INVESTIGATION INTO THE STRUCTURE AND COMPOSITION OF FOREST STANDS GROWING IN DIFFERENT TOPOGRAPHIC CONDITIONS

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ABSTRACT

In Myanmar among the different types of forests growing in different climatic, topographic and edaphic conditions growing in Myanmar, mixed deciduous types are of most economical importance. Data collection was conducted in compartment no (40) of Petsut Reserved Forest, Katha Township for comparative study on structure and composition of this forest. Silvicultural parameter of the forest stands occurring on the southern exposure, northern exposure and along the ridge top are discussed and the enrichment planting which caused very little impact on natural forest eco-system is also suggested.

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1. INTRODUCTION

The Union of Myanmar, situated in continental Southeast Asia, has a total land area of 676,577 square kilometer. It is also termed as a land of forest-clad mountains. The country lies between latitude 9º53´ and 28º10´ and longitude between 92º10´ and 101º 10´ E. It has a total coastline 2,832 km and stretches 2,090 km from north to south and 525 km from east to west at its widest points. Annual rainfall ranges from below 900 mm in the central dry zone to over 5,000 mm in coastal regions. Temperature also ranges from below 10º C in hilly regions to over 40º C in the central dry zone (Forest Department, Myanmar 1998).

Due to the physiographic and climatic conditions, the different forest types occur throughout the country. The standard types are;

- Tidal forests
- Beach and dune forests
- Swamp forests
- Evergreen forests
- Mixed deciduous forests
- Dry forests
- Deciduous Dipterocarp or *Indaing* forests, and Hill forests

Among these types, mixed deciduous forests occurring around the dry zone play an important role as they contain the best quality teak (*Tectona grandis* Linn. f) and other valuable timber species. These kinds of forests cover large area in the Pegu Yomas (a low range of hill) and also extend across the Irrawaddy westwards in the northern Myanmar as in Katha, Bhamo, Myitkyina, etc., The usual habit is in hilly country with a drier type on the ridge tops. Mixed deciduous forests occupy about 134,069 km^2 (Forest Department, Myanmar 1998) have been already classified into three types;

- Moist Upper Mixed Deciduous Forests (MUMD)
- Dry Upper Mixed Deciduous Forests (DUMD)
- Lower Mixed Deciduous Forests (LMD)

This classification is based on their common species composition, rainfall distribution and characteristic bamboo species. The classification according to the bamboo occurrences is Kyathaung-wa (*Bambusa polymorpha*) and Tin-wa (*Cephalostachyum pergracile*) in MUMD of Lower Myanmar, Wabo-myet-san-gye (*Dendrocalamus hamitonii*), Wa-pyu (*Dendrocalamus membrana-ceus*) and Tin-wa (*Cephalostachyum pergracile*) in MUMD of Upper Myanmar respectively. For DUMD Thana-wa (*Thyrsostachys oliveri*) and Thaik-wa (*Bambusa tulda*) are characteristic bamboo species for Lower Myanmar and, (Hmyin-wa) (*Dendrocalamus strictus*) and Thana-wa (*Thyrsostachys oliveri*) in Upper Myanmar. LMD is characterized by the scarce or absence of bamboo.

According to KERMODE, 1964, the commonly occurring species of **MUMD** are teak (*Tectona grandis* Linn f.), Pyinkado (*Xylia dolabriformis*), Taukkyan (*Terminalia tomentosa*) Thitsein (*Terminalia belerica*), Lein (*Terminalia pyrifolia*), Myauk-chaw (*Homalium tomatosum*), Didu (*Bombax insignis*), Yemane (*Gmelina arborea*), Nabe (*Lannea grandis*), *Vitex spp*., Padauk (*Pterocarpus macrocarpus*), Thinwin (*Millettia pendula*), Petwun (*Berrya ammonilla*), and Binga (*Mitragyna rotundifolia*).

The common species of **DUMD** are teak (*Tectona grandis* Linn f.), Pyinkado (*Xylia kerri*), Taukkyan (*Terminalia tomentosa*), Lein (*Terminalia pyrifolia*), Panga (*Terminalia chebula*), Padauk (*Pterocarpus macrocarpus*), Hnaw (*Adina cordifolia*), Ingyin (*Pentaceme siamensis*), Thit-ya (*Shorea oblongifolia*) and occasionally In (*Dipterocarpus tuberculatus*).

The characteristics species of **LMD** are teak (*Tectona grandis* Linn f.), Pyinkado (*Xylia kerri*), Taukkyan (*Terminalia tomentosa*), Yon (Anogeissus aciminata), Myauk-chaw (*Homalium tomatosum*), Pyinma (*Lagerstroemia speciosa*), Leza (*Lagerstroemia tomentosa*), Zinbyun (*Dillenia pentagyna*) and Sit (*Albizzia procera*). On ridge top and hot aspect, MUMD is often replaced by the DUMD (KERMODE, 1964).

Although these deciduous forests have been roughly classified as described above, the quantitative data for a particular forest including in this categories are still needed for scientific forest management in accord with the sustainability.

2. OBJECTIVES

The natural vegetation of a site is determined by the prevailing climatic and soil condition. ASHTON & BRUENIG (1975) stated that variation of intrinsic structure, the dynamics of forest stands and the regional floristic situation relate mainly to physical, environmental, especially to the water and energy regimes. The present study examines on the basic of a systematic sampling inventory for silvicultural stand structure analysis whether there will be significant differences in stand structure, composition, species diversity of forest stands growing on different exposures within a moist deciduous forest.

The main purposes of the study are:

1. to document the variation in sites, structure and composition within the moist deciduous forest due to topographic differences
2. to provide some information on the spatial distribution pattern of teak and its associates by comparing stand structures among three sites, south exposure, ridge top and north exposure
3. to present some factors relevant to sustainable forest management, regarding structure and floristic composition of a moist deciduous forest

3. STUDY AREA

3.1. Location

The study area is situated at approximately and at 24º 14′ N and 96º 16′ E with an elevation of 459 m above sea level at the highest ridge top. The study was carried out in compartment No. (40) of Petsut Reserved Forest of Katha Township.

3.2. Topography and Soil

The study area is approximately allocated at an elevation of is a rather steep long ridge stretching in east-west direction. The slope of south exposure is from 20º - 25º and north exposure is steeper and about 35º - 40º.

The soils are mostly yellow brown mountain forest soils of tropical monsoon forests (ROZANOV, 1965, quoted in BENDER, 1983). Soil samples were taken at the depth of 10 cm and 50 cm in three sites. The samples were analyzed at the FRI. The data related to dry weight of the soil sample are given in the table (1a) and (1b).

Table (1a) Physical Properties of the Soil Samples of the Investigated Stands (extractable nutrient in percentage of dry weight)

Texture	Southern exposure		Ridge top		Northern Exposure	
Depth (cm)	10 cm	50 cm	10 cm	50 cm	10 cm	50 cm
Sand %	46	31	47	38	46	48
Silt %	24	31	21	25	23	26
Clay %	26	37	28	33	31	25
Organic material %	5.59	5.52	5.97	5.31	4.3	3.67
Remark	Sandy clay loam	Clay loam	Sandy clay loam	Clay loam	Sandy clay loam	Sandy clay loam

Table (1b) Chemical Properties of the Soil Samples of the Investigated Stands (Extractable nutrient in percentage of dry weight)

Sites	Southern exposure		Ridge top		Northern Exposure	
Depth (cm)	10 cm	50 cm	10 cm	50 cm	10 cm	50 cm
pH	5.53	5.55	5.31	5.03	4.65	4.66
Ava P %	0.000030	0.000016	0.000017	0.000009	0.000027	0.000023
Total N %	0.0739	0.0599	0.0851	0.0638	0.0689	0.0655
K %	N.A	N.A	N.A	N.A	N.A	N.A
Ca %	N.A	N.A	N.A	N.A	N.A	N.A
Mg %	N.A	N.A	N.A	N.A	N.A	N.A

Analysis of soil samples revealed the acid nature of soils. Soil pH ranged from 5.53 to 5.55, at the depth of 10 cm and 50 cm of the southern exposure respectively. On the ridge, the values ranged from 5.31 to 5.03 at those depths.

Northern exposure shows more acidic nature with the pH of 4.65 to 4.66 at the depth of 10 cm and 50 cm respectively. Soil pH is to be considered a gradient that gives different species an advantage. Most tree species grow optimally on slightly acidic soils, and trees generally live between pHs of 4.0 (very acidic) to 7.5 (slightly basic) (SPURR & BARNES (1980) quoted in CHADWICK & LARSON 1996). The nitrogen (N) content is relatively high in all sites.

3.3. Climate

The climatic condition of the study area is influenced by tropical savannah climate with a pronounced dry period between the monsoon rains. Although Katha has an elevation of about 95 m a.s.l, the study site along the ridge running east-west direction has an elevation of about 457 m a.s.l. According to the climatic data of 1972 – 2002 show that raining season begins by the end of April or the first week of May and end in September. The area gets 7 months of more than 20 aridity index by DE MARTONNE 's method.

Average temperature	24.4 ºC
Average maximum rainfall month:	September (288.4 mm)
Average minimum rainfall month:	December (1.3 mm)

Table (2) The Climatic Data (Monthly Means) and DE MARTONNE's Aridity Index of the Study Area (Katha)

Month	Jan	Feb	Mar	Apr	May	June
Temperature (ºC)	16.1	19.7	24.8	28.9	28.3	28.3
Rainfall (mm)	5.8	18.3	27.9	39.4	188.4	230.8
Aridity index	2.7	7.4	9.6	12.1	**59.0**	**72.3**

Month	July	Aug	Sep	Oct	Nov	Dec	**Year**
Temperature (ºC)	27.1	27.1	27.1	25.1	22.6	18.2	**24.4**
Rainfall (mm)	265.8	252.9	288.4	177.7	188.7	1.3	**1685.4**
Aridity index	**86.0**	**81.8**	**93.3**	**60.8**	**69.4**	0.5	**48.9**

Source: The Meteorological Station, Katha

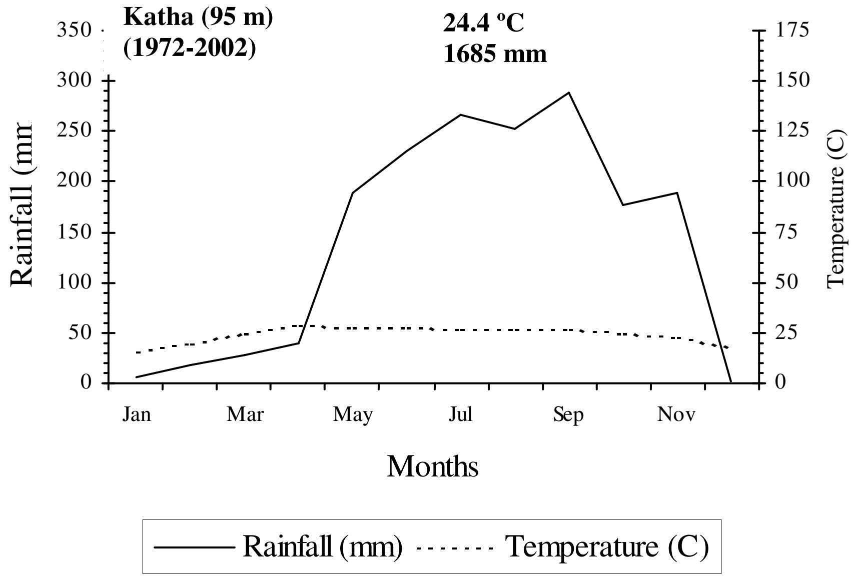


Fig. 1 Climatogram of the study area

3.4. Vegetation

In the study area, the most occurrence species **along the ridge** are teak (*Tectona grandis*) Ye-mein (*Aporosa villosa*), Sagat (*Quercus spicata*), Thitsi (*Melanorrhoea usitata*), Zaungbale (*Lagerstroemia villosa*), Lettok-gyi (*Holarrhena antidysenterica*), Thadi (*Protium serratum*) and Panma (*Anneslea fragrans*).

The most abundant species of **south exposure** are teak (*Tectona grandis*), Ye-mein (*Aporosa villosa*), Sagat (*Quercus spicata*), Thitsi (*Melanorrhoea usitata*), Zaungbale (*Lagerstroemia villosa*), Lettok-gyi (*Holarrhena antidysenterica*), Thadi (*Protium serratum*), Laukya (*Schima khasiana*) and Sa-thange-on-hnauk (*Cratoxylon prunifolium*).

The most abundant species growing on **north exposure** are Ye-mein (*Aporosa villosa*), Sagat (*Quercus spicata*), Thit-ni (*Amoora rohituka*), Kyilan (*Shorea assamica*), Myaukma-kun-thwe (*Myristica angustifolia*), Kyetyo-po (*Vitex quinata*), Yigat-gyi (*Gardenia coronaria*), Thabye-pinbwa (*Eugenia formosa*), Thit-swele (*Schrebera swietenioides*) and Panma (*Anneslea fragrans*).

The recorded climber, shrubs and herbs in most common on three sites are Baung-baung nwe (*Bridelia macrophylla*, Euphorbiaceae) Katcho-nwe (*Dioscorea burmanica*, Dioscoreaceae) Lettok-nwe (unidentified), Nabu-nwe (*Combretum accuminatum*, Combretaceae) Nya-ne-pan (*Clematis cadmia*, Ranunculaceae) Panga-nwe (*Combretum extensum*, Combretaceae) Pauk-nwe (*Butea parviflora*, Papilionaceae), Sayo-nwe (*Piper attenuatum*, Aristolochiaceae) Tamalan-nwe (*Dalbergia stipulacea*, Papilionaceae) and Thindauk (*Dioscorea decipiens*, Dioscoreaceae).

Among them **Pauk-nwe (*Butea parviflora*, Papilionaceae)** and **Tamalan-nwe (*Dalbergia stipulacea*, Papilionaceae)** are the **stranglers** and it was observed that some trees are severely affected by these stranglers. Taung-kyein (*Calamus doriaei*, Palmae) is found as an only rattan species in three investigated sites. In some gaps where large trees were felled, a dense thicket of an exotic weed Bizat (*Chromolaena odoratum*) were found especially along the ridge.

4. MATERIALS AND METHOD

4.1. Sampling Design

Systematic sampling survey with an interval of 20 m was applied in the data collection for three investigated stands. The minimum representative area was decided according to LAMPRECHT (1986) having 10,000 m^2.

In this study, samples plots laid on the ridge are 20 m apart from each other. On southern and northern exposures, the distances between the plots are not unique as those of the plots because of slope degree's differences and discontinuity of slope, especially north exposure is steeper (35º - 40º) and much more discontinuities as compared to the south one. Data collections were made the design described below as far as possible according to the running direction of the ridge. This is a time-consuming procedure which nonetheless permits the recording of sufficient information about a forest area in its entirely.

25 sampling units with 400 m^2 each
Total survey area = 1 ha (10000 m^2)

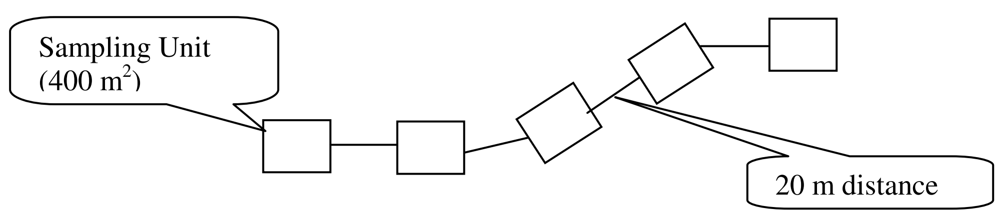


Fig 2a. Sampling Design Applied in the investigated stands

4.2. Sample Plot Design Adopted

The following sampling unit was applied in the study in conducting the structure analysis of the forest stands occurring on three different sites. A sampling unit covers the area of 400 m^2 in the compartment (A) and the compartment (B), 100 m^2 respectively. 25 sampling plots are required for total survey area of 1 ha in the compartment (A).

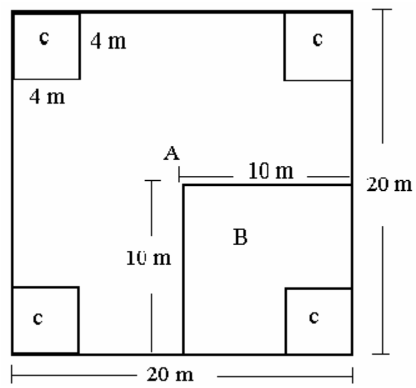


Fig.2b Layout of sample unit

Legend: **Compartment (A)** Size: 20 m x 20 m (400 m^2)

Compartment (B) Size: 10 m x 10 m (100 m^2)

Compartment (C): Natural Regeneration (all tree species between ≥ 30 cm height and < 130 cm dbh) Size: 4 m x 4 m (16 m^2) total cover area (64 m^2)

Compartment (A) is only for trees (DBH ≥ 5 cm) and the following features of the individual tree will be included in it for the species identified.

1. Dimension (DBH at breast height)
2. Total height and crown point by (SYNNOTT, 1992)
3. Tree condition by (SYNNOTT, 1992)
4. Climber infection by (SYNNOTT, 1992)
5. Crown position classification by DAWKINS (after SYNNOTT 1992)
6. Foliage condition, flower, fruit and other phenological features

In this compartment, crown diameters of the trees (DBH ≥ 10 cm) were also recorded to find correlation between crown development and diameter growth.

In the compartment (B), pole and sapling with height equal and above 1.3 m and DBH less than 5 cm were recorded as in measurement and classification features of compartment (A) other than crown diameter measurement.

In the compartment (C), natural regeneration were recorded for the seedlings of height less than 1,3 m and greater than 0.3m. In this sub-compartment, only species identification of the existing seedlings found therein was carried out.

DBH: It was determined at 1.3 m from the ground for the trees without buttress and at the height of 0.3 m above the buttress swell for the trees with buttresses.
Height: measured by using a digital Forester Vertex Hypsometer.

Crown classification by DAWKINS 1958, (quoted in LAMPRECHT 1986) is

5: Crown is full overhead light and lateral light.
4: Crown is full overhead light and lateral shade
3: Crown partially exposed to overhead light, lateral shade
2: Crown without overhead light, partial lateral light
1: Crown shaded on all sides, no direct light

The identification of tree species was carried out by the standard nomenclature of forest plant including commercial plants, (Forest Department, Burma). All of the calculations and construction of height curves were made by using Excel 6.0

Diversity index, species richness and Evenness were calculated by using the following formulae:

4.3. Diversity Indices

Shannon –Index (1948/1976)

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

where,

p_i = n_i /N, i.e., the proportional abundance of i th species = (n_i /N)
n_i = number of the species i
N = total number of individual

The maximum diversity (H_{max}) which could possibly occur would be found in a situation where all species were equally abundant, in other words maximum diversity would occur if $H' = H_{max} = \ln S$ (where S = total number of species)

4.3.1. SHANNON Evenness (E)

This is the ratio of observed diversity to maximum diversity, and it can be calculated by:

$$E = \left[H' / \ln S \right] * 100$$

Therefore, E is between 0 and 100. The value100 represents a situation that has all species as equally abundant. The value E is regard as a suitable dimension for recording the second diversity component “evenness”; it gives an impression of the structure species distribution in a stand. Increasing evenness values denote a rise in diversity. The value of E gradually goes down to the zero (0) when the number of species decreases.

4.3.2. SIMPSON-Index (D)

Another index for measuring diversity is the SIMPSON-Index, which indicates the dominance measure because such indices are weighted towards the abundance of the commonest species rather than providing a measure of species richness. The formula to calculate for a community is as follows:

$$D = \sum \left[\frac{n_i (n_i - 1)}{N(N-1)} \right]$$

n_i = the number of individuals in the i[th] species
N = the total number of individuals

As D increases, diversity decreases and the SIMPSON index is therefore usually expressed as 1-D or 1/D to produce a higher value with increasing diversity.

4.3.3. Species richness

Both MARGALEF and MENHINICK indices were used in the study.
MARGALEF’s index is by:

$$D_{Mg} = (S - 1)/\ln N$$

and MENHINICK’s index (WHITTAKER,1977)

$$D_{Mn} = S / \sqrt{N}$$

Where, S = the number of species recorded
N = the total number of individuals summed over all species

4.4. Coefficient of similarities between forest stands growing on different topographic conditions were calculated by using SORENSEN, WEIDELT and Modified SORENSEN indices

SORENSEN Index

$$K_s = \left(\frac{2c}{a+b}\right) * 100$$

Where,

a = total numbers of species found in the first forest stand

b = total numbers of species found in the second forest stand

c = total numbers of the common species found in both stands

WEIDELT (1968) quoted in WEIDELT (lot. cit)

$$K_d = \frac{2\sum dc}{\sum da + \sum db} * 100$$

Where,

d_c = sum of common dominance, which means the sum of the smaller dominance values for the common species of the both stands

d_a = total dominance of species found in the first forest stand

d_b = total dominance of species found in the second forest stand

Modified SÖRENSEN-index by BRAY and CURTIS (1957) is also applied to compare the similarity of both stands by the formula:

$$C_N = \frac{2_{jN}}{(aN + bN)} * 100$$

where,

C_N = Coefficient of similarity by BRAY and CURTIS

aN = Number of individual in the first forest stand

bN = Number of individual in the second forest stand

jN = Sum of individual number, which means the sum of the smaller number for the common species of the both stands

5. RESULTS

5.1. Silvicultural Parameters of Forests Stand Growing on Three Different Topographic Conditions

Compart	Parameter	Southern Exposure	Ridge top	Northern Exposure
	Elevation (m)	1509 feet (459 m) estimated		
	Latitude	N 24° 14′		
	Longitude	E 95° 16′		
	Annual precipitation	1685 (mm)		
	Av. min monthly precipitation	1.3 (mm) December		
	Av. max monthly precipitation	288.4 (mm) September		
	Av. mean temperature (°C)	24.4		
A	Plot size (ha)	1 ha		
	Subplots	20 x 20m		
	Number of trees/ha	502	414	625
	Number of species/ha	64	63	69
	Av. no of individual/species	7.8: 1	6.5:1	9.1:1
	Basal area (m^2 ha^{-1})	18.42	21.5	22.6
	top height (m)	21.6	21.6	18.0
	Frequency classes			
	1-20%	50	50	57
	21-40%	7	8	5
	41-60%	4	3	4
	61-80%	3	2	2
	81-100%	0	0	1
B	Plot unit (100m^2)	10 x 10 m	10 x 10 m	10 x 10 m
	Number of saplings	153	88	280
	Number of species	32	27	39
	Frequency classes			
	1-20%	30	24	31
	21-40%	1	3	6
	41-60%	1	-	1
	61-80%	-	-	1
	81-100%	-	-	-
C	Plot unit (16m^2)	4 m x 4 m	4 m x 4 m	4 m x 4 m
	Number of units	100	100	100
	Number of seedlings	993	992	1035
	Number of species	75	81	64
	Frequency classes			
	1-20%	69	77	59
	21-40%	5	2	3
	41-60%	0	1	1
	61-80%	1	1	1
	81-100%	0	0	0

5.2. Diversity

Table (3) The diversity indices and evenness of the investigated stands

	South Exposure	Ridge top	North Exposure
SIMPSON-Index (D)	0.06	0.06	0.08
1/D	17.28	17.72	11.89
1-D	0.94	0.94	0.92
SHANNON-Index (1948/1976)	3.38	3.36	3.08
SHANNON-Evenness (1948/1976)	81.56	81.17	72.76

5.2.1. Species Richness

Table (4) Indices for Species Richness by MARGALEF and MENHINICK Based on the Trees (dbh ≥ 5 cm) in the Compartment (A) of the Investigated Stands

Index	Southern Exposure dbh ≥ 5 cm	Ridge Top dbh ≥ 5 cm	Northern Exposure dbh ≥ 5 cm
MARGALEF	2.86	3.10	2.76
MENHINICK	10.13	10.29	10.56

5.2.2. Species area curves of the investigated stands

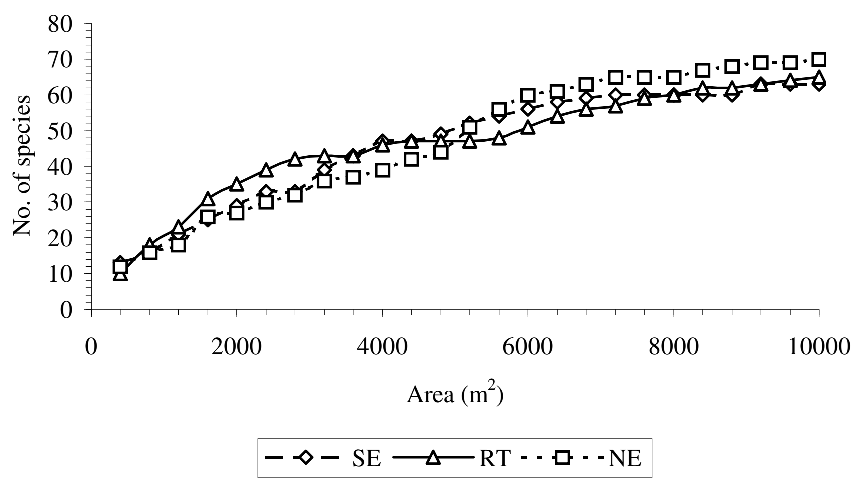


Fig. 3: The species area curves of the investigated stands in compartment (A) of all woody species (DBH ≥ 5 cm)

5.2.3. Coefficient of similarity

Table (5) Coefficient of Similarity between Forest Stands Investigated by SÖRENSEN (K_s), WEIDELT (K_d) and BRAY and CURTIS (C_N)

	Southern exposure			Ridge Top			Northern Exposure		
	K_s	K_d	C_N	K_s	K_d	C_N	K_s	K_d	C_N
Southern exposure	-	-	-	-	-	-	***66.2***	***35.2***	***47.6***
Ridge Top	***67.7***	***69.2***	***75.2***	-	-	-	-	-	-
Northern Exposure	-	-	-	***66.7***	***55.5***	***46.4***	-	-	-

Similarity Indices	Remark
SÖRENSEN (K_s)	based on the species
WEIDELT (K_d)	based on the species dominance
BRAY and CURTIS (C_N)	based on the individuals

5.3. Stand Structure
5.3.1. Horizontal stand structure
5.3.1.1. Species distribution by frequency classes

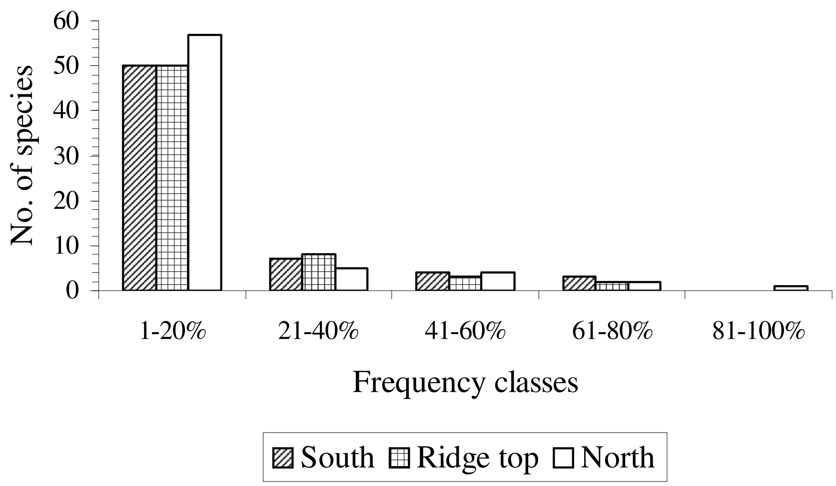


Fig. 4: Comparison of frequency distributions of the species occurring in all stands

5.3.1.2. Dominance, abundance and frequency

Table (6a) Abundance, Frequencies, Dominance and IVI of the Species Occurring on the South Exposure Stand (species IVI ≥ 8)

No.	Local Name	Scientific Name	Family	Abu.	Freq.	Dom.	IVI
1	Kyun	*Tectona grandis*	Verbenaceae	44	20	5.86	48.03
2	Ye-mein	*Aporosa villosa*	Euphorbiaceae	84	20	1.27	31.10
3	Thitsi	*Melanorrhoea usitata*	Anacardiaceae	14	11	2.36	19.72
4	Thadi	*Protium serratum*	Burseraceae	29	13	1.24	17.35
5	Sagat	*Quercus spicata*	Fagaceae	38	11	0.91	16.59
6	Lettok-gyi	*Holarrhena antidysenterica*	Apocynaceae	35	19	0.28	15.60
7	Thitsein	*Terminalia belerica*	Combretaceae	21	11	0.19	9.31
8	Laukya	*Schima khasiana*	Theaceae	3	3	1.26	8.56
9	Zaungbale	*Lagerstroemia villosa*	Lythraceae	19	9	0.20	8.24
10	Sa-tha-nge-ohnauk	*Cratoxylon prunifolium*	Hypericaceae	20	7	0.30	8.22
+ 54	Other			195	144	4.56	117.31
64	Grand total			**502**	**268**	**18.43**	**300**
	% of these 10 species in all trees found in compartment (A)			**61 %**	**54 %**	**75%**	**61%**

Table (6b) Abundance, Frequency, Dominance and IVI of the Species Occurring on the Ridge Top Stand (species IVI ≥ 8)

No	Local Name	Scientific name	Family	Abu.	Freq.	Domi.	IVI
1	**Kyun**	***Tectona grandis***	**Verbenaceae**	**39**	**17**	**5.01**	**39.91**
2	Ye-mein	*Aporosa villosa*	Euphorbiaceae	63	16	1.34	28.23
3	Sagat	*Quercus spicata*	Fagaceae	37	9	1.99	21.99
4	Thitsi	*Melanorrhoea usitata*	Anacardiaceae	19	13	1.54	17.28
5	Zaungbale	*Lagerstroemia villosa*	Lythraceae	26	14	0.84	16.13
6	Lettok-gyi	*Holarrhena antidysenterica*	Apocynaceae	26	12	0.32	12.85
7	Thadi	*Protium serratum*	Burseraceae	20	10	0.61	11.92
8	Panma	*Anneslea fragrans*	Theaceae	9	8	1.27	11.46
9	Kyilan	*Shorea assamica*	Dipterocarpaceae	14	7	0.88	10.42
10	Laukya	*Schima khasiana*	Theaceae	9	7	1.09	10.19
11	Kyetyo-po	*Vitex quinata*	Verbenaceae	12	8	0.70	9.55
12	Thitswele	*Schrebera swietenioides*	Oleaceae	9	5	0.87	8.32
+51	Other			131	110	5.05	101.76
63	**Grand total**			**414**	**236**	**21.51**	**300**
	% of these 12 species in all trees found in compartment (A)			**68 %**	**53 %**	**77 %**	**66 %**

Table (6c) Abundance, Frequencies, Dominance and IVI of the Species Occurring on the North Exposure (species IVI ≥ 8)

No.	Local Name	Scientific Name	Family	Abu.	Freq.	Dom.	IVI
1	Ye-mein	*Aporosa villosa*	Euphorbiaceae	119	22	1.9	36.4
2	Sagat	*Quercus spicata*	Fagaceae	86	17	3.0	34.0
3	Kyilan	*Shorea assamica*	Dipterocarpaceae	51	15	2.1	23.6
4	Thit-ni	*Amoora rohituka*	Meliaceae	74	14	0.9	23.3
5	Gon	*Castaneopsis argyrophylla*	Fagaceae	12	5	2.0	12.8
6	Myaukma-kun-thwe	*Myristica angustifolia*	Myristicaceae	34	9	0.8	12.7
7	Yigat-gyi	*Gardenia coronaria*	Rubiaceae	21	13	0.4	10.3
8	Kyetyo-po	*Vitex quinata*	Verbenaceae	23	12	0.4	10.1
9	Thit-swele	*Schrebera swietenioides*	Oleaceae	14	11	0.7	9.8
10	Thitsi	*Melanorrhoea usitata*	Anacardiaceae	9	6	1.3	9.5
11	Kanyin	*Dipterocarpus alatus*	Dipterocarpaceae	7	3	1.6	9.3
+57	Other			174	123	7.11	108.2
68	Total			**624**	**255**	**22.21**	**300**
	% of these 11 species in all trees found in compartment (A)			**72 %**	**52 %**	**68 %**	**64 %**

5.4. Vertical Stand Structure

5.4.1. Species distribution by height classes

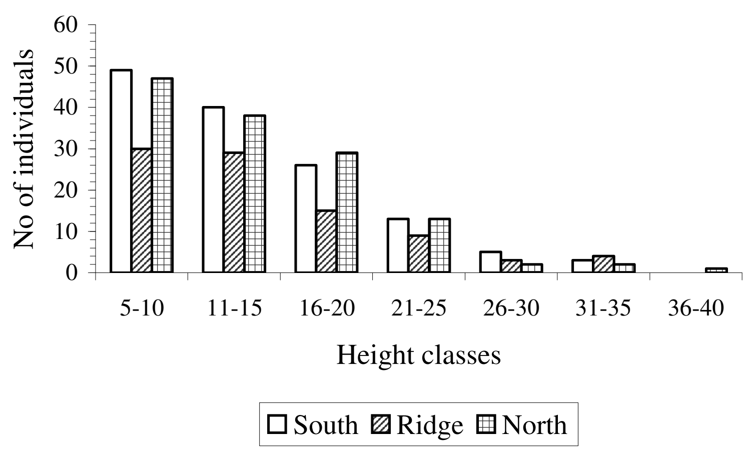


Figure 5: Species distribution by height classes (based on the individuals having a DBH ≥ 5 cm).

5.4.2. Distribution of individuals by height classes

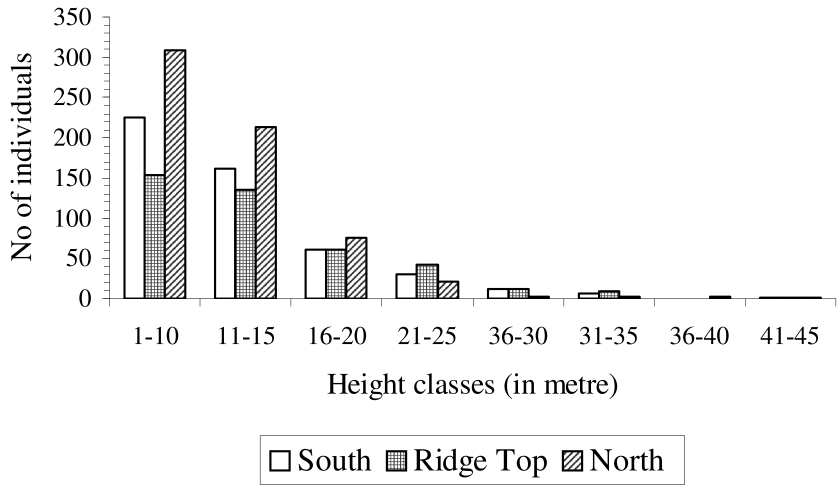


Figure 6: Distribution of individuals by height classes (based on dbh ≥ 5 cm)

5.4.3. Distribution of species by storey

Table (7) Average Individual Numbers Found in Plot (B) Estimated Total Individual Number for 1 ha of the Investigated Stands.

Storey	South Exposure			Ridge top			North exposure		
	%	Est. no/ha	S.D	%	Est. no/ha	S.D	%	Est. no/ha	S.D
MS	2	12	5	-	-	-	6	63	12
LS	98	600	5	100	356	4	94	1037	12

Table (8) Number of Specie Representing in Three Storeys

Storey	South Exposure		Ridge top		North exposure	
	Tree species		Tree species		Tree species	
	No.	%	No.	%	No.	%
US	42	65.7	37	58.7	46	66.7
MS	48	75.0	49	77.8	53	76.8
LS	40	62.5	41	65.1	41	59.4

Table (9) Species Representation in Different Storeys of the Stands Investigated

Site	US+MS+LS		US		US + MS		MS		MS + LS		US + LS		LS	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%
South	21	33	9	14	11	17	12	19	7	11	1	2	3	5
Ridge top	16	25.4	8	12.7	12	19	14	22.2	7	11.1	1	1.6	5	7.9
North	14	20	12	17	20	29	20	29	3	4	0	0	0	0

5.5. Stand Dynamics

5.5.1. Distribution of species and individuals by DBH class

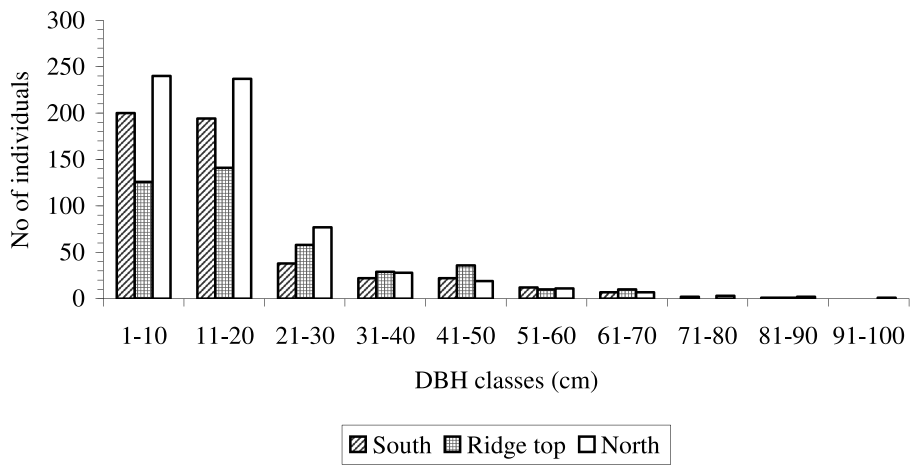


Figure 7: Comparison of distribution of individual by DBH classes, compartment (A) of the investigated stands, 1 ha each (based on the trees with dbh ≥ 5 cm)

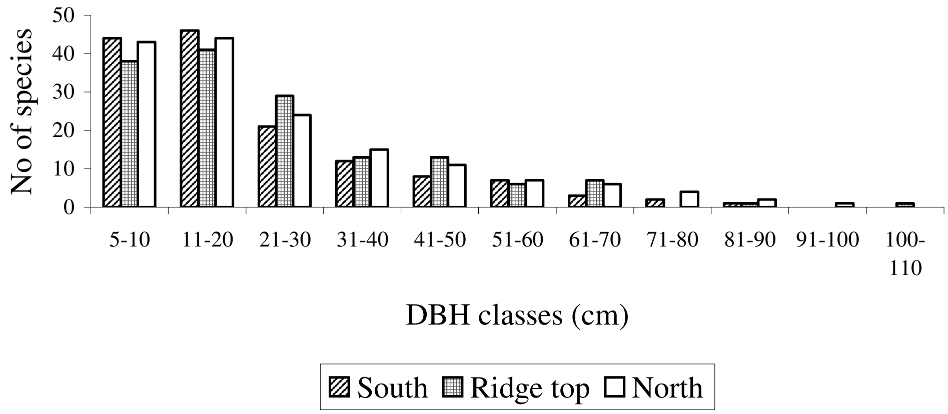


Figure 8: Distribution of species by DBH classes in the investigated stands (based on the individuals with dbh ≥ 5 cm, area 1 ha each).

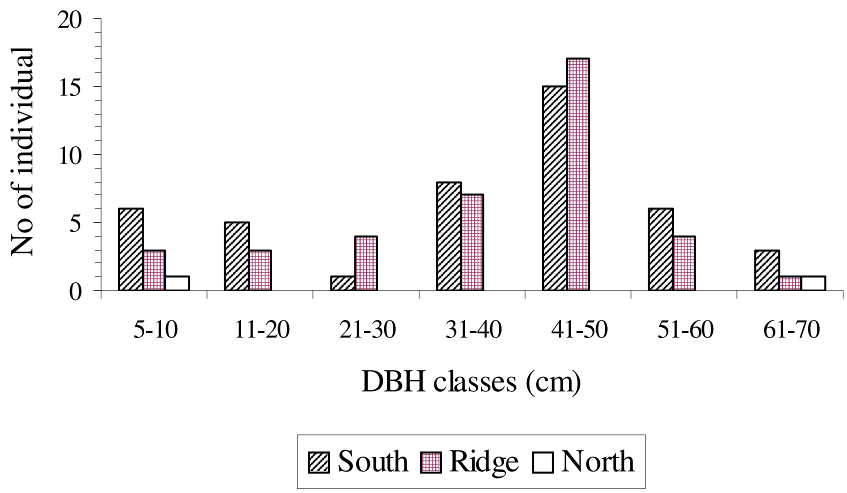


Figure 9: Diameter distribution of teak trees growing in the investigated stands (based on the individuals with dbh ≥ 5 cm, area 1 ha each)

5.5.2. Natural regeneration

5.5.2.1. Abundance and frequency of the natural regeneration

Table (10a) Abundances and Frequencies of Seedlings of South Exposure Stands (species with Rel (Abu + Freq) < 4 are omitted).

No.	Name	Scientific name	Family	Abu.	Freq.	Rel. (Abu+ Freq)
1	Ye-mein	*Aporosa villosa*	Euphorbiaceae	184	67	31.97
2	Lettok-gyi	*Holarrhena antidysenterica*	Apocynaceae	77	38	15.20
3	Taukte-letwa	*Schefflera venulosa*	Araliaceae	85	26	13.86
4	Ondon	*Listaea moupineisis*	Lauraceae	56	28	11.12
5	Nagye	*Pterospermum semisagittatum*	Sterculiaceae	39	21	8.02
6	Thitsi	*Melanorrhoea usitata*	Anacardiaceae	34	20	7.30
7	Thadi	*Protium serratum*	Burseraceae	33	20	7.19
8	Tamalan	*Dalbergia oliveri*	Papilionaceae	35	15	6.52
9	Seiknan	*Phoebe lanceolata*	Lauraceae	23	19	5.93
10	Panma	*Anneslea fragrans*	Theaceae	20	18	5.43
11	Pan-swelwe	*Engelhardia spicata*	Juglandaceae	23	14	5.02
12	Sagat	*Quercus spicata*	Fagaceae	18	14	4.49
+62	Other species			325	228	76.47
74	Grand Total			932	548	200
	Percentage of the above 12 species in the total number in the stand			**65.1**	**58.4**	**61.8**

Table (10b) Abundances and Frequencies of Seedlings of Ridge Top Stands (species with Rel (Abu + Freq) < 4 are omitted

No	Name	Scientific name	Family	Abu	Fre	Rel (abu+fre)
1	Ye-mein	*Aporosa villosa*	Euphorbiaceae	206	68	33.5
2	Lettok-gyi	*Holarrhena antidysenterica*	Apocynaceae	81	47	16.9
3	Thadi	*Protium serratum*	Burseraceae	43	26	9.2
4	Sagat, Thit-e	*Quercus spicata*	Fagaceae	45	24	9.0
5	Tamalan	*Dalbergia oliveri*	Papilionaceae	40	15	6.8
6	Nagye	*Pterospermum semisagittatum*	Sterculiaceae	29	19	6.5
7	Thit-swele	*Schrebera swietenioides*	Oleaceae	35	13	6.0
8	Pan-swelwe	*Engelhardia spicata*	Juglandaceae	31	12	5.4
9	Thitsi	*Melanorrhoea usitata*	Anacardiaceae	23	16	5.3
10	Shaw-ah	*Sterculia coccinea*	Sterculiaceae	38	7	5.1
11	Ondon	*Listaea moupineisis*	Lauraceae	17	16	4.7
12	Seiknan	*Phoebe lanceolata*	Lauraceae	19	13	4.3
13	Kinbalin	*Antidesma velutinum*	Euphorbiaceae	20	12	4.3
14	Thitsein	*Terminalia belerica*	Combretaceae	16	14	4.2
15	Petka	*Clerodendrum petasites*	Verbenaceae	34	3	4.0
16	Panma	*Anneslea fragrans*	Theaceae	17	12	4.0
+62	Other species			298	219	70.9
78	Grand total			992	536	200
	Percentage of the above 16 species in the total number in the stand			**70.0**	**59.1**	**129.1**

Table (10c) Abundances and Frequencies of Seedlings of North Exposure Stands (species with Relative (Abu + Freq) < 4 are omitted.

No	Local Name	Scientific Name	Family	Abu	Freq	Rel (Abu+freq)
1	Ye-mein	*Aporosa villosa*	Euphorbiaceae	242	74	38.61
2	Thit-ni	*Amoora rohituka*	Meliaceae	92	41	17.33
4	Sagat	*Quercus spicata*	Fagaceae	81	33	14.62
3	Kanyin	*Dipterocarpus alatus*	Dipterocarpaceae	85	9	10.06
5	Panma	*Anneslea fragrans*	Theaceae	41	28	9.72
6	Lettok-gyi	*Holarrhena antidysenterica*	Apocynaceae	35	22	7.91
7	Myaukma-kun-thwe	*Myristica angustifolia*	Myristicaceae	43	15	7.24
8	Seiknan	*Phoebe lanceolata*	Lauraceae	26	20	6.63
9	Thitsi	*Melanorrhoea usitata*	Anacardiaceae	27	19	6.52
10	Yigat-gyi	*Gardenia coronaria*	Rubiaceae	21	17	5.53
11	Thit-swele	*Schrebera swietenioides*	Oleaceae	24	15	5.41
12	Kyetyo-po	*Vitex quinata*	Verbenaceae	20	15	5.02
13	Sa-thange-on-hnauk	*Cratoxylon prunifolium*	Hypericaceae	21	10	4.09
+52	Other species			277	168	61.3
65	Grand total			1035	486	200
	Percentage of the above 13 species in the total number in the stand			**73.2**	**65.4**	**69.3**

5.5.3 Frequency distribution of species of natural regeneration

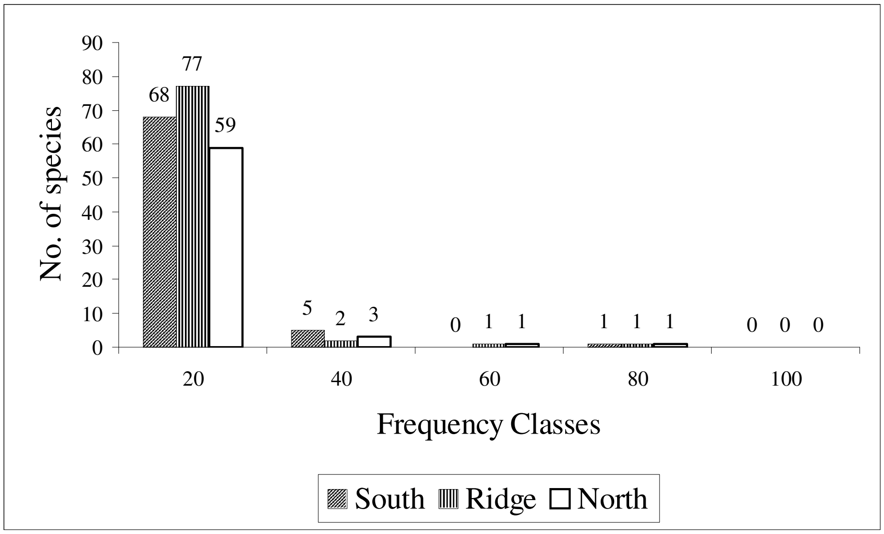
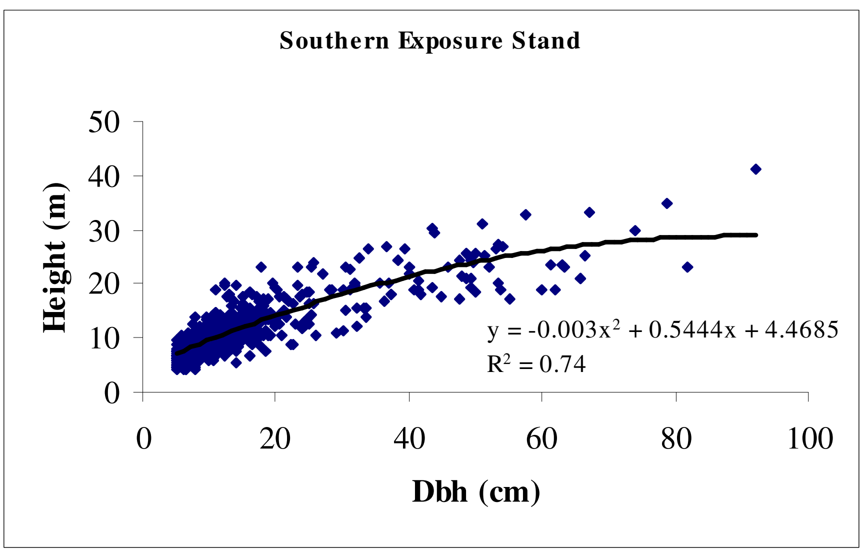
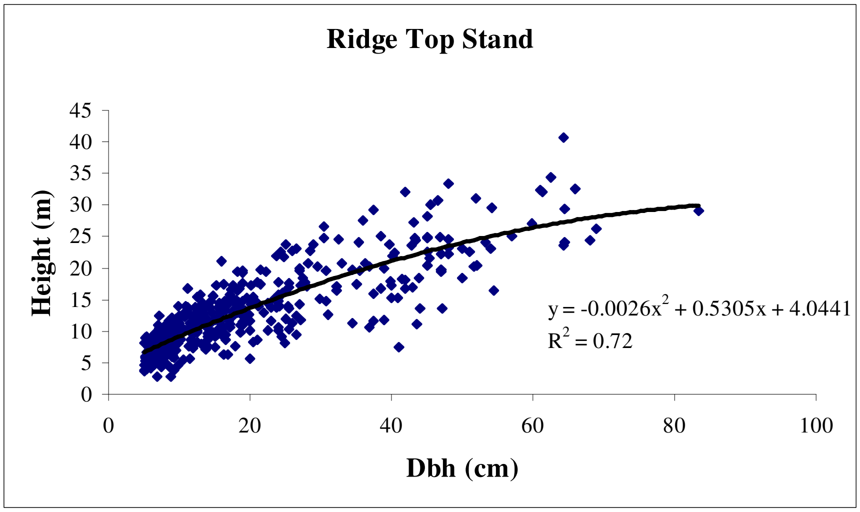
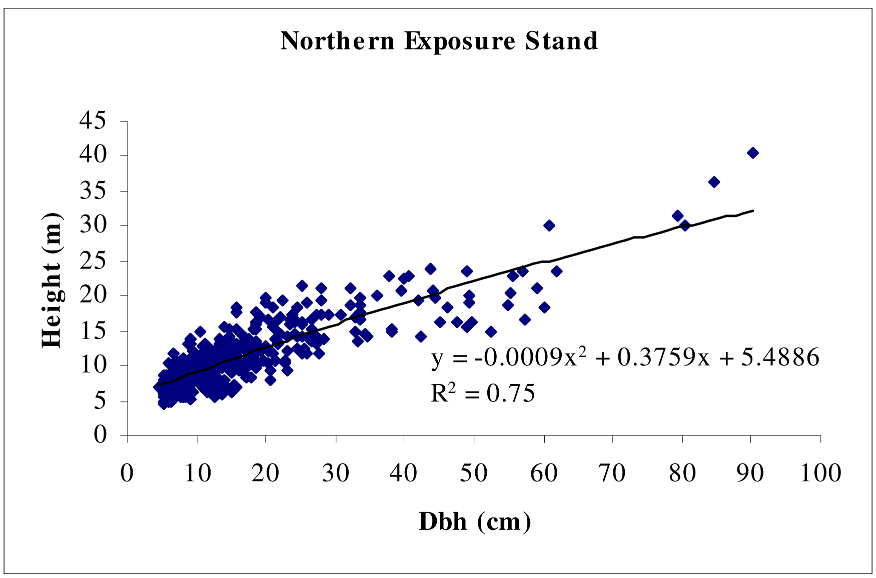


Figure 10: Frequency distribution of natural regeneration of three investigated stands (Compartment C)

5.5.4 Respective height curves of the investigated stands (based on dbh ≥ 5 cm)




Ridge Top Stand
Height (m)
Dbh (cm)
y = -0.0026x2 + 0.5305x + 4.0441
R2 = 0.72
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100


Northern Exposure Stand
Height (m)
Dbh (cm)
y = -0.0009x2 + 0.3759x + 5.4886
R2 = 0.75
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80
90
100

6. DISCUSSION

6.1. Forest Type

The study area consisted of three sites, south and north exposures, and ridge top sites. It was found that forest types on two sites, southern and northern exposures; are different from each other due to their microclimate environments, particularly water availability and thermal regime. Daily fluctuations in growing space follow a general pattern (HELMS, 1965; HODGES, 1967 quoted in OLIVER & LARSON 1996) that varies somewhat depending on the severity of the climate and soil. The lack of light limits growth. Temperature may limit growth on cool sites during the early morning. High evapotranspiration demand (at midday) can cause stomatal closure and temporarily reduce photosynthesis (OLIVER & LARSON 1996). Structure and dynamics of forest (competition of species), vitality, preference of niches, diameter distributions, succession of species, diameter increment are related to plant water potential and plant osmotic potential (MITLÖHNER, 1997).

None of the teak bearing forests of Myanmar are primeval virgin forests. Almost all of them are secondary forests. (BRANDIS 1896). All of them have, to some extent, been affected by man (KERMODE, 1964). The study area is also a secondary forest, according to the questionnaires to local labours about the past history of forest reserved investigated, it was very old teak plantation established in colonial age. It may be true as most of the teak trees are more or less equal in dimension and height, about 80-90 years old according to the annual ring counting made on the stump left because of illicit felling. Secondary forest is primary forest modified by logging, or light shifting cultivation, but which contains a full cover of indigenous tree species (REDHEAD & HALL, 1992). Forest growth has come up naturally after some drastic interference with the previous forest crop.

Climate and soils are determining factors in the formation of different types of forests. According to the classification of tropical forests based on temperature and rainfall, the forest investigated can be classified as a moist deciduous type according to the following conditions.

1. The mean annual rainfall (N_a) is greater than 2 (T_a + 14) cm and less than 5 (T_a + 14) cm; N_a = 1685 mm, T_a = 24.4º C
2. DE MARTONNE's aridity index shows that 5 months fall under 20.
3. According to KERMODE (1964), this is also a moist deciduous type because its characteristic bamboo species of upper Myanmar, Wa-pyu (*Dendrocalamus mem-branaceus*) and Tin-wa (*Cephalostachyum pergracile*) are present abundantly in the study area.
4. According to CHAMPION and SETH (1968) based on the mean annual rainfall the forest type investigated can also be classified into a moist deciduous forest.

6.2. Diversity and Species Richness

MAGURRAN, (1988) stated that diversity is difficult to define because it consists of two components. They are the species richness and the relative abundance of species. The number of species (species richness) and their relative abundance can vary. So the diversity can be measured by recording the number of species, by describing their relative abundance or by using a measure, which combines the two components.

The species diversity measure can be divided into three main categories. These are;

(a) Species richness indices
(b) Species abundance models that describe the distribution of species
abundance
(c) Indices based on the proportional abundance of species, which seek to
crystallize richness and evenness into a single figure.

Here the diversities of the stands are compared by applying MARGALAF's diversity index and MENHINICK's index for species richness and SHANNON and SIMPSON indices for diversities of the stands on both sites.

6.2.1. Diversity indices

Among the many kinds of indices for diversity measurement, SHANNON and SIMPSON indices are widely used for the determination of species diversity: The indices are based on the proportional abundance of species, which seek to crystallize richness and evenness into a single figure. (MAGURRAN loc.cit.). According to WEIDELT (loc.cit.), the SIMPSON index emphasize more the common species while the SHANNON Index place more emphasize on the rare species.

6.2.2. SHANNON - Index (1948/1976)

The index assumes that individuals are randomly sampled from an „indefinitely large,, (that is an effectively infinite) population (PIELOU 1975 quoted in MAGURRAN loc.cit). The index also assumes that all species are represented in the sample. Here the index is applied for comparison of diversities, evenness and differences among the stands investigated.

In table (3), ridge top stand shows the highest in species diversity and southern exposure stand also has nearly same index as compared to that of ridge top stand. North exposure stand is the lowest in both species diversity and species evenness. So it can be assumed that southern exposure and ridge top stands are more homogeneous than north exposure stand. Germination and establishment of species occurring in the study area may have more favourable conditions in those two stands.

6.3. Species Richness

Species richness measures also have to be considered as a measure of diversity because it can provide an instantaneous comprehensive expression of diversity. Species richness indices are essentially a measure of the number of species in a defined sampling unit. (MAGURRAN loc.cit.) It can also be termed species density, which is the number of species per collection area (HURLBERT, 1971 quoted in MAGURRAN loc.cit.). Species richness can be measured by using MARGALEF's diversity index (CLIFFORD & STEPHENSON 1975 quoted in MAGURRAN loc.cit.). The values of the indices decrease with increasing of the number of individuals indicating that they are largely dependant on the number of species.

Table (4) indicated that the forest type on the ridge top site can be said the highest in species richness by MARGALEF's diversity index and the second position by MENHINICK's diversity index.

6.3.1. Species area relation

The species area curves of the investigated stands are shown in the figures. The species area curves, which express the numbers of species in relation to the sizes of the area censused constructed to determine the rate of at which species number changes with change in area of habitat (CECO quoted in U SAW HAN, 1997), are the best criterion for the determination of the minimum study area. According to CAIN and OLIVEIRA CASTRO (quoted in LAMPRECHT, 1986), the minimum representative area is considered to have been reached when the increase in the number of species per unit area remains below 10% with a 10% expansion of the sample plot. It is usually sufficient to survey the stocks with dbh ≥ 10 cm for plotting specie/area curves. But for analysis of stand structures and dynamic processes, smaller trees including young trees are also required (LAMPRECHT, 1986).

It is conspicuous that the compartment (A) of the north exposure has higher species numbers as compared to that of the ridge tops and south exposure. The newly encountered species fall under 10% and the course of curves run similarly for whole of three plots. The total number of species was 69 in the compartment (A) of the north exposure and 65 and while it is 63 in those of the ridge top and south exposure respectively.

Figure (10) shows that about 40% ,48% 38% of the total species are already contained and represented in the first four plots (1,600 m^2) of the stands of southern exposure, ridge top, and northern exposure respectively. The numbers of newly encountered species were getting more and it was found that 68% of the total surveyed area represented about 94%, 86% and 91% of the total species recorded in the stands of southern exposure, ridge top, and northern exposure respectively. With increasing sample plot area, the newly encountered species were much less than 10% of the total. Therefore the sample area can be said to be sufficient as a minimum representative area for the study. All species area curves run asymptotically.

6.3.2. Coefficient of similarity

To calculate coefficient of similarity among the stands floristically and their structural similarities have to be taken into account for the comparison of three investigated stands. It is because these three stands exist in the same area. However, the different types show a difference with moisture content, which can easily be observed. The index is used as a means for comparing the floristic similarity between two forests. In this way, the coefficient of similarity proposed by SÖRENSEN (1948) (quoted in WEIDELT loc.cit.) can be used for the species comparison.

This index can lead to the considerable distortion in calculating the similarity because it is only based on presence or absence of species. Since the present work mainly concerns the comparison of floristic composition the formula can be used with advantages. Here, it was found that the representative species were not so different from each other, but the structures were different depending on the dominance of the high abundant species. Therefore WEIDELT (1968) proposed a correction for the silvicultural purpose by using the dominance of the species in place of number of species. The corrected formula is as follows;

The high coefficient of similarity value given by SÖRENSEN shows that the investigated stands of ridge top and southern exposure are more or less similar in species composition (67.7%), 69.2 in species dominance and 72.2% in individuals. It may be because the two sites are not so far from each other and of the same macroclimate and similar ecopedological conditions. So more or less the same silvicultural treatment or system could be adopted for those two sites. Economically important light demanding species should be introduced in those two sites.

As threes investigated stands are situated in a long ridge of the same area, they are more or less similar in species composition. Northern exposure stand and southern exposure stand are **66.2%** species composition and **67.7%** in northern exposure and ridge top stands. But in case of common individuals, **47.6%** in the former and **75.2%** in the latter.

According to indices modified by WEIDELT (1968), the values are much less than the former one given by SÖRENSEN. So it can be said that the structures of the investigated stands are different from each other. It could also be the result of difference in the human intervention on the ridge one. The indices given by BRAY and CURTIS also show the same tendency of the indices of WEIDELT. The last two indices, which are based on the dominance and abundance of the species, should be taken into consideration to adopt silvicultural treatment because a species can become established and reach its optimum growth only if the climatic and soil condition of a particular site are favorable.

If all trees were only used to calculate the similarity between two stands, the values obtained by SÖRENSEN get less and the similarity index comes to be 54%. Therefore it can be said that all of the well-established species (i.e. DBH ≥ 10 cm) of both sites are only of a little similarity to each other. The index given by BRAY and

CURTIS shows higher value as compared to the same index based on all trees (height ≥ 1.3 m). It is because the common species with their respective trees with DBH ≥ 10 cm are not quite different like the index based on the trees with height ≥ 1.3 m. According to the index modified by WEIDELT, the stands are different from each other as this index is based on the smaller dominance numbers of common species. There are two reasons for the difference and they are;

1. different growth rate of a species on different sites due to its water availability and,
2. site sensitivity of the species due to different soil conditions.

6.4. Stand Structure

6.4.1. Horizontal stand structure

6.4.1.1. Species distribution by frequency classes

Figure shows the distribution of species by frequency classes in the investigated stands. The absolute frequency of a species is the percentage of the sample plots, in which it occurs, by the total number of sample plots. Frequency class **I** represents for the species that have frequency value below 20, class **II** is for the frequency value between 21 to 40, class **III** is between 41-60 and so on. High values in classes **I/II** indicate a high degree of floristic heterogeneity (LAMPRECHT loc.cit.)

The frequencies give an approximate indication of the homogeneity of a stand. Figures with high values in frequency classes **IV/V** and low frequency values in **I/II** indicate constant or similar trees species composition over the whole area. In the figure, most of the species found in compartment (A) occur in the frequency class **I** and it amounts to 78% (50 species) in the southern exposure, 79% (50 species) in the ridge top type and 83% (57 species) in the northern exposure

In the stand on the **southern exposure**, species with highest frequency values (IV and V) are Lettok-gyi (*Holarrhena antidysenterica*), Kyun (*Tectona grandis*) and Ye-mein (*Aporosa villosa*). On the **ridge top site**, the most frequent species are also Kyun (*Tectona grandis*) and Ye-mein (*Aporosa villosa*). The most occurrence species by ascending rank flourishing in the stand on the **northern exposure** are Kyilan (*Shorea assamica*), Sagat (*Quercus spicata*), Thit-ni (*Amoora rohituka*) and Ye-mein (*Aporosa villosa*).

As already described, stands on the southern exposure and ridge top were very old teak plantation established in more than 80 years ago. For that reason, its frequencies in the respective stands were observed in highest values as compared to that of northern exposure. On the other side, it could be assumed that teak was not artificially regenerated on the northern exposure on account of the following two reasons;

1. The slope is too steep (30º-40º, and sometime more than 40º) for teak to regenerate artificially and,
2. Teak, a light demander, could encounter difficulty for the regeneration establishment in competition with other shade bearers under the shade of the ridge, running in almost east-west direction.

6.4.1.2.Dominance, abundance and frequency

The absolute abundance is the number of individuals per species. The relative abundance is a percentage of each species of the total stem number. Frequency is the occurrence, or absence, of a given species in a subplot. Absolute frequency is expressed as a percentage. The relative frequency of a species is calculated as a percentage of the total of the absolute frequencies of all the species.

Dominance is "**the degree of coverage**" of a species as an expression of the space it occupies. The sum of the individual stem basal area in m^2 is referred to as the absolute dominance of a species. Relative dominance is the percentage of a given species of the total measured stem basal area.

The importance value index (IVI) developed by CURTIS and MCINTOSH (1951) is calculated for each species and is defined as the sum of relative abundance, relative frequency and relative dominance. The ecological significance of a species can be compared by IVI in a given forest type (LAMPRECHT loc.cit.). The values obtained are shown in the tables. The species are ranked by their IVI value. The species with IVI values less than 8 are omitted

Species of high IVI value in a given area can also be considered as representative species of a forest type studied and they should be taken into account ecologically important species in reforestation operations. In the study area, teak stands at the highest IVI value in the stands of southern exposure and ridge top. Other species having higher IVI values **shown in the table 6a, 6b and 6c** can be regarded as associates of teak in the study area. When we try to adopt proper natural forest management and silvicultural systems for teak bearing forests flourishing in different localities with different flouristic compositions, silvicultural characteristics of teak associates should be taken into account for the well being of teak, consequently so as to obtain optimum benefit from those forests. No doubt that there is a good correlation between abundance and frequency since in the table 9a, 9b and 9c high individuals number of species are mostly with high frequency values in all investigated stands.

In the study area, teak associates are different from those found in the Pegu Yoma area. On the southern exposure, teak stands at the first place in the rank of IVI values and its associates are of no economic importance. 10 species including teak occupy 61% of total number of trees (dbh ≥ 5 cm), 54 % of total frequencies and 75 % of the dominance. It shows that though our forests are diverse in species composition, only about 15-20 % of the species are dominant and they form a particular forest type and therefore we should bear in mind ecological importance of associates of our desirable species if we wish to achieve optimum benefits from them.

Forest canopy of this stand is already open, and with total basal area of 18.43m^2. Other economically not important species were found in higher number individually as compared to those of teak and other valuable species. In such forest, gap planting, line planting or any methods of enrichment planting of teak need to be carried out followed by intensive tending operations. The forest essentially needs to be protected from any kind of extraction to ensure sustainable productivity.

In the table (9b) the most dominant species of ridge top stand show that 12 species make up 68 % of the total individuals, 53 % of the total frequency and even 77 % of the total basal area of the stand. Teak stands in the first place in the rank of IVI values, but it 9.2 % of the total number of trees. Other species having highest IVI values are of no economic importance. The highest IVI species of south exposure stand and ridge top stand are generally similar as 8 species are common in both stands. They are Kyun, Ye-mein, Thitsi, Thadi, Sagat, Lettok-gyi, Laukya and Zaungbale. So silvicultural treatments to be given for these two types of forests should be more or less the same from the aspect of economical considerations.

These areas are already opened and may be of favourable conditions for regeneration of light demander species (e.g., teak). Teak plantation establishment was abandoned in the study area and its neighboring areas on account of bee-hole borers attack. Instead, gap planting or line planting not only to enrich the forest with valuable species but also to fulfill the socio-economic needs of the local people and of the country as well instead of planting other less valuable species.

Padauk (*Pterocarpus macrocarpus*, Papilionaceae) should also be tried to be introduced in this area though there is no trace of this species because it grows well on the ridge top site on the Ngalaik area (Than Soe Oo, 2000). If this species would be enriched in these forest types with line planting, close spacing with narrow line width should be applied to avoid heavy branching. For line planting or any kind of enrichment methods, follow up tending operations are very essential and should never be lost sight of.

Species with high IVI values of north exposure stand are shown in the table 6c, Kyilan, Thit-ni, Gon, Myauk-ma-kun-thwe, Yingat-gyi and Kanyin are those which are low in IVI values or a few are very rare or missing in the stands growing on the southern exposure and ridge top sites. So structure and composition of the stand of north exposure can be generally assumed different from those of other two stands. Economically most important species are very rare in this stand. In this stand, species with high IVI values seem to be shade tolerant and can regenerate and establish under the dense overhead. Cooler aspect and steep gradient may be great obstacles for the regeneration and establishment of light demanding species.

If such forests are to be enriched with economically important species, in other words, if they are to be upgraded into economically important forest cum ecological considerations, the only recourse is to adopt appropriate enrichment methods with valuable shade bearing species. Pyinkado should be taken into account in this aspect with suitable line width, as there is evidence of well-established Pyinkado plantations in the study region. For this reason Pyinkado could easily adapt to the environmental conditions of the study region and it should be tried for enrichment planting in the stand of northern exposure.

6.4.2. Vertical stand structure

6.4.2.1. Species distribution by height classes

The figure (5) shows that most of the species found in all investigated stands are in lower height classes, below 10 m and 11-15 m. Distribution of species decreases with increasing height classes. There are no trees higher than 35 m in the stand on ridge top and species reaching height class (31-35) are Gwe (*Spondias pinnata*), Kyilan (*Shorea assamica*), Sagat (*Quercus spicata*) and Panma (*Anneslea fragrans*). On the southern exposure, species reaching this height classes and above are teak (*Tectona grandis*), Gon (*Castaneopsis argyrophylla*), Thitsi (*Melanorrhoea usitata*) and Laukya (*Schima khasiana*). In the stand of the northern exposure Taw-thayet (*Mangifera caloneura*), Kyilan (*Shorea assamica*), Thitsi (*Melanorrhoea usitata*) and Kanyin (*Diptero-carpus alatus*) were found to be in the highest height classes.

Ka-nyin (*Dipterocarpus alatus*) was found only in the stand on the northern exposure and its growth in height and dimension are the highest and the largest as compared to the others. So it can be assumed that the forest type on the northern exposure is gradually changing to semi-evergreen on account of moister exposure though the investigated area fall under the MUMD due to its climatic condition and elevation.

In this figure above, it is obvious that though there are 64, 63 and 69 species in the stands of southern exposure, ridge top and northern exposure have respectively, only 16 (25%), 12 (19%) and 15 (22%) species of the respective stands reaching height of 20 m and above. In the natural forest, tree species compete vigorously for their survival and existence, and only few species can reach in the higher strata. It depends not only on growth characteristic of a species but also on the ecological niche on which it grows.

6.4.2.2. Distribution of individuals by height classes

The figure (6) represents the distribution of individuals by height classes and it shows that the individuals of three investigated stands decrease with increasing height classes. As all the study sites are situated on the sloping ground, height growth of the trees growing in the area is found to be relatively low as compared to those on the flat plain of the Ngalaik Reserved Forest. Heights of the trees above 25 m are rare, 3.8% in south exposure, 4.1% in ridge top and 1.1% in north exposure respectively.

The individuals of all stands investigated are concentrated in the lowest height classes i.e., > 10 m and 11-15 m classes. In fact they make up more than 75% of the total number (dbh ≥ 5 cm), 77.9% of the stand on the southern exposure, 78.3% of the ridge top stand and 83.5% of the northern exposure respectively. From the silvicultural point of view, this may be on account of lower water storage ability i.e., there may be difficulties for tree species of upper slopes and ridge to store water received for a long enough period in the growing season. It depends not only on the amount of rainfall but also on the rainfall pattern, and on how dense is the upper canopy.

Teak

As already described, southern exposure and ridge top sites were old teak plantation established in the colonial age and height distribution of teak trees was found to be concentrated in the higher height classes (see figure 6) and the pattern shows abnormality (i.e., contrast from the reversed J shape). Here we should take into consideration the dynamic of teak tree compared with that of natural teak bearing forest so as to realize current situation of dynamic of teak, and consequently to find out a proper treatment for those forests. In this way the optimum benefit from those forests could be gained in the long run.

6.4.2.3.Distribution of species by storey

Though all of the woody species are recorded in the compartment A, B and C, some are small trees that can be mostly found in the lower stratum and rare in higher one. The IUFRO classification (LEIBUNGUT 1958 quoted in WEIDELT) is used to distinguish the vertical structure of the investigated stands by the following categories.

Upper storey (US)	=	tree height > 2/3 of the top height
Middle storey (MS)	=	2/3 of the top height >tree height >1/3 of the top height
Lower storey (LS)	=	tree height < 1/3 of the top height

Top height is here obtained from the average height of the 20% thickest trees of each stand. The top heights of the stands on the southern exposure, ridge top and northern exposure are 21.6 m, 23.6 m and 17.4 m respectively. Therefore the heights of the different storeys of three stands become as shown in the table.

Table (10) The Respective Heights of the Investigated Stands

Storey	Southern exposure	Ridge top	Northern exposure
Upper storey (US)	Tree height > 14.4m	Tree height > 15.7m	Tree height > 11.6m
Middle storey (MS)	7.2 m< tree height < 14.4 m	7.9 m< tree height < 15.7 m	5.8 m<tree height < 11.6 m
Lower storey (LS)	Tree height < 7.2 m	Tree height < 7.9 m	Tree height < 5.8 m

Since differentiation of storey heights is based on the 20% thickest trees of all trees found in compartment (A), top height of a stand having more percent of big trees will be higher than that of other stand though both have more or less the same basal area. In this study it can be noticed that top height of ridge top stand has 23.6 m with basal area of 21.5 m^2 and stand on northern exposure has 17.4 m top height and 22.6 m^2 basal area.

In the area, most of the species were found represented in all three storeys and the middle storey of the all stands investigated were observed with the highest number of species and the upper storeys with the lowest number. This may be due to the sampling design adopted i.e., analysis here is mainly concerned with individuals found in the plot (A), in which trees (dbh ≥ 5 cm) were recorded. Nonetheless, trees with dbh ≥ 10 cm are considered as already established in structural analysis of forests. Therefore, under this limit, it can be considered as not very important for this purpose.

Table (13) Number of Specie Representing in Three Storeys

Storey	South Exposure		Ridge top		North exposure	
	Tree species		Tree species		Tree species	
	No.	%	No.	%	No.	%
US	42	65.7	37	58.7	46	66.7
MS	48	75.0	49	77.8	53	76.8
LS	40	62.5	41	65.1	41	59.4

Although it was found that there are more or less equal number of species in all the three different storeys in all stands: some are only in the upper storey, some are in the upper and lower storey and absent in the middle storey and some are only in the lower storey and so on. Their distributions are shown in the table below.

Table (14) Species Representation in Different Storeys of the Stands Investigated

Site	US+MS+LS		US		US + MS		MS		MS + LS		US + LS		LS	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%
South	21	33	9	14	11	17	12	19	7	11	1	2	3	5
Ridge top	16	25.4	8	12.7	12	19	14	22.2	7	11.1	1	1.6	5	7.9
North	14	20	12	17	20	29	20	29	3	4	0	0	0	0

Here, more than 20% of the species growing in the stands investigated are represented in every storeys: these are termed as species with the *regular vertical distribution*. Others are causal. Stand on the southern exposure has the highest number of species with the *regular vertical distribution*. Open canopy with enough light condition of south aspect could give favourable condition for the occurrences and development of the light demanding tree species. In that stand it can be seen that there are representative species in all classes. Ridge top stand also has the same tendency as of the former.

The stand on the northern exposure shows that only 20% of the species are represented in the upper, middle and lower storeys and some of the species found in the upper storey are with no saplings and there are no tree species found in the lower storey. It shows that moist and limited light conditions of the north exposure make it difficult in introducing of new species and if so there could be severe competitions for their establishment. In the table 6c, it can be seen that eight species of high IVI values occupy 69.9 % of the total number of trees. If we want to enrich this type of forest, there will be enough light condition. Species selected for this purpose should be valuable shade demander (e.g. Pyinkado) and even for this it is essential to create enough light condition and growing space.

But it has to be taken into consideration that natural occurrence of Pyinkado is absent in the study area and potential Pyinkado plantations were observed in the neighborhoods. Fire protection is strongly needed for this species on the ridge top and south aspect. For this reason, if we want to enrich forests in the study area and its neighboring areas, teak and Padauk (no traces in the study area) should be tried in the south (or south-westerly) aspect and on along the ridge top site. Pyinkado should be tried in the east or north-easterly aspects with the patches having sufficient light conditions. In this study, it can be noticed that there are no valuable species (light demanders or shade bearers) in the stand on the northern exposure.

If we want to richly endow our natural forests with valuable species on one side and maintain their nature of high species heterogeneity on the other, the only recourse to take is to conduct enrichment planting with proper methods for a particular species by creating suitable conditions for it.

6.4.3. Stand dynamics

6.4.3.1. Distribution of species and individuals by DBH class

All of the species growing in an area have severe competitions for light, space, and for their survival for existences. For this reason, some are dead, suppressed and checked in growth rate, while some other have the favourable conditions required to reach large dimension in size. One that cannot adapt itself to available environmental conditions of an area will gradually disappear from this area. Species can therefore be investigated by its horizontal distribution of individuals whether it can adapt to its environment or not. In investigating the diameter distribution of individuals in the study area, it can clearly be seen that there are most number of trees in small diameter classes in all investigated stands as shown in the figure 7. The reserve of small-diameter trees in moist tropical forests is in any case adequate to replace the losses in large diameter trees. Natural sustained yield is therefore evidently completely assured (LAMPRECHT loc.cit).

As LAMPRECHT stated on diameter distribution of moist tropical forests as described above, our natural forests also show that the most number trees are accumulated in the small diameter classes. In fact these classes make up 79.1% in the stand on south exposure, 64.8% in ridge top stand and 76.3% in northern exposure, number of trees in all stands decrease with increasing diameter classes. So there is no doubt on the dynamic of our forests that they will fill up the losses of big trees because of regular extraction (i.e., Myanmar Selection System of 30 year felling cycle). Nonetheless one has to taken into consideration on what our desirable valuable species will have different species with different demand upon site, growing space; soil and other factors for their establishment and whether it could successfully regenerate or not up to the stage of establishment.

Therefore it is important to examine the species distribution of a stand by their respective diameter classes. This distribution of all stands investigated is illustrated in the figure (8).

In figure (8), it can clearly be seen that though there are numerous species flourishing in the investigated stand, only a small number of species can reach to the lager diameter classes. Actually, there are 7 species (11% of the total) in the south aspect stand, 6 species (10% of the total) in ridge top stand and 7 species (10% of the total) in the stand on northern exposure which are standing in the respective stands with the representative individuals having dbh $\geq$ 50 cm and above. It is evident that tree species occurring in the forest stands are extremely difficult to reach maximum dimensions in the forest. To examine the economic and ecological potential of teak, it needs to know how its individuals distribute in the stands investigated and it was observed that the distribution is in the pattern of abnormality as described in the figure (9).

As already stated, the areas investigated on the southern and ridge top sites were old teak plantation established in the colonial age. Therefore, the age of plantation is about or older than 55 years (may be more) at the time of data collection. As a result, the distribution pattern of teak does not follow the normal distribution. Nonetheless one point to be deliberated is the abundance and frequency of its younger individuals (saplings) or small diameter classes' trees which were observed in unsatisfactory situation. In the current situation, the canopies of both stands on the southern exposure and ridge top are already open, and so the question encountered is why its advanced growth are extremely low as compared to those of others.

KEH (1995 quoted in THAN SOE OO, 2000) pointed out that the regeneration of teak does not follows the normal distribution pattern in two of the reserved forests of Pegu Yoma areas, North Zamayi and South Zamayi. WEIDELT 1991 (quoted in THAN SOE OO, 2000) also stated that the problem of the capacity for self-renewal through natural regeneration of commercial species, in which he pointed out the diameter frequency curves for the total stand might give the impression that there are plenty of small-sized trees left to provide new growth; but detailed analysis reveals that, there is a dearth of small diameter trees in many economically important species with light requirements.

In this case, we should bear in mind that the future of teak though it is fire-hardy species it needs intensive cares whether in plantations or in natural forests if we want our forests to be enriched with valuable teak trees for sustainable purposes. Another point to be considered is whether we should regard our valuable teak plantations as a natural forest in which we have already invested much time and money. It is because of the fact that as we can give more intensive cares to the plantation than the natural forests, consequently we can achieve much more economic outturn.

6.4.3.2.Natural regeneration

The natural regeneration of the stands growing on the different topographic conditions were surveyed in the compartment (C) by enumerating of the seedlings having the heights of ≥ 30 cm and < 130 cm. The total representative area was 1600 m^2, 16% of the total sample plot area of each stand. The occurrence of regeneration is dependent on numerous prerequisites, which may vary greatly from species to species, but the following factors are in any case indispensable LAMPRECHT (1986).

1. A sufficient volume of viable seeds
2. Appropriate climatic and edaphic conditions for germination and establishment

The presence of seedlings does not mean that natural regeneration is established it may be only ephemeral. It is necessary to consider the ratio and kind of species, which have already reached the dbh above 5 cm in some of their competition for establishment (WEIDELT, 1998). In the present study, it is found that there are 74 woody species with 933 seedlings in the south exposure stand, 78 woody species with 989 seedlings in the ridge top stand and 65 species with 1035 seedlings in the respective study area of 1600 m^2 of compartment (C). Here we can generally know that there may be difficulties for tree species to introduce themselves in moister type of northern exposure as it has smallest number of species and largest number of seedlings as compared to those of other two stands. The abundances and frequencies of seedlings found in the plot (C) are shown in the table described below and they are ranked by the sum of relative abundance and relative frequency as they occurred.

6.4.3.2.1. Abundance and frequency of the natural regeneration

In table 10a, species found in the south exposure stand are described with the respective abundances and frequencies. South exposure, which suffers higher temperature as compared to north one, the microclimatic conditions will be more favourable for the species of strong light demanders and more hardy species as well (e.g. teak). Nonetheless, natural regeneration of teak is found to be very unsatisfactory under its relatively abundant seed bearers i.e., it has been already described before that southern exposure stand and ridge top stand were old teak plantations. The abundance and frequency of teak is as shown below.

Abundance	Frequency	Rel. abundance	Rel frequency	Rel (Abundance + frequency)
6	5	0.64	0.91	1.6

One issue to be taken into consideration is whether germination and establishment of teak have probably long been encountering difficulties under the dense growth of bamboo clumps in the stand and thicket of Bizat (*Chromolaena odoratum*) in the opening areas or the shade of its mother trees (most of the teak trees in the southern aspect and ridge top are in the upper canopy) is hampering its regeneration and establishment.

HAIG *et.al* 1958 (quoted in GYI, M. K.K, 1993) stated that sometimes germination can be less than 15 per cent even under favourable conditions. Moreover, seedlings mortality is also high in the natural forest. G. KUMURAVELU, (1993) also described restraints of teak germination and establishment in the forests of India, in which it grows. Two of these are:

(1) The forest floor under a natural teak forest is always covered by a dense mantle of herbaceous and grass growth that prevent the germinating teak seedlings from touching the mineral soil.

(2) Establishment of teak seedling is governed by light factor: in moist localities, seedlings require light from their infancy; but in dry hot regions, a sudden influx of light on young seedlings proves fatal.

It shows that intensive cultural operations as improvement felling are essentially required for teak for its successful establishment in a forest stand in which it must compete severely with the other (most of them are to date economically not important). Also its occurrence in the ridge top stand shows the similar pattern with low abundance and frequency as described below.

Abundance	Frequency	Rel. abundance	Rel frequency	Rel (Abundance + frequency)
10	9	1.01	1.68	3

Anyway, it has to thrive to enrich our natural forests with the desired valuable species viewed from an economical point in one hand and at the same time not to diminish other lesser-used species as viewed from the ecological point in other. Researches on natural distribution pattern of teak and its sustainability are urgently needed to acquire the optimum benefit from it so as to avoid any misgivings to our valuable teak bearing forests.

The abundances and frequencies of seedlings (having relative abundance + frequency > 4) found in the stand on the northern exposure are shown in the table 10c. Due to cooler aspect and steeper gradient seemingly having different microclimatic condition from those of two other sites and in consequence, formation of forest type is gradually changing to the semi-evergreen one. In regard to this situation, CHAMPION, H.G and SETH, S.K (1968) also advocated that, in hilly country the factors of topography that exert most influence on vegetation are aspect and gradient. In the main, they are reflected in the variations caused in the altitudinal limits of species and vegetation types, the latter appearing to express the integration of many climatic variables.

These conditions seem to provide favourable conditions for regeneration of tender species with shade bearing characters as among the most abundant and frequent species of north exposure stand, five species which are relatively low in abundances and frequencies in both stands growing on the southern exposure and ridge top. These are Thit-ni (*Amoora rohituka*, Meliaceae), Kanyin (*Dipterocarpus alatus*, Dipterocarpaceae), Myauk-ma-kun-thwe (*Myristica angustrifolia*, Myristicaceae), Yingat-gyi (*Gardenia coronaria*, Rubiaceae), Kyetyo-po (*Vitex quinata*, Verbenaceae), and Sa-thange-on-hnauk (*Cratoxylon prunifolium*, Hypericaceae). In this stand, 17.2% (11 species) make up 73.2% of the total number of seedlings and 65.4% of the total frequencies. As compared to the total number of species found in the compartment (C), north exposure stand is with the lowest number, 64, then south exposure has 74 and ridge top, 81 respectively.

In all investigated stands, seedlings some species were found with high abundance and frequency (i.e., Relative abundance plus relative frequency ≥ 4). These are:

1. Ye-mein	*Aporosa villosa*	Euphorbiaceae
2. Lettok-gyi	*Holarrhena antidysenterica*	Apocynaceae
3. Thitsi	*Melanorrhoea usitata*	Anacardiaceae
4. Seiknan	*Phoebe lanceolata*	Lauraceae
5. Panma	*Anneslea fragrans*	Theaceae
6. Sagat	*Quercus spicata*	Fagaceae

Not only natural regeneration but also established trees in the compartment (A) these six species were found with relative higher IVI values. Among these, economically important species are noticeably lacking; for these reason proper silvicultural practices for them have to be urgently find out with the objectives conveying both economical and ecological approaches.

DAWKINS, H.C. & PHILIP, M.S. (1998) pointed out that the criteria of success in Tropical Moist Forest Silviculture include maintaining the:

- productivity of the site, including soil fertility, hydrological stability and the productivity of the forest biome for timber and other needs of humans;
- level of biodiversity, if not completely unchanged, then at least substantially so compared with other forms of trees cover such as plantations of one or few species.

6.4.3.2.2. Frequency distribution of species of natural regeneration

When the succession and prospect of a natural forest want to be evaluated for the future and how homogeneous a forest type is, it also needs to examine its various seedlings growing on the forest floor in quantity and their respective frequency. By looking at the frequency distribution diagram of the forest, it can be generally said which forest is more homogeneous or heterogeneous by comparing their respective distribution. Frequency distributions of natural regeneration of three stands investigated are shown in the diagram shown below.

In figure (10) described above, most species of all stands found in the compartment (C) concentrate in the lowest frequency class and species number drastically fall down in the second up to the fourth and no species are found in the highest class. According to their frequency distribution, ridge top stand made the highest in heterogeneity, south exposure stand stood in the second and the northern exposure the last.

It is because ridge top stand possesses the highest number of naturally regenerated species, 74 species, and 95% (77 species) is in the lowest class; south exposure stand having 74 species and 92% (68 species) in this class and meanwhile the north exposure stand only with 64 species and 59 species (also 92%) in the same class. It shows that germination and establishment of the species essentially require sufficient light, enough growing space for their development as some of the species growing on the northern aspect are in patches (e.g., Kanyin (*Dipterocarpus alatus,* Dipterocarpaceae) was observed with 85 individuals but frequency 8). Again species having highest value in the sum of relative abundances and frequencies take up 65.4 % of the total frequency whilst the stands of southern exposure and ridge top make up 58.4 % and 56.3% respectively. In table (3) Shannon Index and Evenness show that the indices (based on the trees with dbh ≥ 5 cm) of north exposure stand is the lowest 3.08 and 72.76 respectively.

7. CONCLUSION

As already stated and discussed, formation of different types of forest are mainly dependent on the physical units of sites on which they grow. Silvicultural treatments given to a particular forest should be based on the silvicultural parameters of these forest types. The blanket silvicultural system has to be avoided to obtain optimum benefit conveying both economic outturns and conservation of existing ecological situations. Before a silvicultural system is adopted for a forest, diagnosis sampling survey should be carried out in this forest, which should lead to the adoption of a system with the most proper means and suitable means and ways of silvicultural treatment because of long-term investments in time and money.

Forest stands investigated are found to be satisfactory in vegetation cover, but are scanty in term of economic important species. To conserve it natural species composition on one hand and to change these forest stand into a more valuable one from the economic aspect, enrichment planting with suitable species such as teak, Pyinkado, Padauk, Tamalan, etc., should be tried in suitable sites to achieve economic benefit in the long run. Though there are less number of trees per unit area in enrichment planting as compared to plantations, the internal microclimate and soil protection is at least partially preserved by the initial growing stocks.

Forest needs to be effectively managed; Silviculture is the prime tool of effective forest management. It is critical to realize the dynamics of forest, especially those of the economically most important species. To examine how forests are changing and to give proper silvicultural treatments, there is a need to establish permanent sample plots in the natural forests with regular interval assessments. By comparing coefficients of similarity between forests types, the most appropriate method best suited to a particular forest type has to be applied with some long-term economic consideration.

The study indicated that tree species that want not to be extracted by Myanmar Timber Enterprise (MTE) are most abundant in the forest (e.g. Yemein. *Aporosa villosa*). Two species, Sagat (*Quercus spicata*) and Yemein (*Aporosa villosa*) are most abundant and researches on the utilities of these species should be conducted. Most of the species growing in our forests are lesser used ones and the more we get wide knowledge on the utilities of these species the lesser the concentrated extraction of more valuable timber species.

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