Government of the Union of Myanmar
Ministry of Forestry
Forest Department

Species Composition and Stand Structure of Mangrove Forest in Relation with Soil Condition in Kadon Kani Reserved Forest, Bogalay Township

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July, 2008

ဘိုကလေးမြို့နယ်၊ ကဒုံကနီ သစ်တောကြိုးဝိုင်းအတွင်းရှိ ဒီရေတောများ၏ အပင်ပေါက်ရောက်မှုနှင့်ဖွဲ့စည်းတည်ဆောက်ပုံအားမြေဆီလွှာအခြေအနေနှင့်ဆက်စပ်လေ့လာခြင်း။

ဦးဇော်ဝင်းမြင့် (တောအုပ်ကြီး၊ သစ်တောသုတေသနဌာန)
ဒေါ်သီတာဆွေ (သုတေသနလက်ထောက်-၂၊ သစ်တောသုတေသနဌာန)
ဒေါက်တာညီညီကျော် (ဒုတိယညွှန်ကြားရေးမှူး၊သစ်တောသုတေသနဌာန)

စာတမ်းအကျဉ်းချုပ်

ဒီရေတောများသည် ပင်လယ်ဆားငံရေများ မြေပြင်သို့ရောက်ရှိ ထိတွေ့ရာမှ ဖြစ်ပေါ်လာပြီး ပင်လယ်ဆားငံရေဒဏ်ကို ခံနိုင်စွမ်းရှိသော အပင်အုပ်စုများ (Salt-tolerant forest ecosystem) ဖြစ်ကြပါသည်။ မြန်မာနိုင်ငံတွင် ဒီရေတောများကို ရခိုင်ကမ်းရိုးတန်း ဒေသ၊ တနင်္သာရီတိုင်းနှင့် ဧရာဝတီတိုင်း မြစ်ဝကျွန်းပေါ်ဒေသများတွင် တွေ့ရှိရပါသည်။ ဒီရေတောများရှိခြင်းဖြင့် မြစ်ကြောင်းနှင့်ပင်လယ်ကမ်းခြေ တည်ငြိမ်မှုကိုဖြစ်ပေါ်စေခြင်း၊ ရေတိုက်စားခြင်းမှကာကွယ်ပေးခြင်း၊ ဒီရေတောများအတွင်း နုံးပို့ချခြင်းဖြင့် မြစ်၊ ချောင်းများ အတွင်း သဲသောင်ဖြစ်ထွန်းမှုကိုလျော့နည်းစေခြင်း စသည်ဖြင့် အကျိုးကျေးဇူးများစွာကို ရရှိစေပါသည်။ ၎င်းအပြင် ဒီရေတောများသည် ဒေသခံပြည်သူများ၏ လူမှုစီးပွားရေး ဖွံ့ဖြိုး တိုးတက်မှုကိုလည်း အထောက်အကူ ဖြစ်စေပါသည်။ ထင်း၊ မီးသွေး၊ မျော၊ တိုင်နှင့် သစ်နှင့် သစ်မဟုတ်သော အခြားသစ်တောထွက်ပစ္စည်းများဖြစ်သည့် ဓနိ၊ သင်၊ ဓနိနွယ်၊ ပျားရည်နှင့် သစ်ခေါက် စသည်တို့ကို ဒီရေတောများမှ ရရှိစေနိုင်ပါသည်။ ထို့အပြင် ဒီရေတောသစ်ပင်များသည် ငါး၊ ပုဇွန်၊ ဂဏန်း တို့ အတွက် အစာရေစာရရှိရာ အရင်း အမြစ် ဖြစ်ပြီး၊ ၎င်းတို့ခိုအောင်းနေထိုင်ရာ နေရာလည်း ဖြစ်ပါသည်။ ဒီရေတောများကို ထာဝစဉ်ဖွံ့ဖြိုးတိုးတက်စေမည့် သစ်တောစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်း နည်းလမ်းများ ဆောင်ရွက်နိုင်ရန် အတွက် မြေဆီလွှာအခြေအနေများနှင့်ဒီရေတောသစ်မျိုးများ၏ အပင်ပေါက်ရောက်မှုနှင့် ဖွဲ့စည်းတည်ဆောက်ပုံအား ဆက်စပ်တည်ရှိနေမှုကို သိရှိရန် လိုအပ်ပါသည်။ ဒီရေတောများအတွင်း မြေဆီလွှာအခြေအနေ၊ ဂုဏ်သတ္တိနှင့် မြေအနေအထားအလိုက် ပေါက်ရောက်သော သစ်မျိုးများနှင့် ပေါက်ရောက်မှုအခြေအနေကိုသိရှိခြင်းအားဖြင့် ဒီရေတောစိုက်ခင်းများ တည်ထောင်ခြင်း နှင့် သဘာဝတောများ ထိန်းသိမ်းခြင်းတို့တွင် အထောက်အကူပြုစေရန်၊ ဒီရေတောများ ထိန်းသိမ်း စိုက်ပျိုးခြင်းဖြင့် ဒေသခံ ပြည်သူများ၏ စီးပွားရေး၊ လူမှုရေးနှင့် ပတ်ဝန်းကျင်ထိန်းသိမ်းရေး တို့တွင် အထောက်အကူပြုစေရန်၊ ဒီရေတောများ၏ မြေဆီလွှာနှင့် အပင်ပေါက်ရောက်မှုကို လေ့လာခြင်းဖြင့် ဒီရေတောများ၏ ဂေဟစနစ် ထိန်းသိမ်းရေးကို အထောက်အကူပြုစေရန်အတွက် လေ့လာတင်ပြထားခြင်း ဖြစ်ပါသည်။

Abstract

Mangrove forests are salt-tolerant forest ecosystem and they are formed when the marine water reached to the coastal area. In Myanmar, mangrove forests occur in the coastal area of Rakhine State, Tanintharyi Division and delta area of Ayeyawady Division. Mangrove provides many other functions such as coastal stabilization, erosion prevention and saves as a sink for several pollutants. Moreover, they provides many economics benefits. Firewood, charcoal, logs and other minor forest products such as daninwe, thin, thabaw, dani, honey and barks are useful products derived from the mangrove forests. For successful sustainable forest management practices, it is necessary to understand the soil site relationship, species composition and stand structure of mangrove forests. The objectives of this study are to support in the establishment of mangrove forest plantations and maintenance of natural forest by studying soil properties and the species grown at different topography of mangrove forests, to find out suitable silvicultural techniques by studying species composition and stand structure of mangrove forests and to find suitable ways to conserve the environment and to promote socio-economic condition of local people by maintaining mangrove forests.

Key words: Mangrove, species composition, species diversity, soil properties, electrical conductivity

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1. Introduction

The term 'mangrove' is said to have been derived from a combination of the Malay word 'manggi-manggi', for a type of mangrove tree (*Avicennia*) and the Arabic 'el gurm', for the same, as 'mang-gurm'. It may be used to refer to a species, plant, forest or even a community. Mangroves are found in the tropical and subtropical coasts which are bathed by warm ocean currents. Mangroves cannot survive in winter conditions and need warm temperatures above 24°C.

Mangrove forests are salt-tolerant forest ecosystem and they are formed when the marine water reached to the coastal area. In Myanmar, mangrove forests occur in the coastal area of Rakhine State, Tanintharyi Division and delta area of Ayeyawady Division. Mangrove forests are one of the most productive and biologically diverse wetlands on earth. It is an ecosystem that is made up of both a community of living things and the non-living environment. The mangrove ecosystem does not have as many species of plants and animals as other ecosystems due to the harsh and constantly changing environment.

In general, geography, coastal topography and tidal regime determine the presence or absence and extent of the mangroves. Structure, physical properties and chemical composition, salinity, acidity of soil and sediments, the nature of the substratum as well as the climate determine the development, growth and productivity of mangrove ecosystem.

Although small in comparison with the world's total forests, they play a very important role in the ecosystem of the region. They prevent soil erosion by acting as a wind and water break. They maintain moisture and breeding grounds for many plants and animals both on land and in the sea. They also provide food, construction materials, fibbers, and medicinal plants to dwellers in and near the coastal zones.

Therefore, it is necessary to understand the soil-site relationship, species composition and stand structure of mangrove forests for successful sustainable forest management practices.

1.1 Objectives

The objectives of this study are;

(1) To study soil-site relationship in order to support in the reforestation and restoration of mangrove ecosystem.
(2) To find out suitable silvicultural practices possible by analyzing species composition and stand structure of mangrove forests.
(3) To study the quantitative assessment of mangrove vegetation and ecological condition of the mangrove ecosystems.

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2. Materials and Methods

2.1 Study area

The research was carried out at the compartment 49, Kadonkani Reserved Forest, Byone Mwe Island, Bogalay Township, Ayeyawady Division.

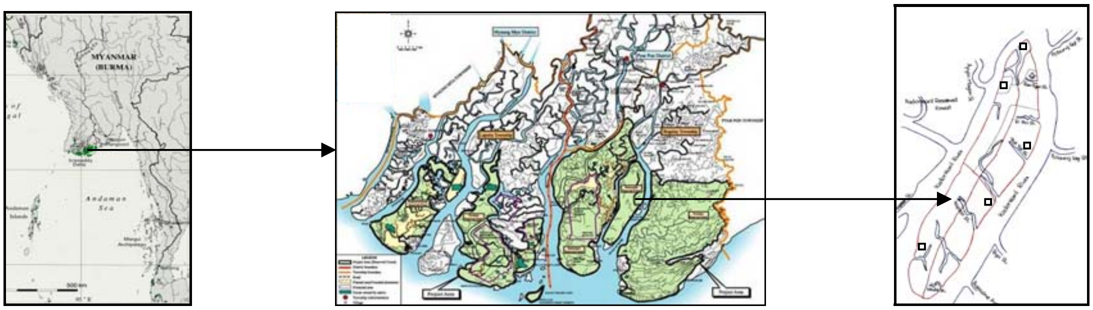


Fig.1 Location of the study area

Fig.2 Kadonkani Reserved Forest, Byone Mwe Island

2.2 Climatic condition

Climatic condition of the study area is presented based on the observation for the period of 1995 to 2005 as shown in table 1 and figure 3.

Table 1. Monthly mean rainfall, mean temperature and humidity measured at Myaung Mya Meteorological station

Months	Rainfall (mm)	Temperature (°C)	Humidity %
January	0.15	23.60	65.6
February	0.08	25.78	66.0
March	7.62	27.60	64.0
April	226.06	29.79	63.0
May	300.48	27.25	73.8
June	503.68	25.91	82.6
July	442.98	25.09	81.0
August	527.81	25.24	84.6
September	393.70	25.29	84.6
October	171.45	25.62	78.2
November	39.88	25.53	78.8
December	0.05	23.84	71.3
	Annual = 2613.94	**Avg. = 25.88**	**Avg. = 74.46**

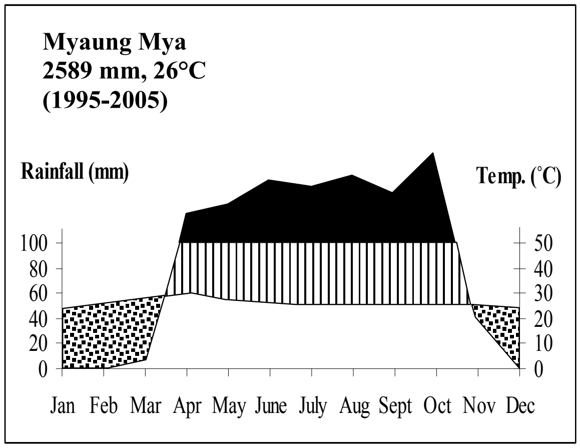


Fig.3 Climatogram (mean monthly rainfall and temperature) of the study area

2.3 Silvicultural analysis and diversity measures

2.3.1 Silvicultural analysis

2.3.1.1 Sampling design

Since the detailed analysis on the basis of complete studies of the forest's structure, composition and ecological conditions cannot be carried out on large areas, but only by a process of systematic sampling (Lamprecht, 1989). For the purpose of structural description, transect lines, along which the sample plots were systematically oriented, were laid down at equal intervals over each study area. The minimum area is in accordance with the sum of areas, in which all species are represented. Five sample plots were laid out at three different places namely Lowest, Middle and Highest depending on the tidal action. In Lowest level, the tide usually rises and falls twice in every 24 hours, in Medium level, once a week and in Highest, once in 2 weeks. Each sample plot covers an area of 625 m^2 (Plot A) which was divided into subplot B (5 m x 5 m) (25 m^2). Total survey area is 0.9375 ha (2.317 acres). The distance between the sample plots is 100 m.

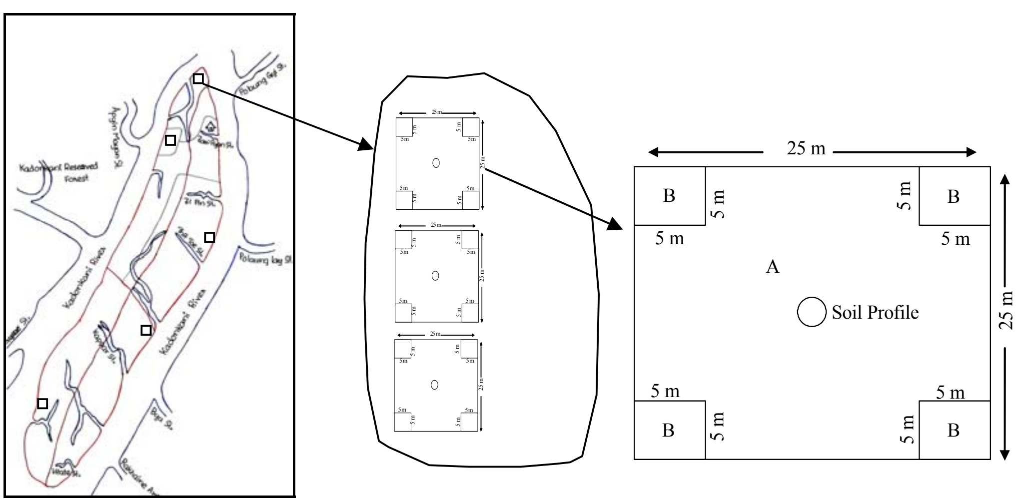


Fig.4 Layout of the sample plot and sample plot design

In plot (A), all trees with DBH ≥ 10 cm were recorded and the following parameters were measured for the tree species identification;

1. Dimension (diameter at breast height-dbh)
2. Number of individuals (abundance)
3. Total height

In subplot (B), seedlings with the height of between 30 cm and 130 cm were recorded. In this subplot, only seedlings found therein were recorded for tree species identification.

For the tree investigated stands, the total survey area for each stand was 3,125 m^2 with five sampling units of 625 m^2.

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; It was measured by using a digital Forester Vertex Hypsometer.

Tree species identification was carried out by using a guide book of "A Checklist of the Trees, Shrubs, Herbs, and Climbers of Myanmar".

2.3.2 Species diversity measures

2.3.2.1 Diversity indices

Species Diversity expresses the degree of evenness of the mixture of species. Diversity is greatest if each species contributes the same proportion to the number of individuals of the forest community (Bruenig, 1989). The typical feature of species frequency distribution is that many rare species with only few individuals are found in combination with a few species, which are presented by high numbers of individuals (Kyaw, 2003).

Since the species of a forest in different abundance, it has become a scientific ritual to calculate a diversity index, which also considers the uneven distribution of species abundances. The diversity indices are better measures of the species diversity of a forest than the species density and mixture ratio and more informative than species counts alone (Weidelt, 2000). Species diversity is often expressed by the SHANNON index (H), Evenness (E %) and SIMPSON's index (D) (Magurran, 1988).

SIMPSON-Index (D)

$$D = \sum_{i=1}^{s} \left[\frac{n_i (n_i - 1)}{N (N-1)} \right]$$

where,

D = Simpson's index of diversity

ni = number of individuals of species "i" in the samples

s = number of species in the sample

N = total number of species in the sample

SIMPSON's index indicates the most abundant species but it is less sensitive to species richness. Simpson's index is usually expressed as 1-D or 1/D because D increases, diversity decreases.

SHANNON Diversity Index

$$H' = \sum_{i=1}^{s} P_i \ln(P_i) \qquad ; \qquad P_i = {n_i}/{N}$$

where,

H' = index of species of diversity
S = number of species in the sample
P_i = proportion of total sample belonging to "i^{th}" speices
ln = the theoretical maximum value of diversity by a given number of total species (S) found in the sample

SIMPSON's index emphasizes more the common species while the SHANNON diversity index places more weight on the rare species (Weidelt, 2000).

SHANNON Evenness (E)

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

$$E = \left\lfloor {H'}/{\ln S} \right\rfloor * 100$$

Therefore, E is between 0 and 100. The value 100 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.

2.3.2.2 Coefficient of similarity

To calculate coefficient of similarity, the floristically and structural point of views have to be taken into account for the comparison of both investigated stands. It is because the both 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 mean for comparing the floristic similarity between two forests. In this way, the coefficient of similarity proposed by Sorensen (1948) can be used for the species comparison. The formula is as follows;

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

where,

a = total number of species found in the first forest stand
b = total number of species found in the second forest stand
c = total number of species found in both stands

Another formula to modify the coefficient and use dominances or abundances is (Weidelt, 2000);

$$K_d = \frac{2c_d}{a_d + b_d} * 100$$

where,

a_d = total dominance in the first stand
b_d = total dominance in the second stand
c_d = sum of common dominances, which means the sum of the smaller dominance values for the common species

Bray and Curtis (1957) modified SORENSEN-index and it is also applied to compare the similarity of forest stands by the formula.

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

where,

C_N = Coefficient of similarity by BRAY and CURTIS
a_N = Number of individual in the first forest stand
b_N = Number of individual in the second forest stand
j_N = Sum of individuals number, which means the sum of the smaller number for the common species of the both stands

2.3.3 Stand structure

2.3.3.1 Horizontal stand structure

A forest stand is defined as an aggregation of trees occupying a specific area and sufficiently uniform in species composition, age, arrangement and condition so that it is distinguishable from the forest in adjoining areas. Stand structure in forestry is concerned generally about the various horizontal and vertical physical elements of the forest such as basal area and volume, the diameter frequency distribution, height of stand and vertical structure (Dunster and Dunster, 1996). This quantitative information about a stand is related directly to silvicultural and management decisions (Van Laar and Akça, 1997).

2.3.3.2 Importance-Value-Index (IVI)

Importance-Value-Index (IVI) is the sum of relative abundance, relative dominance and relative frequency (Lamprecht, 1989). This index can also permit a comparison of the ecological significance of species in a given forest type. Importance-Value-Index (IVI) can be mathematically expressed as follow;

$$IVI = R.A + R.F + R.D$$

Dominance - considered as an equivalent of the space a plant is occupying in the stand. It can be defined as the horizontal projection of the plant at ground level. The relative dominance is the percentage of a species in the total basal area of a stand.
Abundance - considered as the number of trees per species. The relative abundance is the percentage of each species in total stem number per hectare.
Frequency - considered as the occurrence of absence of a given species in the subplots. The relative frequency is the percentage of the total of the absolute frequencies of all the species.

2.3.4 Soil sample collection

In mangrove forests, depending on the different topography such as flat, slope and ridge and the extent of the marine water reached to the land, the species grown are different. Therefore, by using systematic line survey, soil samples were collected at three different depths (0-10 cm, 40-50 cm and 80-90 cm) in each stand. Soil profiles were also studied at different sites depending on topography and tidal reached to the land. Field description and soil sample collection were made during the dry season to ensure to be free from salt disturbance through ground water availability. Physical and chemical properties of collected soil samples were analyzed at soil laboratory of FRI and soil properties were compared with species composition and stand structure found in the study area. The physical and chemical properties of mangrove soils are presented in appendix I.

Fig.5 soil sample collection in the study area

2.3.5 Data analysis

After field work has been done, the data were entered into Excel worksheets as the basic format for analysis, thereafter, transformed into other formats according to the software used. The common software used in this analysis was STATISTICA for WINDOWS and MICROSOFT EXCEL 2003.

3. Results and Discussion

3.1 Species composition

3.1.1 Species richness

One of the measures of species richness and diversity in individual forest communities is the number of species per unit area. Species richness is commonly expressed as the number of species (tree species over a specified minimum diameter at breast height) per hectare, which can also be seen as species density. In forest vegetation analysis in Highest, Middle and Lowest stands, the number of tree species over 10 cm dbh per hectare is commonly quoted and 22 species, 38 species and 35 species per hectare respectively were found.

The most common species found in study area are Kanazo (*Heritiera fomes*), Thayaw (*Excoecaria agallocha*), Thinbaung (*Phoenix paludosa*) and Myinka (*Cynometra ramiflora*) respectively. Whitmore (1975) noted that an increase in a particular factor would probably only cause an increase in the number of individuals of certain species, but it would not increase the number of species. He also explained that a large number of rare species is matched by a small numbers of species, which are found almost throughout the ecosystem.

3.1.2 Species-area curve

Species-area curve was drawn to show the representative sample of the species composition and it was obtained by the sample plots. A total sample area is considered representative according to Cain (1959) when an enlargement of the sample area by 10% results in species number increases less than 10% (Kyaw, 2003). In this study, five squares sub-plots, each covering an area of 625 m^2 has been used for data collection. Species area curve of study area is shown in figure 6.

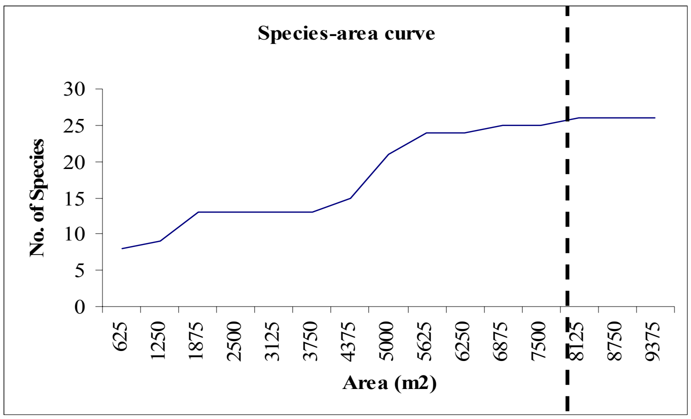


Fig.6 Species-area curve for all trees of $\geq$ 10 cm dbh in the study area (Sample area =15 sub-plots x 625 m^2)

For the determination of representative minimal area for a tree species spectrum, it is common by showing so-called species-area curve. 0.5 -1 ha in moist forest and less in dry forests are enough to plot the species area curves (Lamprecht, 1989). The species area curve shows that no new species were found after enumeration on 9,375 m^2 (0.9375 ha). Thus 0.9375 ha sample plot is enough for silvicultural analysis of the study area.

3.1.3 Species Diversity

3.1.3.1 Diversity indices

The study revealed that the relatively low species diversity in the Highest stand resulted obviously from fewer species than in other two stands and highest species diversity were found in Middle stand. The result from SIMPSON's index (D) of Middle stand is significant at 95% significant level from Highest and Lowest stands. Nearly the same diversity indices were observed in Highest and Lowest stands and Middle stand has the lowest diversity index.

Table 2. Diversity parameters of the stands of Highest, Middle and Lowest areas of Mangrove forest (included all trees ≥10 cm dbh)

	Highest	**Middle**	**Lowest**
Number of species per ha	22	38	35
Number of trees per ha	1395	1075	701
Individual per species	63	28	20
SHANNON index (H')	1.29	0.84	1.46
SHANNON Evenness (E %)	10.44	33.76	60.76
SIMPSON's index (D)	0.38	0.61	0.36
1/D	0.62	0.39	0.64
1-D	2.61	1.65	2.74

According to the significance test, SHANNON index (H') of the Middle stand was significantly different with the Highest and Lowest stands, although there was no significant different between these two stands. The result from SIMPSON's index (D) of the Middle stand is different from the Highest and Lowest stands at 95% significance level. The Lowest stand has the highest evenness according to the calculation of Evenness (E %), which is based on the abundance of species.

3.1.3.2 Coefficient of similarity

The coefficient of similarity for all investigated stands are calculated and presented in table 3. K_S gives higher similarity value between the stands of Highest and Lowest in terms of floristic composition. There are altogether six common species found in both stands. Although K_S of Highest and Middle stands showed a lower value as compared to the K_S of Highest and Lowest stands, the flora between the Middle and Lowest are not different from that of these two stands. There are also seven common species found between the stands of Lowest and Middle and K_S gives the lowest similarity value between them.

Table 3. Coefficient of similarity among the investigated forest stands

Forest stands	**Sörensen's index (%) (based on species)(K_S)**	**Weidelt index (%) (based on BA)(K_G)**	**Bray & Curtis index (%) (based on no. of individuals)(K_D)**
Highest stand vs. Lowest stand	66.67 (6)	48.24	41.89
Highest stand vs. Middle stand	63.16 (6)	83.20	71.38
Middle stand vs. Lowest stand	60.86 (7)	30.84	26.75

The similarity index, which is based on the dominance of the species (K_G), also gives the highest similarity value between Highest and Middle stands. It is due to the dominance of Thayaw and, which occupied 48% of the total basal area of the Highest stand and 45% in the Middle stand. It can be clearly seen that the coefficient, K_G, gives low value by calculating similarity between the stands of Lowest and the other stands. This means that the stand in the lowest level is much different from the other stands in terms of dominance of the species. Its basal area cover is low which meant the abundance of small trees occur in lower diameter classes. It could be the influence of tide, salinity, moisture content, etc.

3.2 Stand structure

3.2.1 Horizontal structure

The number of trees per hectare is a measure for the density of a forest. According to Dawkins (1958), a tree population is best described in the form of a stand table with basal area or volume, the number of trees, by given diameter classes and it can also be separated by species or economic groups. The basal area and number of trees per hectare in different diameter classes in the study area are presented in table 4.

Table 4. Stand table of the study area showing basal area and tree numbers per hectare in different diameter classes

dbh class	Highest stand		Middle Stand		Lowest stand	
	n/ha	m^2/ha	n/ha	m^2/ha	n/ha	m^2/ha
10-14.9	992	3.098	694	2.483	451	1.621
15-19.9	394	2.593	320	2.242	182	1.275
20-24.9	6	0.066	58	0.738	42	0.462
25-29.9	3	0.052	3	0.049	13	0.197
30-34.9	0	-	0	-	10	0.253
35-39.9	0	-	0	-	0	-
40-44.9	0	-	0	-	0	-
45-49.9	0	-	0	-	0	-
>50	0	-	0	-	3	0.213

Figure 7 shows the lowest diameter (10-19.9 cm) represents more than half of the total number of trees and two upper classes occupy 20% that means the largest number of trees occurs in smaller diameter classes in the highest stand.

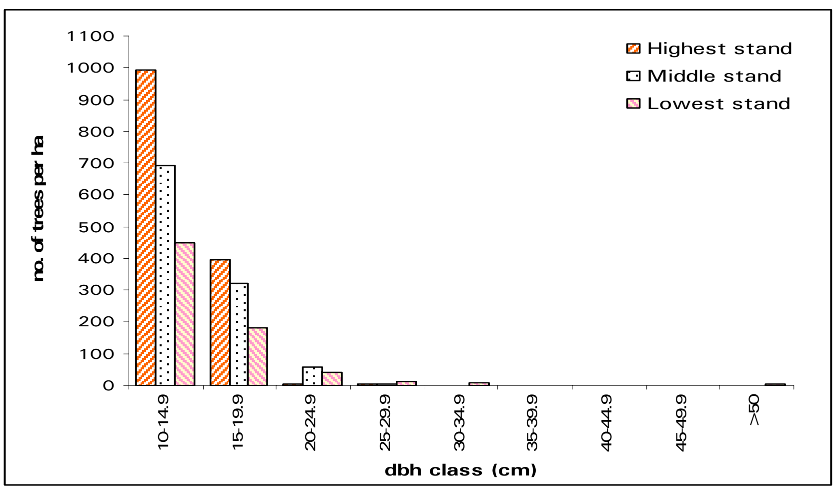


Fig.7 Diameter frequency distributions of the all stands

Lamprecht (1978) stated that the stem number in a primary forest decreases from class to class with a steeper gradient in lower diameter classes, and then it decreases with a slower rate in higher diameter classes. In this study, the diameter frequency distribution of these stands seems to follow this phenomenon.

3.2.2 Dominance, Abundance, Frequency and Importance-Value-Index (IVI)

Silvicultural parameters such as dominance, abundance, frequency, relative dominance, relative abundance, relative frequency and Importance-Value-Index (IVI) for all investigated stands are calculated according to (Lamprecht, 1989). The calculated values of them are given in table 5, 6 and 7.

Table 5. Abundance, dominance, frequency and importance value index (IVI) for all species with highest importance value index in the Highest stand arranged in descending order of IVI

No.	Species	Total			Relative			IVI
		Ab. N/ha	Dom. m^2/ha	Freq. %	Freq. %	Ab. %	Dom. %	
1	Thayaw	396	5.266	100	62.79	57.64	62.79	183
2	Thinbaung	136	1.178	80	14.04	19.80	14.05	48
3	Kanazo	47	0.935	100	11.15	6.84	11.15	29
4	Myinka	46	0.459	40	5.47	6.70	5.47	18
5	Khayar	31	0.280	20	3.10	4.51	3.34	11
6	Ye Khayar	30	0.259	60	3.34	4.37	3.10	11
7	Pantahka	1	0.009	20	0.11	0.15	0.11	0
Total		**687**	**8.386**	**-**	**100**	**100**	**100**	**300**

Table 6. Abundance, dominance, frequency and importance value index (IVI) for all species with highest importance value index in the Middle stand arranged in descending order of IVI

No.	Species	Total			Relative			IVI
		Ab. N/ha	Dom. m^2/ha	Freq. %	Freq. %	Ab. %	Dom. %	
1	Thayaw	306	4.791	100	74.39	75.93	74.65	225
2	Kanazo	69	1.208	100	18.76	17.12	18.82	55
3	Thametgyi	1	0.132	20	2.05	0.25	2.06	4
4	Nyaung Lan	7	0.061	20	0.94	1.74	0.95	4
5	Myinka	4	0.070	40	1.08	0.99	1.09	3
6	Thinbaung	5	0.039	20	0.61	1.24	0.61	2
7	Ye Khayar	4	0.041	40	0.63	0.99	0.63	2
8	Byu u talone	3	0.033	40	0.51	0.74	0.52	2
9	Yemanay	1	0.012	20	0.19	0.25	0.19	1
10	Tha Khut	1	0.011	20	0.18	0.25	0.18	1
11	Byushwewah	1	0.010	20	0.16	0.25	0.16	1
12	Panthakar	1	0.009	20	0.15	0.25	0.15	1
Total		**403**	**6.418**	**-**	**100**	**100**	**100**	**300**

Table 7. Abundance, dominance, frequency and importance value index (IVI) for all species with highest importance value index in the Lowest stand arranged in descending order of IVI

No.	Species	Total			Relative			IVI
		Ab. N/ha	Dom. m^2/ha	Freq. %	Freq. %	Ab. %	Dom.%	
1	Kanazo	130	2.183	100	58.89	57.78	54.14	171
2	Thayaw	31	0.536	60	14.15	13.78	13.30	41
3	Thametgyi	8	0.556	20	3.65	3.56	13.78	21
4	Byu u talone	15	0.184	60	6.85	6.67	4.56	18
5	Thinbaung	17	0.122	40	5.48	7.56	3.04	16
6	Thame Phyu	9	0.259	20	4.11	4.00	6.41	15
7	Pantha Kha	11	0.134	60	5.02	4.89	3.32	13
8	Byushaytauk(Po)	1	0.030	20	0.46	0.44	0.74	2
9	Khayar	1	0.012	20	0.46	0.44	0.30	1
10	Zalat	1	0.008	20	0.46	0.44	0.21	1
11	Ye Khayar	1	0.008	20	0.46	0.44	0.19	1
Total		**225**	**4.033**	**-**	**100**	**100**	**100**	**300**

Lamprecht (1989) assumed that the most abundance species usually have high frequency values, i.e. they belong to the group of tree species with regular horizontal distribution. In all investigated stands, Thayaw and Kanazo trees are found to be the most abundance species with the high frequency values of 100% and this indicate favorable site condition for the development of these species. It can be assumed that these trees have regular horizontal distribution.

It can be observed that there is a close relationship between abundance and frequency values in all investigate stands. According to (Lamprecht, 1989), it can also be considered that the species such as Thayaw, Kanazo, Thinbaung, Byu u talone, Ye Khayar, Panthakar and Myinka are the species with regular horizontal distribution. Furthermore, they can also be considered as the characteristic species for their respective forest stands.

Weidelt (2000) noted that “In assessing the ecological importance or significance of a species, it is difficult to decide which of the parameter is to be taken into account". However, Importance-Value-Index (IVI) developed by Curtis and McIntosh (1951) can be used to compare the ecological significance of species in a given forest types. Thayaw and Kanazo trees in all study areas where different tidal action are reached have the highest IVI values and it can be considered as representative species of these stands and Kanozo tree species is ecologically important species in the delta areas.

Similarly, the species such as Thinbaung, Thamegyi, Nyaung Lan, Byu u talone, Khayar and Myinka are assumed as the species with the highest IVI values. These species are also assumed as the most important species for all investigated stands.

3.2.3 Vertical structure

The tree height is a dimensional characteristic, which is required to estimate the volume of the standing trees, to predict the future growth, and to determine the site quality and site index of a stand (Van Laar and Akça, 1997). According to Philip (1994), stand height is usually expressed by mean height, stand height curve, or top height. For practical reasons and because of cost considerations, it is usually assumed that the height curves of the individual sample plots are thought to have a common intercept and shape for a specific site condition. The stand height curve, which is the relationship between tree height and tree diameter, is curvilinear and many non-linear regression models have been proposed to fit a stand height curve. The selection of regression functions is to be based on the behavior of the curve within the range of diameter measurements and the statistical parameters such as coefficient of determination (r^2) and regression coefficient (r).

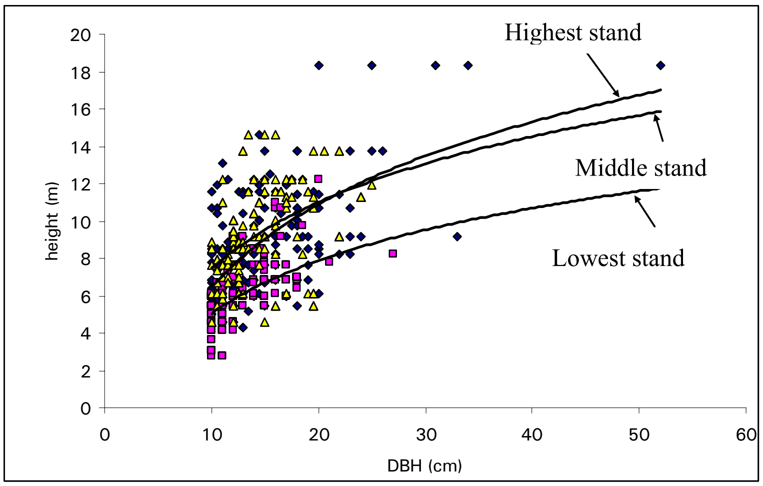


Fig.8 Stand height curves (total tree height) of all species (≥ 10 cm dbh) of the investigated stands

$h_{Highest}$ = 1.9908 ln (d) - 1.1319 (r = 0.636)
h_{Middle} = 3.7091 ln (d) - 4.8464 (r = 0.694)
h_{Lowest} = 3.6521 ln (d) - 5.0261 (r = 0.726)

In this study, logarithmic function fitted suitable regression for all height curves figure 8. A comparison of the height curves for all species reflects the dominant position of the highest stand with total height of about 19 m. The stand in the Middle stand area is dominated in terms of basal area but smaller total height compared to that in the Highest stand. Trees in the lowest stand reach only total height of 12-13 m. According to the tree height for all species, the stands are significantly different from each other ($p < 0.01$).

3.3 Physical and chemical properties of the soils in the study area

Mean values for selected soil properties were statistically tested. Soil chemistry data and soil profile description for the study sites are shown in table 8.

Table 8. Physical and chemical data of soils in the study area

Soil properties	Highest stand	Middle stand	Lowest stand
pH	6.40 (0.20)	6.50 (0.20)	6.60 (0.10)
Total N %	0.12 (0.05)	0.13 (0.03)	0.11 (0.04)
Ava. P (ppm)	0.70 (0.20)	0.80 (0.40)	1.00 (0.20)
Ext. K (%)	0.01 (0.00)	0.015 (0.00)	0.01 (0.00)
Ext. Ca (me/100g)	0.0001 (0.00)	0.00009 (0.00)	0.00011 (0.00)
Ext. Na (me/100g)	3.53 (0.49)	3.98 (0.31)	2.54 (0.92)
Ext. Mg (me/100g)	7.63 (0.28)	7.39 (0.73)	6.95 (0.61)
OM (%)	4.25 (1.53)	4.12 (0.75)	3.24 (0.22)
EC (mmhos/cm)	4.09 (1.52)	3.22 (1.33)	4.31 (2.24)
SAR	1.64 (0.17)	1.93 (0.34)	1.24 (0.358)
Sand (%)	33.00 (10.0)	32.00 (10)	40.00 (8)
Silt (%)	52.00 (2.00)	46.00 (6.00)	26.00 (21.0)
Clay (%)	16.00 (8.00)	23.00 (12.0)	31.00 (12.0)

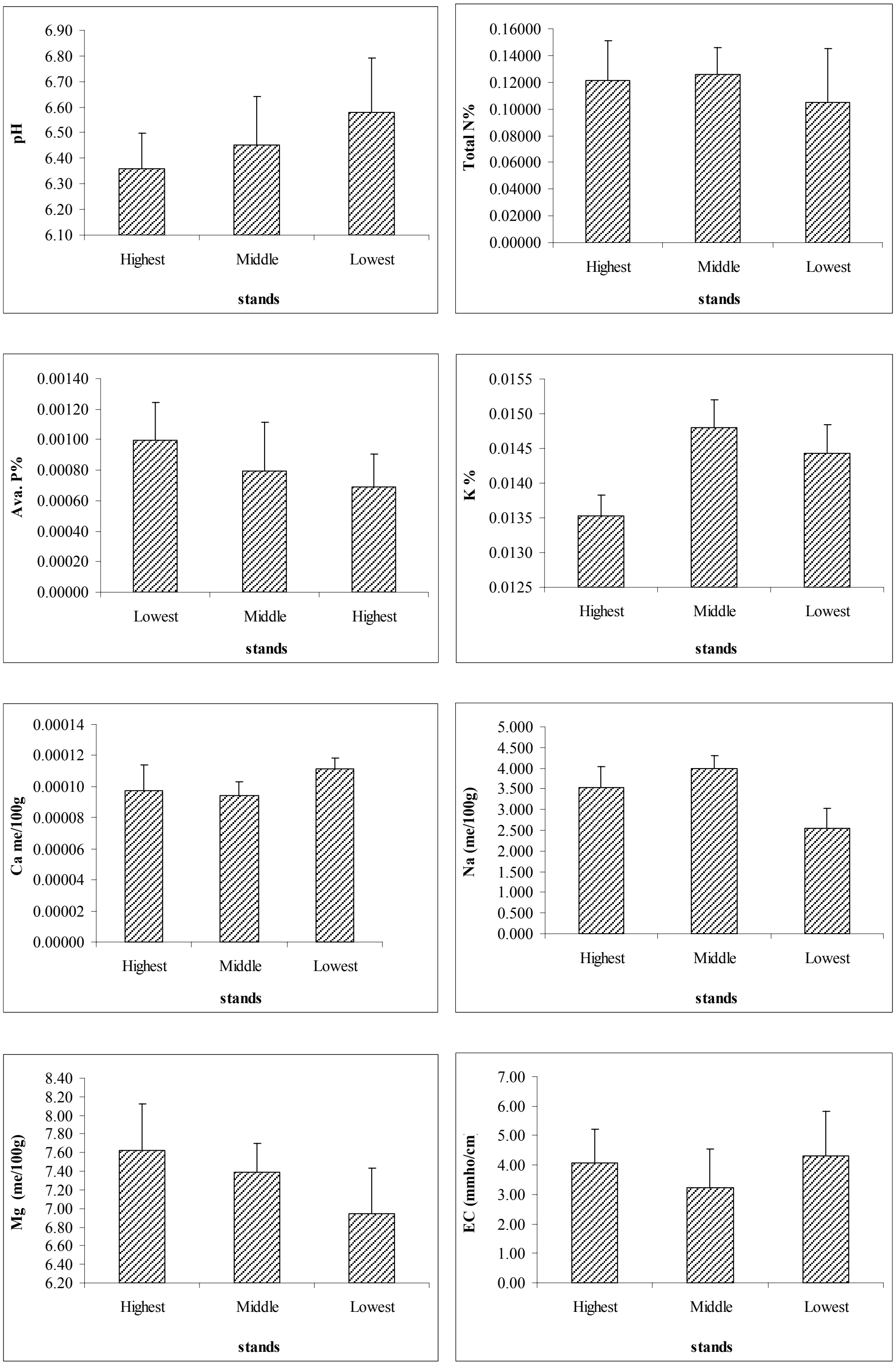
Note; standard deviations are shown in the parentheses

Aspur of Pegu Anticline with Miocene shale and sand stone extends to the south as far as Yangon, where it also disappears under the Ayeyarwadian further to the south. Close to the coast in the Tenasserim coastal area, recent and sub-recent fluviatile sediments lie directly on top of Paleozoic scist, argilite, grewacks, sand-stone, quartizite and limestone or above granitic rocks (Bender, 1983).

The soil from lowest stand was found to have about 31% of clay content and about 26% of silt and 40% of sand while the soils of middle and highest stands have 23-16% of clay, 46-52% of silt and 32-33% of sand. The texture did not change with increasing depth in highest stand, whereas silt contents were increased with increasing depth in the lowest and middle stands.

The slightly acid and high levels of nutrient content of soils were found in all study areas. The nutrient content was not notably different in layer by layer; however, nitrogen contents were decreased with increasing depth and organic matter percent had the same trend as nitrogen. A slight increase was found in phosphorous also with increasing depth in the study areas except in lowest stand where slightly decreased content was found with increased depth. Slightly decreasing potassium, calcium, sodium and magnesium contents and increasing electrical conductivity (EC) content were found with increasing depth.

Comparing to other two study areas, highest pH content and lowest soil organic matter content were found in lowest stand. Most of the nutrient concentrations such as nitrogen, potassium and sodium were highest in Middle stand and however, very low concentration of EC was found in this area. The highest magnesium and organic matter contents were found in the highest stand.


6.90
6.80
6.70
6.60
6.50
6.40
6.30
6.20
6.10
pH
Highest
Middle
Lowest
stands
0.16000
0.14000
0.12000
0.10000
0.08000
0.06000
0.04000
0.02000
0.00000
Total N%
Highest
Middle
Lowest
stands
0.00140
0.00120
0.00100
0.00080
0.00060
0.00040
0.00020
0.00000
Ava. P%
Lowest
Middle
Highest
stands
0.0155
0.0150
0.0145
0.0140
0.0135
0.0130
0.0125
K %
Highest
Middle
Lowest
stands
0.00014
0.00012
0.00010
0.00008
0.00006
0.00004
0.00002
0.00000
Ca me/100g
Highest
Middle
Lowest
stands
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Na (me/100g)
Highest
Middle
Lowest
stands
8.40
8.20
8.00
7.80
7.60
7.40
7.20
7.00
6.80
6.60
6.40
6.20
Mg (me/100g)
Highest
Middle
Lowest
stands
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
EC (mmho/cm
Highest
Middle
Lowest
stands

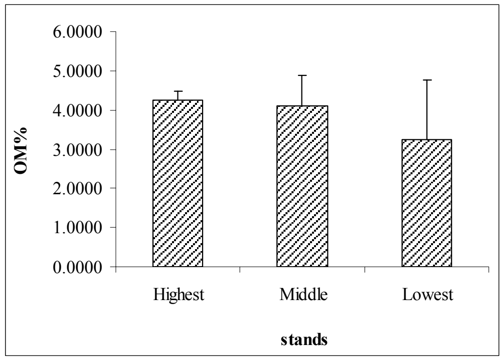


Fig.9 Nutrient contents of soils in all study area

Although the soil properties were statistically not significant different among the study areas, some variations were found in EC content. Mangrove soils are under the influence of tidal blackish or salt water; hence the soil salinity is high. The soil salinity as EC of mangrove soil is more than 4 mmhos/cm at 25ºC (Sarwono, 1986).

The mean values of EC content found in the Highest, Middle and Lowest stand are 4.09 mmhos/cm, 3.22 mmhos/cm and 4.31 mmhos/cm respectively. The common range of EC present was found in the Highest and Lowest stands. In this study, differences in soil salinity reveal the different species compositions of the investigated stands.

(a) Highest stand (b) Middle stand (c) Lowest stand

Fig.10 Soil profiles of study areas (a) Highest stand, (b) Middle stand and (c) Lowest stand

4. Recommendations and Conclusion

Species and zonal distribution of mangroves are controlled by the degree of inundation (tide), sedimentation process, rainfall, upstream water flow and hidden environmental factors. Then, bio-community is created with its inter-relationship (Myint, 2002). Statistical analysis exhibited spatial differences in soil salinity and suggested that the parameter is most correlated to the development and distribution of mangrove vegetation in the area indicating that basal area and biomass volume are inversely correlated with soil salinity.

Mangrove soil has unique biological and physical properties in supporting the system. The higher numbers of species composition found in the Highest and Lowest stands could be the higher amounts of Nitrogen and Organic matter contents found in these stands because nitrogen is known as the most important and limited nutrient source.

High land areas being tidally elevated above the inundation level are too dry to get sufficient amount of moisture for mangrove species to survive. In this study, common species found in the Highest stand such as Thayaw (*Excoecaria agalocha*), Kanazo (*Heritiera fomes*) and Myinka (*Cynometra ramiflora*) can persist under dry soil conditions. Dry type of these mangrove species are commercially important species because they are good to be used as sawn timber as well as fuelwood (FAO, 1992).

Myinka, Byu u talone and Byushwewah are the majority of mangrove species adapted in the medium tides areas and these species are also good for timber fuelwood and charcoal.

The common species in all investigated stands such as Thayaw (*Excoecaria agalocha*), Kanazo (*Heritiera fomes*) and Thametgyi (*Avicennia marina*) could be used in the reforestation and restoration purposes because these species are ecologically important species for study area based on IVI analysis. Especially Kanazo is one of the commercial tree species both for timber and fuelwood. Thayaw can be noted as most landward distributing mangrove in Myanmar and some people used as fencing post on inland field of coastal area (Myint, 1988). The highest IVI value shown in the Lowest stand reveals that Kanazo seems to be high tolerance to salinity range.

In all study sites, it is obviously found that trees with small dbh classes (10-19.9 cm) represent more than half of total trees. It is meant that bigger trees have been removed and the number of trees as dbh classes showed irregular shape.

Natural regeneration and survival chance of seedlings and saplings depend on different substrate types and light exposure (Aung, 1999). Therefore, it is recommended that the remaining tree species with lower dbh should be encouraged by means of Regeneration Improvement Felling (RIF) and weeding and cleaning unwanted weeds like *Phoenix paludosa* (Thinbaung) which is abundantly found in all study areas. After RIF operations valuable species like Kanazo, Thayaw and Myinka can be found with good height and growth.

For the purpose of artificial regeneration, Kanazo is found to be site matched species in study site, although EC in soil influenced in the occurrence of the said species.

Indigenous knowledge on utilization of mangrove trees and scientific aspect of conserving natural ecosystem are needed to study simultaneously in order to manage remaining mangrove forest sustainability in Ayeyawady Delta.

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APPENDIX I

Physical and Chemical Properties of Mangrove Forest Soil

Samples	Soil depth	pH	Total N %	Available P %	Extractable Nutrients K%	Ca%	CEC meq/100g	OM%	Na me/100g	Mg me/100g	Partical Size Distribution Sand%	Silt%	Clay%	Textural Classes
1	0-10	6.43	0.0690	0.00117	0.0120	0.0259	26.10	3.40	3.39	7.37	30	37	29	Clay Loam
	40-50	6.61	0.1578	0.00110	0.0141	0.0218	19.43	2.99	1.57	6.25	45	2	50	Sandy Clay
	80-90	6.7	0.0876	0.00071	0.0172	0.0193	41.47	3.34	2.65	7.22	44	39	14	Loam
2	0-10	6.32	0.1630	0.00030	0.0152	0.0209	40.84	4.91	3.80	8.1	41	42	16	Loam
	40-50	6.37	0.1137	0.00061	0.0144	0.0184	21.46	4.03	3.81	7.43	22	43	37	Clay Loam
	80-90	6.67	0.1009	0.00148	0.0148	0.0172	40.60	3.41	4.34	6.64	33	52	16	Silt Loam
3	0-10	6.14	0.1879	0.00070	0.0140	0.0212	27.84	6.00	3.94	7.91	41	50	12	Silt Loam
	40-50	6.56	0.0830	0.00048	0.0132	0.0186	35.09	3.57	2.99	7.35	36	53	11	Silt Loam
	80-90	6.38	0.0928	0.00090	0.0134	0.0188	43.20	3.18	3.67	7.62	22	52	25	Silt Loam
4	0-10	6.61	0.1386	0.00097	0.0153	0.0188	27.55	4.33	3.87	8.33	25	53	17	Silt Loam
	40-50	6.67	0.0899	0.00070	0.0151	0.0156	38.20	3.29	4.34	6.85	44	43	12	Loam
	80-90	6.72	0.0841	0.00071	0.0151	0.0167	19.72	3.07	2.49	6.41	34	47	18	Loam
Profile1 A1	0-10	6.98	0.1305	0.00036	0.0140	0.0125	28.81	3.61	3.66	7.35	30	54	14	Silt Loam
A2	40-60	6.73	0.1015	0.00036	0.0185	0.0126	28.13	3.57	6.79	6.6	48	41	9	Loam
A3	60-100	6.62	0.0835	0.00111	0.0227	0.0244	37.70	3.29	8.69	8.21	32	27	38	Clay Loam
Profile2 A1	0-10	6.60	0.0812	0.00084	0.1430	0.0178	26.97	3.22	5.97	7.64	26	55	18	Silt Loam
A2	,10-60	6.65	0.0882	0.00104	0.0141	0.0166	37.41	2.73	6.79	7.89	38	46	14	Loam
A3	60-100	6.83	0.0974	0.00099	0.0135	0.0180	34.22	2.29	7.61	6.79	25	25	48	Clay
Profile3 A1	0-10	6.36	0.1206	0.00071	0.0158	0.0184	38.86	5.76	8.42	7.29	39	48	15	Loam
A2	,10-70	6.73	0.0905	0.00043	0.0156	0.0168	20.01	3.41	6.66	7.33	32	56	13	Silt Loam
A3	70-100	7.02	0.0806	0.00074	0.0178	0.0174	42.05	3.42	6.11	6.14	43	36	22	Loam
	0-10	7.35	0.0679	0.00066	0.0198	0.0223	13.03	3.10	11.14	7.17	25	36	40	Clay Loam
	40-50	6.62	0.0534	0.00086	0.0940	0.0191	35.96	2.91	9.78	6.62	12	43	49	Silt Loam
	0-10	5.90	0.1253	0.00079	0.0125	0.0183	32.77	3.83	8.01	7.33	21	31	45	Clay
	40-50	6.35	0.0574	0.00094	0.0116	0.0163	37.12	3.14	9.23	7.42	24	31	42	Clay Loam
	0-10	6.98	0.0974	0.00037	0.0156	0.0228	33.35	3.39	13.99	6.93	26	38	36	Clay Loam
	40-50	6.37	0.1056	0.00088	0.0145	0.0130	39.15	5.46	12.04	6.56	54	28	22	Sandy Clay Loam

Note:

N% = Nitrogen percent
Ava. P% = Avalable Phosphorus
K% = Potassium
Ca = Calcium

CEC = Cation Exchange Capacity
OM = Organic Matter
Na = Sodium
Mg = Magnesium

APPENDIX II

Global distribution of mangrove

Region	**Mangrove Area (sq.km)**
South and Southeast Asia	75,173 (41.5%)
Australasia	18,789 (10.4%)
The America	49,096 (27.1%)
West Africa	27,995 (15.5%)
East Africa and the Middle East	10,024 (5.5%)
Total Area	**181,077**

Mangrove Forest Areas of Asia-Pacific Region

Country	**Area of Mangroves (ha)**	**Population Density (n/km^2)**
Indonesia	216,271	77.9
Malaysia	6,522,219	43.0
Bangladesh	417,013	629.0
Papua New Guinea	411,600	6.7
Myanmar	382,023	60.6
India	356,500	209.9
Thiland	287,000	110.0
Vietnam	286,400	168.8
Pakistan	249,489	105.1
Philippines	246,699	165.3
Srilanka	4,000	-

Source; UNDP/FAO (MYA/90/003): Report on Mangrove forest Products and Utilization of the Ayeyarwaddy Delta.

APPENDIX III

The Status of Mangroves in Myanmar

State/Division Township	Reserved Forest	Reserved Forest Area(ac)	Mangroves Area (acre)		
			Reserved Forest	**Public Forest**	**Total**
Rakhine State					
Yanbye Township	Wanbike	56,633	56,000	28,000	84,000
Taungoke Township			-	76,000	76,000
Rakhine State Total		**56,633**	**56,000**	**104,000**	**160,000**
Ayeyarwady Division					
Bogalay Township	Kadokani	149,511	102,207	-	102,207
	Meinmala	33,779	31,114	-	31,114
	Pyindaye	189,876	137,785	-	137,785
Township Total		373,166	271,106		271,106
Malamyaing Kyun Township	Nyinaung	17,259	8,343	-	8,343
	Kalayaik	23,654	3,050	-	3,050
Township Total		40,913	11,393	-	11,393
Laputta Township	Kyakan-Kwinpauk	70,926	30,182	-	30,182
	Pyinalan	107,534	76,268	-	76,268
	Kalayan	72,642	57,692	-	57,692
Township Total		251,107	164,142	-	164,142
Ayeyarwady Division Total		**665,181**	**446,641**	**-**	**446,641**
Tanintharyi Division					
MyeikEast Township	Panatuang	5,592	5,900	29,100	35,000
Myeik North Township	Aukland	44,995	45,000	171,000	216,000
	Kwe				
Bokyin Township	Lehnyar	436,480	-	8,400	8,400
Kawthaung Bokyin Township	Pakchan	358,780	-	12,000	12,000
Tanintharyi Division Total		**846,177**	**50,900**	**296,100**	**347,000**
State/ Division Total		**1,567,991 (2,450 sq. miles)**	**55,354 (865 sq. miles)**	**400,100 (625 sq. miles)**	**953,641 (1,490 sq. miles)**

Htun Paw Oo (2001). Status of Mangrove Forest in Myanmar, February, 2001.