kathapa National Park. Therefore, strict policies and sustainable conservation plans are considered necessary to protect Alaungdaw Kathapa National Park. Furthermore alternative sources of energy must be substituted to solve the firewood crisis there and extension activities should be carried out. Enrichment planting should be carried out in order to conserve the regeneration potential of valuable commercial species in the Alaungdaw Kathapa National Park. Furthermore, comparative research with the mix deciduous forest situated in the reserved and protected public forests should be conducted.

ACKNOWLEDGEMENTS

I am greatly indebted to Dr Nyi Nyi Kyaw, Direactor General, Forest Department, Dr Thaung Naing Oo, Director of Forest Research Institute for granting us the opportunity to carry out this study. I am very much grateful to Ms Khin Me Me Aung, Research Assistant (3), and Mr Win Naing, Forest Ranger, Forest Research Institute for the coordination of the field works in the Alaungdaw Kathapa National Park. I highly appreciate U Ye Htun, Assistant Directors and Daw Than Than Aung from Alaungdaw Kathapa National Park for supporting accommodation and accompanying and gathering data to carry out the present study. Last but not least, I would like to thank my parents for their patience, encouragement and love throughout my forester life.

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