# SILVICULTURAL ANALYSIS OF A DEGRADED FOREST THREE YEARS AFTER ENRICHMENT PLANTING: A CASE STUDY

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## ABSTRACT

Degraded forests are capable of producing reduced supply of goods and services from a given site and maintain limited biological diversities. In Myanmar, 7.53% of the total land area (ie, 50,968 sq. km) is covered with degraded forests. If these degraded forests could be properly and effectively rehabilitated, they would provide more wood and non-wood forest products. Through the increased supply of forest products from the rehabilitated degraded forests, the pressure on the closed forests of the country could be reduced. Consequently, both degraded forests and closed forests would be improved. Line enrichment planting is one of the best-known techniques in the rehabilitation of tropical forests. In this study, height performance of teak used as planting stock for line enrichment planting established in 1999 in Ngalaik reserved forest, Pyinmana township was compared with that of the pure teak plantation established in the same year in Kaing reserved forest, Pyinmana township. Analysis of stand structure as well as regeneration dynamics of the study area was carried out. Teak showed better height performance in pure teak plantation than in enrichment planting. It was found that main factor governing the survival and height growth of teak in line enrichment is the availability of overhead light. It was found that the success of the line enrichment planting was dependent on the line width cleared. Regeneration density of teak on the cleared planting lines was higher than that in the original stand left untouched. It was noted that many tree species inclusive of teak and commercially important hardwood species did not reach higher diameter

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classes and possessed small number of individuals. So most species did not possess enough seed bearers. Most commercial species including teak showed very poor regeneration density. Species composition of the enriched degraded forest was highly heterogeneous. The recommendations given by the paper are: (1) to do further research to investigate the best line width that will give optimum overhead light with least adverse impact on the existing vegetation, (2) to use a mixture 2 or 3 species, for instance, Teak and *Pyinkado*, for enrichment planting (3) to do gap planting in combination with line enrichment planting to take advantage of the gaps with plentiful overhead light and to increase the target number of planted teak trees per hectare (4) to plant teak, *Pyinkado*, and *Padauk* for enrichment planting in the degraded forests of Ngalaik Reserved Forest and (5) to implement intensive tending operations at least during the first 5 years for the success of the line enrichment planting.

## 1. INTRODUCTION

*"A **degraded forest** delivers a reduced supply of goods and services from a given site and maintains only limited biological diversity. It has lost its structure, function, species composition and/or productivity normally associated with the natural forest type expected at that site. The term **forest degradation** refers to the reduction of the capacity of a forest to produce goods and services"* (ITTO, 2002).

According to the estimates made by ITTO (2002) in its *guidelines for the restoration, management and rehabilitation of degraded and secondary forests*, some 350 million hectares of tropical forest land have been so severely damaged that forests won't grow back spontaneously, while a further 500 million hectares have forest cover that is either degraded or has regrown after initial deforestation. If degraded forests could be restored or rehabilitated properly, they would have high potential to achieve both environmental and economic benefits. Properly rehabilitated degraded forests will provide local people with wood and non-wood forest products. As a consequence, pressure on the primary forests through such forest products will be reduced. Within this context, researches on rehabilitation methods should be initiated and encouraged in tropical countries as 29% of the total tropical forest area was degraded in 1990.

In Myanmar 43.34% of total land area (ie, 293,269 sq. km) is covered with closed forest, 7.53% of the total land area (ie, 50,968 sq. km) is covered with degraded forests (Anon. 1993; Anon. 2000). The area of degraded forests is about 17.38% of the closed forests in Myanmar. To take advantage of the high potential of properly rehabilitated degraded forests in achieving environmental and economic benefits, the degraded forests of the country should be restored or rehabilitated. Through the forest products produced by the rehabilitated degraded forests, demand for wood and non-wood forest products will be fulfilled to some extent and the pressure on the closed forests of the country could be mitigated. Through rehabilitation of degraded forests of the country, closed forests of the country will also be improved both from the environmental and economical point of views.

To achieve effective and successful implementation of rehabilitation projects, it is highly desirable to conduct research on rehabilitation techniques that will have high feasibility for application in Myanmar and will fit to the current situation of the degraded forests of Myanmar. Researches on rehabilitation techniques that will result in optimum environmental and economic benefits with least adverse change to the forest ecosystem should be encouraged in Myanmar.

Out of several techniques for rehabilitation of degraded forests, enrichment planting is one of the best techniques that will improve the natural regeneration of important economic species in degraded forests with insufficient natural regeneration of such species. Forest Management and Silviculture Sub-division of the Forest Research Institute, Yezin initiated a research project on enrichment planting in a degraded forest in the year 1999. It investigated the best weeding regime to be

applied to line enrichment planting. The present study is the follow up activity to do some investigations on line enrichment planting from a different point of view of study with special emphasis on the stand structure, stand dynamics, and regeneration dynamics of the enriched degraded forest by line planting. A comparative study on the performance of the teak seedlings used as the planting stock for enrichment planting and the teak seedlings used as the planting stock for pure teak plantations is also carried out in this study.

## 2. OBJECTIVES

Objectives of the study are as follows:

1. To compare the height growth of teak seedlings used as planting stock in line enrichment planting and that of teak seedlings used as planting stock in pure teak plantations
2. To study the regeneration potential of a degraded forest enriched by line planting
3. To study the floristic composition and structure of a degraded forest enriched by line planting
4. To document the silvicultural parameters of the degraded forest at the initial stage of rehabilitation by line enrichment planting so that the changes with time could be studied in the future

## 3. STUDY AREA

### 3.1. Location

Two study areas were selected, one in a pure teak plantation established in the year 1999 and the other in a degraded forest enriched by line planting in the same year. The study area selected for pure teak plantation is situated in the compartment no. (8) of the Kaing Reserved Forest, Pyinmana Township. The study area selected for the enriched degraded forest is located in the compartment no. (18) of the Ngalaik Reserved Forest, Pyinmana Township.

### 3.2. Climate

Both study areas are situated in the same township and are situated about 15 km far from each other. It could be assumed that they will have more or less the same macro-climate contitions. Climatic data for both study areas were taken from the Pyinmana Weather Station. The climatic data (monthly means) and DE MARTONNE'S aridity index of Pyinmana Township are shown in Table 1.

**Table (1) The Climatic Data (Monthly Means) and DE MARTONNE'S Aridity Index of Pyinmana township.**

| Month | Jan | Feb | Mar | Apr. | May | Jun | |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | 22.7 | 25.1 | 28.6 | 30.9 | 30.6 | 27.8 | |
| Rainfall (mm) | 3.3 | 4.6 | 2.2 | 13.0 | 111.8 | 211.4 | |
| De Martonne's Aridity Index | 1.2 | 1.6 | 0.7 | 3.8 | 33.0 | 67.1 | |
| **Month** | **Jul** | **Aug** | **Sep.** | **Oct.** | **Nov.** | **Dec.** | **Year** |
| Temperature (°C) | 27.6 | 27.3 | 28.1 | 28.1 | 25.8 | 23.9 | **26.9** |
| Rainfall (mm) | 200.5 | 245.0 | 147.4 | 111.7 | 63.5 | 10.9 | **1329** |
| De Martonne's Aridity Index | 64.0 | 78.8 | 46.4 | 35.2 | 21.3 | 3.9 | **36.0** |

**Source: Meteorological Department, Pyinmana.**

According to the climatic data for the period of 1970 to 1999, the number of rainy days was found to be around 90. Some critical climatic data (1970-1999) for Pyinmana township are as follows:

| | |
|---|---|
| Highest maximum temperature | 42.5˚C (May, 1983) |
| Lowest minimum temperature | 12.1˚C (January, 1997) |
| Highest annual rainfall | 1941 mm (1999) |
| Lowest annual rainfall | 898 mm (1978) |
| Month having highest av. rainfall | August (270.5 mm) |
| Month hvaing lowest av. rainfall | February (2.6 mm) |

**(Source: Meteorological Department, Pyinmana.)**

According to Weidelt (1999), months with an aridity index less below 20 are arid months. The aridity indices of both study areas show a pronounced dry season of 5 months from December to April. Rainy season starts in the month of May and ends in November. There are occasional rains in the month of December. A climatogram for Pyinmana was constructed using climatic data for the period of 1970 to 1999. It is shown in Figure 1.

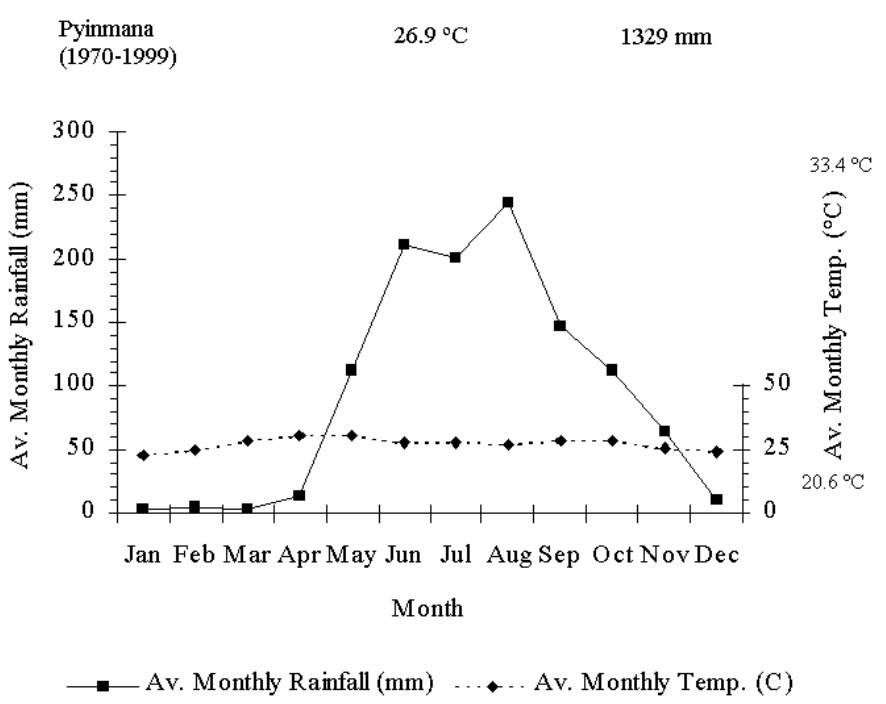



**Figure. 1:** Climatogram for Pyinmana Township.

Teak grows well in warm, moist, tropical regions with an annual rainfall within the range 1,270 mm to 3,810 mm (Haig *et al.*, 1958; Gyi, 1972). Annual rainfall for Pyinmana township is 1329 mm. Both study areas have a favourable rainfall for teak growth. Favourable mean annual temperature range for teak growth is 14-36ºC (ICRAF, 1998). Mean annual temperature for Pyinmana is 26.9ºC and it falls within the favourable temperature range for teak growth.

### 3.3. Soil

One soil profile was dug in each study area. Soil samples were taken from the soil profiles to carry out analysis of their properties. Soil physical and chemical properties tested at the Soil Laboratory of the Forest Research Institute are shown in Table 2 and Table 3.

**Table (2) Physical Properties of Soil for the Study Areas in Pure Teak Plantation and Enriched Degraded Forest**

| Study Areas | **Pure Teak Plantation** | | | **Enriched Degraded Forest** | | |
|---|---|---|---|---|---|---|
| Soil depth | **(0-10) cm** | **(10-50) cm** | **(50-100) cm** | **(0-10) cm** | **(10-50) cm** | **(50-100) cm** |
| Sand % | 88 | 82 | 72 | 34 | 24 | 17 |
| Silt % | 14 | 17 | 21 | 35 | 46 | 63 |
| Clay % | 3 | 7 | 13 | 31 | 29 | 19 |
| Texture | Loamy Sand | Sandy Loam | Sandy Loam | Clay Loam | Clay Loam | Silt Loam |
| MC % | 12.72 | 11.67 | 12.45 | 16.31 | 16.46 | 16.5 |

Remark: MC = Moisture Content

**Table (3) Chemical Properties of Soil for the Study Areas in Pure Teak Plantation and Enriched Degraded Forest**

| Study areas | **Pure Teak Plantation** | | | **Enriched Degraded Forest** | | |
|---|---|---|---|---|---|---|
| Soil depth | **(0-10) cm** | **(10-50) cm** | **(50-100) cm** | **(0-10) cm** | **(10-50) cm** | **(50-100) cm** |
| pH | 6.09 | 5.68 | 5.84 | 5.65 | 5.61 | 6.02 |
| Total N % | 0.0386 | 0.0347 | 0.0296 | 0.0599 | 0.0688 | 0.0291 |
| Av. P % | 0.000165 | 0.000080 | 0.000087 | 0.000029 | 0.000022 | 0.000021 |
| K % | 0.0048 | 0.0040 | 0.0043 | 0.0124* | 0.0073* | 0.0064* |
| Ca % | 1.14 | 0.7375 | 0.9250 | 5.10 | 4.13 | 4.06 |
| Mg % | 0.4792 | 0.3542 | 0.3547 | 4.33 | 6.01 | 6.23 |
| OM % | 1.3 | 0.74 | 0.74 | 3.92 | 3.12 | 2.46 |
| OC % | 2.24 | 1.27 | 1.27 | 6.74 | 5.37 | 4.23 |

Remark: OM = Organic Matter; OC = Organic Carbon; * = $K_2O$%

According to FAO soil classification system, soil of the both study areas is xanthic ferralsols (yellow brown forest soils). Teak usually occurs on soil with a pH within the range of 6.5-7.5. Both study areas possess the soil pH around 6 showing slightly acidic nature.

## 4. MATERIALS AND METHOD

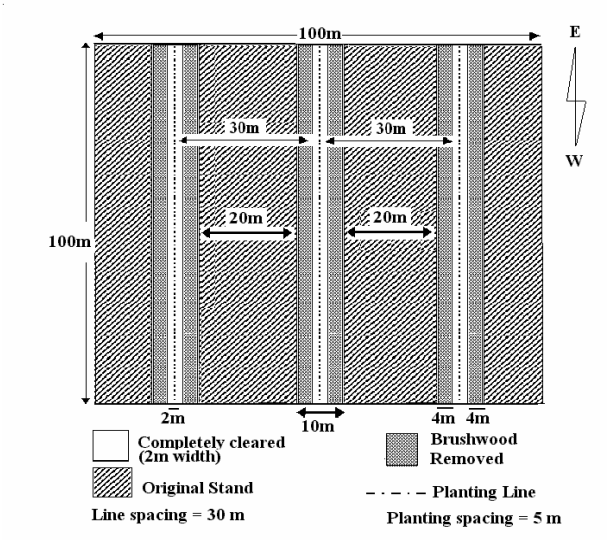
### 4.1. Enriched Degraded Forest

Enriched degraded forest, from which sample was taken for the present study is situated in the compartment no. 18 of the Ngalaik Reserved Forest. The degraded forest was enriched by line planting in the year 1999. Enriched degraded forest covers an area of 3 hectares. It was divided into 3 square plots - each plot covering an area of 1 ha. Plot no. 2 was taken as the sample plot for the present study. Data collection was carried out about 3.5 years after enrichment planting in the selected plot. Planting design of the line enrichment planting is shown in Figure 2.

On the plot selected for data collection, 3 parallel lines with a width of 10 m were cleared in east-west direction at 30 m intervals for enrichment planting. On each planting line, 1m width was completely cleared on both sides of the axis. Up to a distance of 5 m on both sides of the axis, all climbers are cut and brushwood layers together with young trees (with the exception of economic species) up to a height of about 2-4 m were removed. Teak seedlings with an average height of 45 cm were planted on the axis of the cleared line at a distance of 5m.

Weeding was carried out one time on the line no. 1, two times on the line no. 2 and three times on the line no. 3 in the first year after planting. In the following years, weeding was carried out two times in the months of June and November annually.

**Figure 2:** Planting design of the line enrichment planting on the selected sample plot.



## 4.2. Pure Teak Plantation

Pure teak plantation, from which sample was taken for the present study is situated in the compartment no. (8) of the Kaing Reserved Forest, Pyinmana township. Planting of teak seedlings in the field was carried out in the year 1999. Planting was carried out at a distance of 9 feet (ie, approximately 3 m). Weeding was carried out 3 times in the first year, two times in the second year and one time in the third year after planting. Data collection for the present study was carried out about 3.5 years after planting. Fire protection was carried out.

## 4.3. Sample Plot Design for the Enriched Degraded Forest

Standard 100 x 100 m plot (Alder and Synnott, 1992) was used. The 100 x 100 m plot was subdivided into 25 square sub-plots (Record Units), each of 20 x 20 m. The layout of the sample plot is shown in Figure 3.

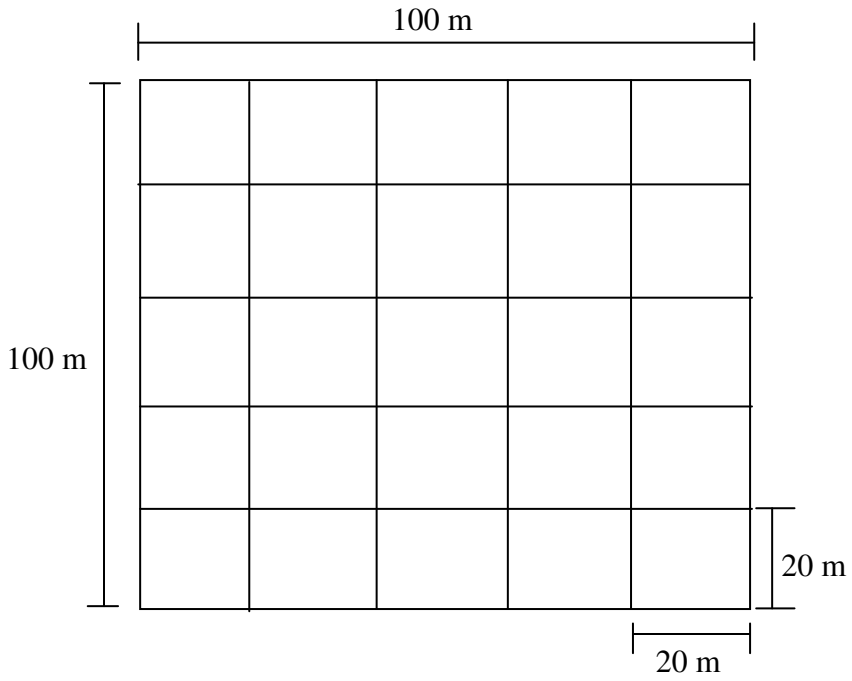



**Figure. 3:** Layout of standard 100 x 100 m plot.

Each square sub-plot contains compartments A and B. Compartment A contains four sub-compartments, A1, A2, A3 and A4. Compartment B contains four sub-compartments, B1, B2, B3 and B4. Layout of a square sub-plot (record unit) is shown in Figure 4.

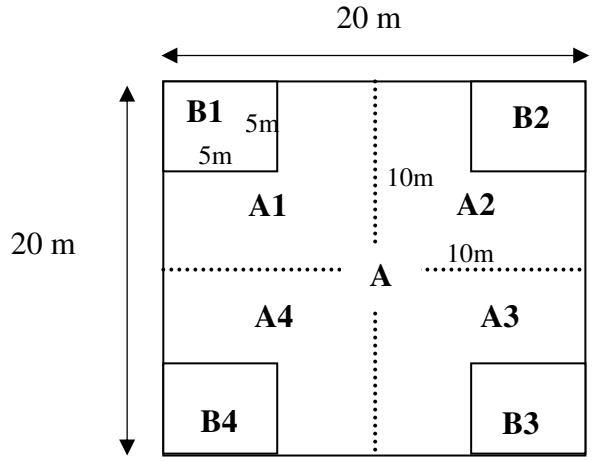



**Figure. 4:** Layout of a square sub-plot (record unit).

### 4.4. Inventory Parameters for Data Collection in the Enriched Degraded Forest

The inventory parameters recorded in each square sub-plot or record unit are shown in in Table 4.

**Table (4) Inventory Parameters Recorded in each Square Sub-plot (Record Unit) in the Enriched Degraded Forest.**

| Sr. | Parameters recorded | Compartment of the Record Unit | Remark |
|---|---|---|---|
| 1. | Measurement for all trees with a height ≥ 1.3 m<br>- For all trees with a DBH ≥ 10 cm, total height, crown point height, and DBH were measured.<br>- For all trees with a DBH ≥ 5 cm and < 10 cm, total height and DBH was measured.<br>- For all saplings with a height ≥ 1.3m and with a DBH < 5 cm, total height was measured. | Compartment A (ie., A1, A2, A3 & A4) | Breast Height = 1.3 m |

| | | | |
|---|---|---|---|
| 2. | Regeneration counting for teak<br>- No. of seedlings, root-suckers and stool-coppices with a height ≥ 30cm and < 130 cm was recorded | Compartment A (ie., A1, A2, A3 & A4) | |
| 3 | Regeneration counting for all species<br>- No. of seedlings with a height ≥ 30 cm and < 130 cm was recorded. | Compartment B (ie., B1, B2, B3 & B4) | |

Total height of all teak seedlings, saplings and poles planted by line enrichment planting was also measured and recorded separately.

### 4.5. Sample Plot Design for the Pure Teak Plantation

The same sample plot design as that for the enriched degraded forest (ie, Standard 100 x 100 m plot) was used for data collection in the pure teak plantation. A representative area of 1 ha was subjectively selected from the pure teak special plantations of three years age in Pyinmana Township for the purpose of comparative study on height growth of teak seedlings/saplings between a pure teak plantation and a degraded forest enriched with teak seedlings by means of line planting. The representative area selected for height measurement in the pure teak plantation is situated in the Kaing reserved forest which is the nearest to the enriched degraded forest. The square sample plot was sub-divided into 25 square sub-plots or record units.

### 4.6. Inventory Parameters for Data Collection in the Pure Teak Plantation

In each square sub-plot or record unit of the sample plot selected for the pure teak plantation, total height of all seedlings, saplings and poles reaching a height ≥ 30 cm was measured and recorded. Outliers from the recorded data were not used in data analysis. Coppices from the failed plantations on the same site were removed from the list and the rest were used for data analysis.

## 5. RESULTS AND DISCUSSION

### 5.1. Comparison of Height Growth between Pure Teak Plantation and Line Enrichment Planting

To compare the height growth between pure teak plantation and line enrichment planting, two tailed two sample t-test was conducted.

For this purpose, over 1ha area, cent per cent enumeration was carried out in a pure teak plantation planted in the same year as enrichment planting. From the data

collected, height measurements of teak coppices that came out from the stumps of failed teak plantations of the past on the same site of the current pure teak plantation were removed. The rest were used as sample trees. Height of teak seedlings and saplings that have been used as planting stock for enrichment planting in a degraded forest with an area of 3 ha was also measured and they have been used as sample trees for the comparative study. Details of test results are shown in Table 5.

**Table (5) Results of Two Tailed Two-Sample T-test for Ht. (cm) by variables.**

| Variables | N | Mean | St. Dev. | SE Mean |
|---|---|---|---|---|
| **Line Enrichment Planting** | 121 | 114.8 | 88.1 | 8.0 |
| **Pure Teak Plantation** | 438 | 217.0 | 103.0 | 4.9 |

Difference = μ (Line Enrichment Planting ) - μ (Pure Teak Plantation- )
Estimate for difference: -102.04
95% CI for difference: (-120.56, -83.53)
T-Test of difference = 0 (vs not =): T-Value = -10.86 P-Value = 0.000 DF = 218

According to the test results, mean height of teak seedlings and saplings of the pure teak plantation is significantly higher than that of line enrichment planting.

Both study areas have similar macro-climatic conditions and the soil properties are also more or less the same in both study areas. There is a considerable difference between pure teak plantation and line enrichment planting in the availability of overhead light for the teak seedlings. So overhead light intensity becomes the growth-determining factor for the pure teak plantation and line enrichment planting.

*"Teak seedlings are intolerant of shade and thrive best entirely in the open"* (Troup, 1921). That is why teak seedlings and saplings of the pure teak plantation shows better height growth than those of line enrichment planting. At the same time, it is also the reason for the poor height growth of teak seedlings and saplings of the line enrichment planting. Main reason for poor height growth is the limited overhead light on the cleared lines. Even though planting lines have been cleared 2 m in width, overhead light available for the teak seedlings is not sufficient especially when the planting lines passes through the valleys, near valley bottom sites and slopes. Bamboo clumps growing on the edge of the cleared planting lines also give side shade to the teak seedlings as their branches bend over the teak seedlings.

In the pure teak plantation, teak seedlings with minimum height growth attained the height of 30 cm. Although the teak seedlings and saplings of the pure teak plantation showed a better height performance than those of the line enrichment planting, some of them still showed poor height growth on the sites with dense growth of thatch. *"Thatch rhizomes mainly confine on the soil surface and thatch is the very aggressive weed regarding in root competition with young seedlings in early*

*age"* (Thein Lwin, 1983). Even if teak roots can compete with thatch roots and get a good anchorage deep below the thatch roots, water permeability of the surface soil will be greatly reduced due to dense growth of thatch roots confined to the surface soil. As a result, teak roots will have to encounter some difficulties in water absorption and nutrient uptake through water due to limited soil water. The cause for poor growth of teak seedlings on the sites with dense growth of thatch is not only the thatch itself but also the annual fire. There is evidence of annual surface fire in the areas with dense occurrence of thatch. In such areas, two dry shoots always accompany the living teak shoot. It can be explained by the die-back phenomenon of teak seedlings. "*The root-stock of teak is fire-resistant because of a special adaptation of thickening, enabling the species to survive in areas subjected to annual fires. The above-ground growth is destroyed in fires but the root-stock survives and gets successively stronger, and finally, a permanent vigorous shoot is produced which survives the fire"* (Troup, 1992). To achieve best height growth in pure teak plantations, it is recommended that a weeding regime more intensive than the weeding regime in current use should be practised and protection against annual fire should be carried out more effectively.

### 5.2. Survival Percentage of Planted Teak by Line Enrichment Planting

In case of survival percentage of teak in the line enrichment planting, it was found to be 65%. One reason for the low survival percentage of teak in line enrichment planting is its intolerance of shade and limited light along the planting lines. It was observed that teak seedlings of the line enrichment planting survived least where the planting lines fell in the valley where overhead light was insufficient. On the other hand teak seedlings of the line enrichment planting survived best where the planting lines fell on the ridge top and near ridge top sites where more overhead light was available. To achieve success in any type of line enrichment planting using teak or any other light demanding species as planting stock, opening of light along the lines is a must. Besides, width of the line to be cleared should be wide enough to provide teak seedlings with sufficient overhead light for their survival and good height growth.

### 5.3. Teak Regeneration Improvement by Line Enrichment Planting

To investigate teak regeneration improvement by line enrichment planting, regeneration counting for teak was carried out both on the cleared planting lines and in the original stand left untouched. Teak regeneration on the cleared planting lines is composed not only of planted teak seedlings and saplings but also of naturally regenerated teak improved by light opening along the planting lines. The number of planted teak seedlings and saplings is 42 and the number of teak seedlings and saplings that regenerated naturally on the cleared planting lines as a result of line opening was found to be 30. It showed that line opening ensured not only good

growth of planted teak but also natural regeneration of teak on the cleared planting lines.

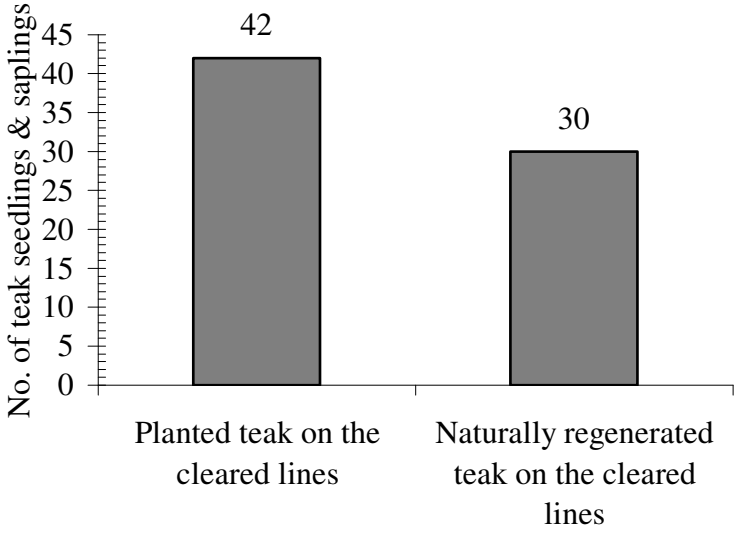



**Figure. 5:** Comparison of planted teak and naturally regenerated teak on the cleared planting lines.

Regeneration density of teak on the cleared lines and that in the original stand were calculated. Total number of teak seedlings and saplings on the cleared planting lines is 72. The area of the three cleared planting lines covers 600 $m^2$. Teak regeneration density on the cleared planting lines is 12/100 $m^2$. Total number of teak seedlings and saplings in the original stand is found to be 189. The area of the original stand left untouched covers 9400$m^2$. Teak regeneration density in the original stand is 2.7/100 $m^2$. Teak regeneration density on the cleared planting line is approximately six times higher than that in the original stand. It shows that line enrichment planting improves teak regeneration density of the degraded forest. A histogram was constructed to have a comparative view and is shown in Figure 6.

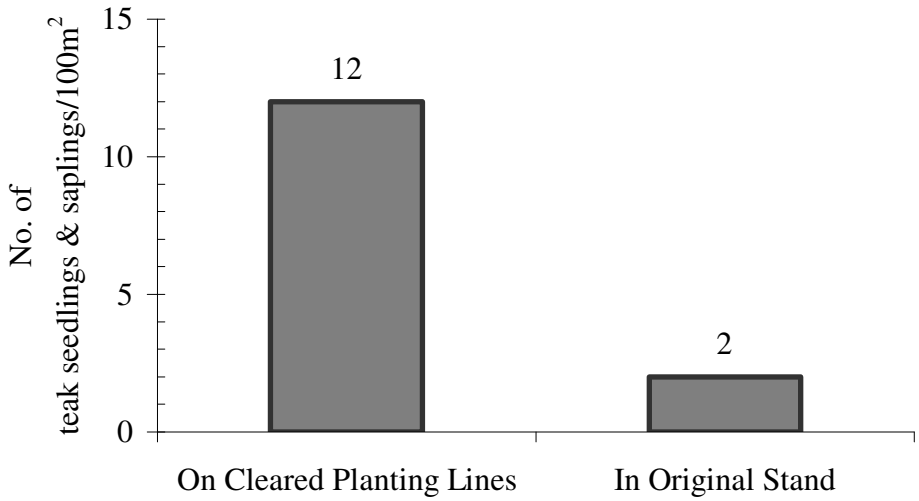



**Figure. 6:** Teak regeneration density on the cleared planting lines and in the original stand left untouched between the planting lines.

### 5.4. Abundance, Dominance, Frequency and Importance Value Index (IVI)

Abundance is the stem number of a given species per hectare. Dominance is the degree of coverage of a species as an expression of the space it occupies. Frequency is the occurrence or absence of a given species in a subplot (Lamprechet, 1989).

Total number of species found in the enriched degraded forest is 49. Total abundance is 401. Total dominance of the enriched degraded forest is 7.4 $m^2$/ha.

Importance Value Index (IVI) is calculated as the sum of relative abundance, relative dominance and relative frequency (Weidelt, 1999). Importance value indices for all species reaching a DBH $\geq$ 5 cm were calculated and the species were ranked according to their importance value index. Yinma is found to be the species with the highest IVI value and Kyun takes the second position. Padauk takes the third position.

As importance value index is a conglomerate of relative abundance, relative dominance and relative frequency of each species, the species possessing high IVI values have high potential for high volume production. Species with high IVI values play vital role in the forest ecosystem of the investigated stand. If timber of a species with high IVI value has economic value, such a species will be important not only from environmental point of view but also from economical point of view. Any silvicultural treatments to be carried out in the future in this enriched degraded forest should be focussed on these species. Abundance, dominance, frequency and importance value index (IVI) of ten species possessing highest IVI values are shown in Table 6.

**Table (6) Abundance, Dominance, Frequency and Importance Value Index (IVI) for 10 Species with Highest Importance Value Index in the Enriched Degraded Forest Arranged in Descending Order of IVI (sample area = 1 ha, min. dia = 5 cm).**

| Ranking | Species | Total | | | Relative | | | IVI |
|---|---|---|---|---|---|---|---|---|
| | | Ab. N/ha | Dom. $m^2$/ha | Freq. % | Ab. % | Dom. % | Freq. % | |
| 1 | Yinma | 55 | 0.612 | 34 | 13.7 | 8.2 | 11.8 | 33.8 |
| **2** | **Kyun (Teak)** | **61** | **0.464** | **29** | **15.2** | **6.2** | **10.1** | **31.6** |
| 3 | Padauk | 31 | 0.595 | 17 | 7.7 | 8.0 | 5.9 | 21.7 |
| 4 | Bebya | 28 | 0.633 | 17 | 7.0 | 8.5 | 5.9 | 21.4 |
| 5 | Seikchi | 23 | 0.729 | 16 | 5.7 | 9.8 | 5.6 | 21.1 |
| 6 | Thadi | 6 | 0.961 | 5 | 1.5 | 12.9 | 1.7 | 16.2 |
| 7 | Didu | 22 | 0.276 | 19 | 5.5 | 3.7 | 6.6 | 15.8 |
| 8 | Pyinkado | 14 | 0.271 | 13 | 3.5 | 3.6 | 4.5 | 11.7 |
| 9 | Kyetyo | 10 | 0.265 | 9 | 2.5 | 3.6 | 3.1 | 9.2 |
| 10 | Thitpagan | 7 | 0.296 | 7 | 1.7 | 4.0 | 2.4 | 8.2 |
| **Total** | | **257** | **5.102** | **-** | **64** | **68.5** | **57.6** | **190.7** |
| 11-49 | Other species | 144 | 2.321 | 121 | 36 | 31.5 | 42.4 | 109.3 |
| **Grand Total** | | **401** | **7.423** | **-** | **100.0** | **100.0** | **100.0** | **300.0** |

### 5.5. DBH Class Distribution of the Enriched Degraded Forest

The best way to assess dynamic processes are observations over long periods. However it is impossible in many cases. Regarding those processes, conclusions could be drawn from the present structure. DBH class distributions are a useful means for this purpose (Weidelt, 1999). DBH class distributions of the enriched degraded forest, based on all trees with a DBH ≥ 5 cm is shown in Figure 7.

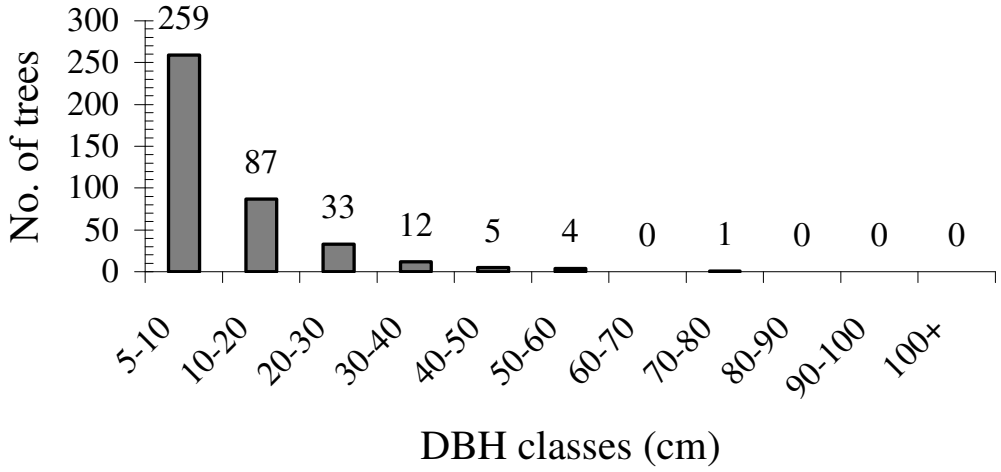



**Figure. 7:** DBH class distribution for all species found in the enriched degraded forest (sample area = 1 ha, min. diameter = 5 cm).

According to the DBH class distribution of the enriched degraded forest, most of the individual trees accumulate in the lower diameter classes. The number of trees decreases from lower diameter classes to the higher diameter classes with a steep gradient. There is a total lack of large diameter trees. There is only one tree which reaches above the harvestable minimum diameter limit set by Myanmar Selection System. It means that the forest has been severely degraded.

### 5.6. DBH Class Distribution of Ten Species with the Highest IVI Values

DBH class distribution for all species (ie, 49 species) was analysed. DBH class distribution of ten species with the highest IVI values is shown in Table 7. Individual trees of these species accumulate in the smaller diameter classes. No species possesses individual trees above the harvestable minimum diameter limit. Only the individual trees of Thadi are distributed evenly in the diameter classes and one Thadi tree reaches above the harvestable minimum diameter limit. Generally almost all species including the species with highest IVI values do not have enough seed bearers. Thus almost all species including the species with highest IVI values will have to face with difficulties to have successful continuous natural regeneration.

**Table (7) Distribution of Individuals in Diameter Classes for 10 Species with Highest Importance Value Index in the Enriched degraded Forest, Arranged in Descending Order of IVI (sample area = 1 ha, min. dia. = 5 cm).**

| Sr. | Species | Diameter Classes (cm) | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | 80-90 | 90-100 | 100+ | |
| 1 | Yinma | 38 | 12 | 4 | 1 | | | | | | | | 55 |
| **2** | **Kyun (Teak)** | **53** | **6** | | **2** | | | | | | | | **61** |
| 3 | Padauk | 15 | 11 | 4 | 1 | | | | | | | | 31 |
| 4 | Bebya | 6 | 17 | 4 | 1 | | | | | | | | 28 |
| 5 | Seikchi | 13 | | 6 | 4 | | | | | | | | 23 |
| 6 | Thadi | 2 | | | | 2 | 1 | | 1 | | | | 6 |
| 7 | Didu | 18 | 3 | | | 1 | | | | | | | 22 |
| 8 | Pyinkado | 8 | 2 | 4 | | | | | | | | | 14 |
| 9 | Kyetyo | 4 | 4 | 1 | 1 | | | | | | | | 10 |
| 10 | Thitpagan | 6 | | | | | 1 | | | | | | 7 |
| **Total** | | **163** | **55** | **23** | **10** | **3** | **2** | | **1** | | | | **257** |
| 11-49 | Other species | 32 | 10 | 2 | 2 | 2 | | | | | | 144 | 32 |
| **Grand total** | | **259** | **87** | **33** | **12** | **5** | **4** | | **1** | | | | **401** |

## 5.7. DBH Class Distribution of Teak

DBH class distribution of Teak follows the same trend as the other species of the enriched degraded forest. DBH class distribution of teak trees concentrates in the lower diameter classes. No teak yield tree is present. Intensive tending operations are necessary to encourage regeneration and to boost up the younger age classes for future recruitment into larger DBH classes. DBH class distribution of Teak is shown in Figure 8.

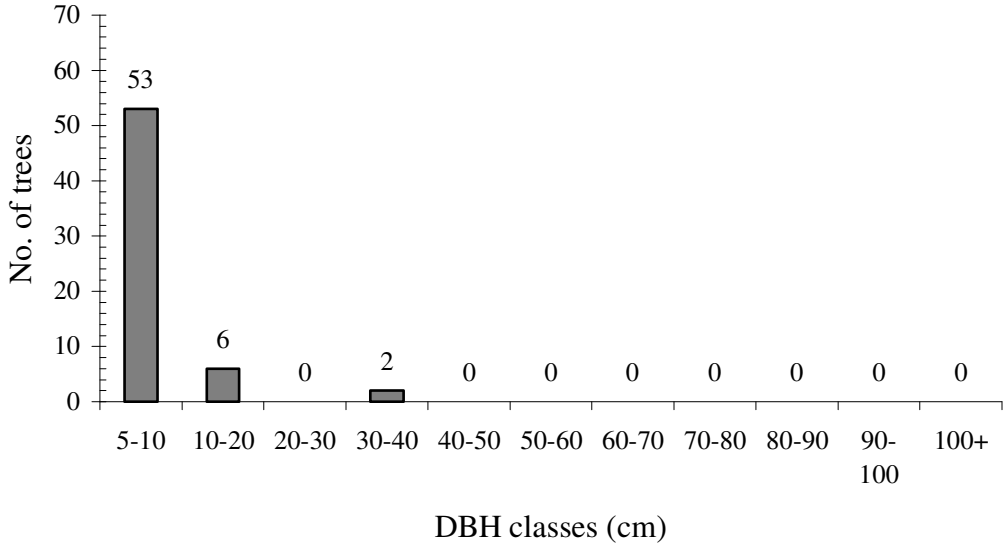



**Figure. 8**: DBH class distribution of teak found in the enriched degraded forest (sample area = 1 ha, min. diameter = 5 cm).

There is no teak tree above 40 cm DBH. There are 53 teak trees in the lowest DBH class (ie, 5-10 cm DBH). It decreases abruptly. Only 6 trees are present in the second lowest DBH class (ie, 10-20cm DBH). There are only 2 teak trees in the 20-40 DBH class. It is not sure that the teak trees below 40 cm DBH will produce sound seeds. Even if they can produce sound seeds, they cannot provide the area with enough seeds due to the relatively small number of seed trees. Due to lack of teak seed trees, there will be problems for successful continuous natural regeneration of teak. As a result of insufficient number of teak seed trees, probability for cross pollination of teak trees is greatly reduced. Consequently, there exists the likelihood that seed trees will produce seeds by selfing. As a result, inbreeding depression will set in and the genetic quality of teak will become inferior in the next generations in this area. Enrichment planting with teak in such a degraded forest with lack of teak seed trees is a right decision.

### 5.8. Distribution of Species in DBH Classes

Distribution species in DBH classes was analysed and is shown in Figure 9. Figure shows that distribution of species in DBH classes concentrate in the lower and middle classes. The number of species decreases with increasing DBH classes. Only a very few species reach the middle classes. There is only one species (ie, Thadi) above the harvestable minimum diameter limit. Generally it can be concluded that most species cannot reach middle and larger diameter classes. In other words most

species have encountered problems in recruiting into larger diameter classes. There are two main reasons for such a situation. The first reason is the relationship between the number trees and the number of species in each diameter classes. The number of individual trees concentrates in the lower diameter classes and decreases into the larger diameter classes. So the number of species also decreases into larger diameter classes in the same manner as the number of individual trees. The second reason is that most of the species have no chance or very rare chance to recruit into larger diameter classes, because they have already been intensively used or over-exploited. Only a very few species that are less used has the chance to recruit into larger diameter classes.

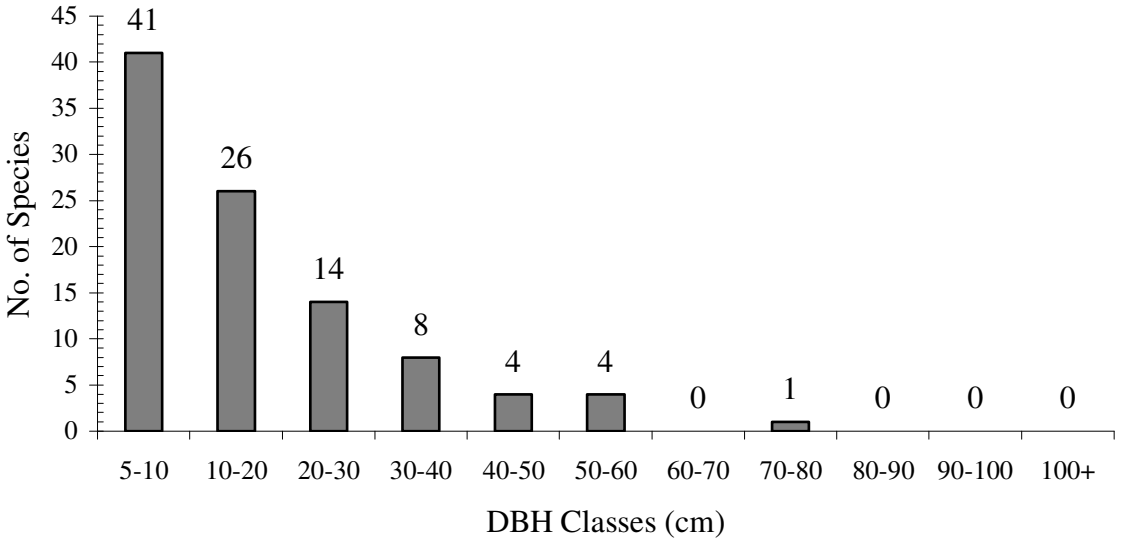



**Figure. 9:** Distribution of species in the DBH classes, in the enriched degraded forest (Sample area = 1 ha, min. dia = 5 cm)

### 5.9. Regeneration dynamics of the enriched degraded forest

To evaluate the regeneration potential of the enriched degraded forest stand, regeneration counting for all species other than teak was carried out in one hundred square sub-plots - each sub-plot covering an area of 25 $m^2$. Total sample area for regeneration counting for all species other than teak is 0.25 ha. Well established seedlings reaching a height between 0.3 m and 1.3 m were recorded. Seedlings below 0.3 m in height were not counted as they are not so sure to survive. They are just ephemeral. Regeneration counting for teak was carried out in 100 square sub-plots - each sub-plot covering an area of 100 $m^2$. Sample area for teak regeneration

counting is 1 ha. To have a reasonable comparison with regeneration density of other species, regeneration density of teak was adjusted for 0.25 ha.

Regeneration density for all species of the enriched degraded forest is found to be 935 seedlings/0.25 ha. List for regeneration density of all species is shown in the appendix. Fifteen species with highest regeneration densities are shown in Table 8.

**Table (8) Regeneration Density of 15 Species Possessing the Highest Regeneration Density in the Enriched Degraded Forest.**

| Sr. | Species | No. of seedlings/ 0.25ha | Sr. | Species | No. of seedlings/ 0.25ha | Sr. | Species | No. of seedlings/ 0.25ha |
|---|---|---|---|---|---|---|---|---|
| 1 | Lettokkyi | 140 | 6 | Seikchi | 39 | 11 | Didu | 20 |
| 2 | Petthan | 96 | 7 | Yon | 39 | 12 | Gyo | 20 |
| 3 | Yinma | 82 | 8 | Tayaw | 35 | 13 | Kinbalin | 19 |
| 4 | Kyun-nalin | 80 | 9 | Madama | 34 | 14 | Pyinkado | 15 |
| 5 | Bebya | 72 | **10** | **Kyun (Teak)** | **30** | 15 | Kuthan | 14 |

Lettokkyi takes the first position in regeneration density among all species found in the enriched degraded forest. Regeneration density of teak takes the tenth position. Pyinkado, an important economic species takes the 14$^{th}$ position. In general, important economic species including teak, Pyinkado and Padauk do not possess the higher positions in regeneration density in the enriched degraded forest. It would be a right decision to encourage the regeneration density of such important economic species with low regeneration density by means of line enrichment planting, in nearby areas in the Ngalaik Reserved Forests.

Positions of regeneration density of species with high IVI values are shown in Table 9.

**Table (9) Regeneration Density Position of 10 Species with Highest IVI Values**

| IVI Rank | Species | Regeneration Density Position | IVI Rank | Species | Regeneration Density Position |
|---|---|---|---|---|---|
| 1 | Yinma | 3 | 6 | Thadi | 17 |
| **2** | **Kyun (Teak)** | **10** | 7 | Didu | 11 |
| 3 | Padauk | 29 | 8 | Pyinkado | 14 |
| 4 | Bebya | 5 | 9 | Kyetyo | 19 |
| 5 | Seikchi | 6 | 10 | Thitpagan | 22 |

Important economic species possessing high IVI values do not take good positions in regeneration density in the enriched degraded forest. For instance, teak takes the tenth position. Padauk takes the 29th position and Pyinkado takes the 14th position. The regeneration density of these three species should be encouraged.

## 5.10. Species Area Curve of the Enriched Degraded Forest

A species area curve was constructed for the enriched degraded forest to investigate whether the sample area (ie, 1 ha)is enough or not for silvicultural analysis of this degraded forest and to investigate on the spatial distribution of floristic forest types. For this purpose, one hundred square sub-plots - each covering an area of 100 $m^2$ have been used for data collection. Species area curve of the enriched degraded forest is shown in Figure 10.

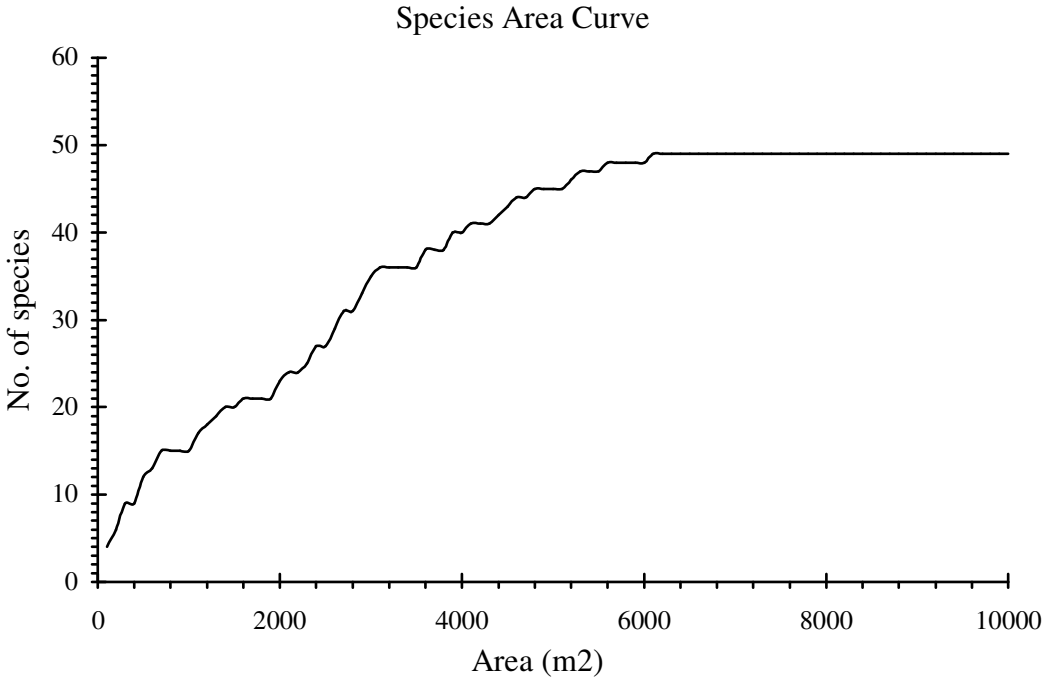



**Figure.10:** Species area curve of the enriched degraded forests. (Sample area = 100 sub-plots x 100 $m^2$, min. dia = 5 cm)

The species area curve shows that no new species was found after enumeration on 0.6 ha (= 60 sub-plots). Thus 1 ha sample plot is enough for silvicultural analysis of this enriched degraded forest. Only one or two new species were found in enumerating a new plot. The number of new species increases with gradual and constant rate in enumerating from plot to plot.

## 5.11. Frequency Diagram of the Enriched Degraded Forest

The frequencies give an approximate indication of the homogeneity of a stand (Lamprecht, 1989). To evaluate the homogeneity of the enriched degraded forest, a frequency diagram was constructed and is shown in Figure 11.

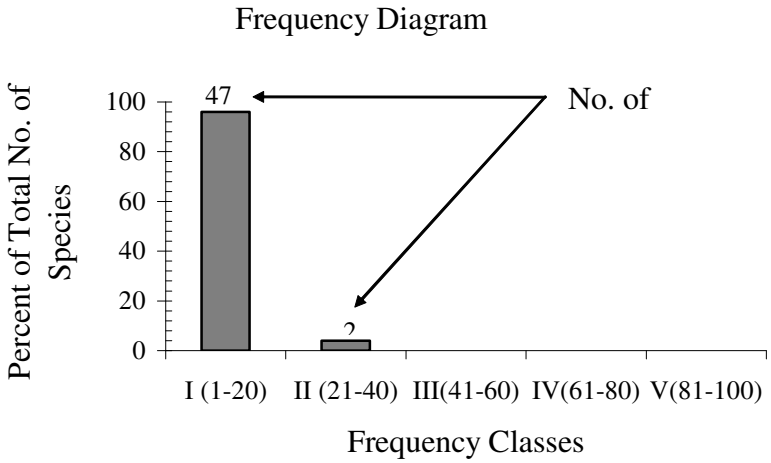



**Figure.11**: Frequency diagram of the enriched degraded forest. (Sample area = 100 sub-plots x100 $m^2$; min. dia. = 5 cm DBH)

47 species (ie, 96% of the species found in the enriched degraded forest) fall in the lowest frequency class, I (1-20). Only 2 species (ie, 4% of the species found in the enriched degraded forest) fall in the second lowest frequency class, II (21-40). No species is present in the higher frequency classes, III to V.

High values in classes I/II indicate a high degree of floristic heterogeneity (Lamprecht, 1989). It could be concluded that the species composition over the whole area of the enriched degraded forest is highly heterogeneous. All the 49 species found in the enriched degraded forest scattered singly.

In case of teak, there are only 6 teak trees in the DBH class 10 to 20 cm, and only 2 teak trees in the DBH class 30 to 40 cm. Due to their small DBHs, it is uncertain that they will produce sound seeds for successful natural regeneration. On the other hand, according to their low frequency values, it could be concluded that they scattered singly over the area. Teak possesses low abundance with small diameter trees scattering singly over the area. This can lead to problems in natural regeneration of teak because of lack of promising seed trees and difficulty of seed distribution over the area as the trees scattered singly. Besides, there exists a high likelihood of selfing due to scattered distribution of teak possessing very small

number of individual trees. As a result, genetic quality of teak seeds of this area will become inferior due to inbreeding depression.

## 6. RECOMMENDATIONS

To achieve more success in line enrichment planting, the author would like to give the following recommendations.

(1) Line width to be cleared depends on the height of existing vegetation of the degraded forest to be enriched and on the degree of light requirement of the species to be used as planting stock for enrichment planting. It is necessary to conduct research on different modifications of line opening that will give optimum overhead light with least adverse change to the existing vegetation and on the height growth of light demanders and shade bearers in response to different line widths.

(2) It is recommended that a mixture of 2 or 3 species with different characteristics especially in shade tolerance should be used for line enrichment planting. In practising enrichment planting, economic species are generally used as planting stock. In the degraded forest to be enriched, overhead light availability is not homogeneous along the planting lines and light conditions are not always satisfactory along the planting lines even after the lines have been cleared. If teak alone is planted, it will fail to survive where overhead light does not meet its requirement as it is a light demanding species. Even if it survives, it will not grow fast where there is lack of overhead light. Shade bearers should be used where the planting lines pass through the valleys and where the planting lines fall under the side shade of the bamboo clumps. For this purpose the author would like to recommend Pyinkado. Teak or any other light demanding species should be planted only where the planting lines have plentiful overhead light.

(3) In the enriched degraded forest, only 63 teak seedlings were planted in 1 ha with three planting lines at an interval of 30 m between the planting lines. In line enrichment planting, very limited number of planted teak per hectare is available. In the study area, gaps with sufficient overhead light were observed. To take advantage of these gaps, gap planting should also be carried out at the time of line planting. By this way, target number of planted teak trees per hectare could be increased.

(4) Before deciding the species to be used in line enrichment planting, regeneration survey and structural analysis of the degraded forest stand should be carried out. Species should be chosen based on the results of regeneration survey and structural analysis. Economic species possessing poor regeneration density and/or insufficient number of seed bearers should be chosen. For the degraded forests in the nearby areas of the study area, teak, Pyinkado and Padauk are recommendable.

(5) To achieve success in line enrichment planting, effective maintenance is necessary for a long period. According to Weidelt (1976), the most decisive factor for the success of line enrichment are the tending operations at least during the first 5 years:

- Weed control- especially during the first two years,
- Poison girdling of all undesirable trees overtopping the lines, especially when the seedlings become older and more light demanding,
- Systematic removal of undesirable secondary vegetation on the lines,
- Climber cutting whenever necessary.

It is absolutely essential, that the required funds for these tending operations are guaranteed at the time of planting, otherwise the funds spent for the establishment are spent in vain.

## 7. CONCLUSION

"If there is an insufficient number of economically valuable trees in the initial stand, or if there is a complete lack of such trees (e.g. in logged-over forests), then enrichment may be a better option than improvement. The best-known enrichment is no-doubt line planting. This system is today used all over the tropics and is found in all sorts of variants, some of them local" (Lamprecht, 1989). To achieve success in line enrichment planting in Myanmar, it is necessary to conduct a series of research activities to find out some types of line enrichment planting that will be best suited and most feasible in rehabilitation of degraded forests in Myanmar. This study attempts to build up some useful information about line enrichment planting already established in Myanmar. This information would be hopefully useful for the forestry practitioners working in the field of forest rehabilitation and plantation establishment. However, the recommendations of this study should not be extendedly applied to all types of degraded forests distributed all over the country as the degraded forests situated in different climatic zones of the country will have different silvicultural parameters. Anyway, the author would like to conclude giving the suggestion that the findings and recommendations of the study would be useful at least for the rehabilitation of the degraded forests possessing more or less the same silvicultural parameters as the forest stand of the present study and for the rehabilitation of the degraded forests of Ngalaik Reserved Forests.

**Appendix 1**

Abundance, dominance, frequency and Importance Value Index (IVI) for all tree species found in the enriched degraded forest, arranged in decending order of IVI (based on the individuals having a DBH ≥ 5 cm).

| Ranking | Species | Total | | | Relative | | | IVI |
|---|---|---|---|---|---|---|---|---|
| | | Ab. N/ha | Dom. $m^2$/ha | Freq. % | Ab. % | Dom. % | Freq. % | |
| 1 | Yinma | 55 | 0.612 | 34 | 13.7 | 8.2 | 11.8 | 33.8 |
| **2** | **Kyun (teak)** | **61** | **0.464** | **29** | **15.2** | **6.2** | **10.1** | **31.6** |
| 3 | Padauk | 31 | 0.595 | 17 | 7.7 | 8.0 | 5.9 | 21.7 |
| 4 | Bebya | 28 | 0.633 | 17 | 7.0 | 8.5 | 5.9 | 21.4 |
| 5 | Seikchi | 23 | 0.729 | 16 | 5.7 | 9.8 | 5.6 | 21.1 |
| 6 | Thadi | 6 | 0.961 | 5 | 1.5 | 12.9 | 1.7 | 16.2 |
| 7 | Didu | 22 | 0.276 | 19 | 5.5 | 3.7 | 6.6 | 15.8 |
| 8 | Pyinkado | 14 | 0.271 | 13 | 3.5 | 3.6 | 4.5 | 11.7 |
| 9 | Kyetyo | 10 | 0.265 | 9 | 2.5 | 3.6 | 3.1 | 9.2 |
| 10 | Thitpagan | 7 | 0.296 | 7 | 1.7 | 4.0 | 2.4 | 8.2 |
| 11 | Tayaw | 9 | 0.194 | 9 | 2.2 | 2.6 | 3.1 | 8.0 |
| 12 | Dwani | 12 | 0.139 | 8 | 3.0 | 1.9 | 2.8 | 7.7 |
| 13 | Magyi-bauk | 13 | 0.086 | 9 | 3.2 | 1.2 | 3.1 | 7.5 |
| 14 | Petwun | 8 | 0.150 | 8 | 2.0 | 2.0 | 2.8 | 6.8 |
| 15 | Kuthan | 10 | 0.085 | 7 | 2.5 | 1.1 | 2.4 | 6.1 |
| 16 | Petthan | 9 | 0.070 | 8 | 2.2 | 0.9 | 2.8 | 6.0 |
| 17 | Gwe | 4 | 0.245 | 4 | 1.0 | 3.3 | 1.4 | 5.7 |
| 18 | Nabe | 8 | 0.071 | 8 | 2.0 | 1.0 | 2.8 | 5.7 |
| 19 | Pokethinma-myetkok | 3 | 0.272 | 3 | 0.7 | 3.7 | 1.0 | 5.5 |
| 20 | Gyo | 7 | 0.082 | 6 | 1.7 | 1.1 | 2.1 | 4.9 |
| 21 | Lettok-gyi | 5 | 0.026 | 5 | 1.2 | 0.3 | 1.7 | 3.3 |
| 22 | Sawbya | 1 | 0.192 | 1 | 0.2 | 2.6 | 0.3 | 3.2 |
| 23 | Unidentifiable | 8 | 0.064 | 1 | 2.0 | 0.9 | 0.3 | 3.2 |
| 24 | Kyun-nalin | 4 | 0.038 | 4 | 1.0 | 0.5 | 1.4 | 2.9 |
| 25 | Hnaw | 2 | 0.111 | 2 | 0.5 | 1.5 | 0.7 | 2.7 |
| 26 | Yinzat | 2 | 0.105 | 2 | 0.5 | 1.4 | 0.7 | 2.6 |
| 27 | Binga | 2 | 0.088 | 2 | 0.5 | 1.2 | 0.7 | 2.4 |
| 28 | Madama | 4 | 0.024 | 3 | 1.0 | 0.3 | 1.0 | 2.4 |
| 29 | Mayanin | 3 | 0.026 | 3 | 0.7 | 0.3 | 1.0 | 2.1 |
| 30 | Thetyingyi | 3 | 0.023 | 3 | 0.7 | 0.3 | 1.0 | 2.1 |
| 31 | Chinyok | 3 | 0.011 | 3 | 0.7 | 0.1 | 1.0 | 1.9 |

Appendix. 1. (continued):

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 32 | Linyaw | 3 | 0.009 | 3 | 0.7 | 0.1 | 1.0 | 1.9 |
| 33 | Nagye | 3 | 0.027 | 2 | 0.7 | 0.4 | 0.7 | 1.8 |
| 34 | Yon | 2 | 0.025 | 2 | 0.5 | 0.3 | 0.7 | 1.5 |
| 35 | Leza | 1 | 0.042 | 1 | 0.2 | 0.6 | 0.3 | 1.2 |
| 36 | Thanat | 1 | 0.042 | 1 | 0.2 | 0.6 | 0.3 | 1.2 |
| 37 | Kinbalin | 2 | 0.004 | 1 | 0.5 | 0.1 | 0.3 | 0.9 |
| 38 | Wetshaw | 1 | 0.015 | 1 | 0.2 | 0.2 | 0.3 | 0.8 |
| 39 | Kathit | 1 | 0.006 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 40 | Kyaungsha | 1 | 0.009 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 41 | Lein | 1 | 0.009 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 42 | Phalan | 1 | 0.006 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 43 | Sa-thange-ohnauk | 1 | 0.006 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 44 | Thande | 1 | 0.005 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 45 | Yindaik | 1 | 0.005 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 46 | Zaungbale | 1 | 0.005 | 1 | 0.2 | 0.1 | 0.3 | 0.7 |
| 47 | Hingut | 1 | 0.001 | 1 | 0.2 | 0.0 | 0.3 | 0.6 |
| 48 | Taung-magyi | 1 | 0.003 | 1 | 0.2 | 0.0 | 0.3 | 0.6 |
| 49 | Thabut-gyi | 1 | 0.002 | 1 | 0.2 | 0.0 | 0.3 | 0.6 |
| Total | | 401 | 7.423 | 287 | 100.0 | 100.0 | 100.0 | 300.0 |

**Appendix 2**

Distribution of individuals in diameter classes for all tree species found in the enriched degraded forest, arranged in alphabetical order (based on individuals with a DBH ≥ 5 cm).

| Sr. | Species | Diameter Classes (cm) | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | 80-90 | 90-100 | 100+ | |
| 1 | Bebya | 6 | 17 | 4 | 1 | | | | | | | | 28 |
| 2 | Binga | 1 | | | 1 | | | | | | | | 2 |
| 3 | Chinyok | 3 | | | | | | | | | | | 3 |
| 4 | Didu | 18 | 3 | | | 1 | | | | | | | 22 |
| 5 | Dwani | 6 | 6 | | | | | | | | | | 12 |
| 6 | Gwe | 2 | 1 | | | | 1 | | | | | | 4 |
| 7 | Gyo | 4 | 2 | 1 | | | | | | | | | 7 |
| 8 | Hingut | 1 | | | | | | | | | | | 1 |
| 9 | Hnaw | | | 2 | | | | | | | | | 2 |
| 10 | Kathit | 1 | | | | | | | | | | | 1 |
| 11 | Kinbalin | 2 | | | | | | | | | | | 2 |
| 12 | Kuthan | 8 | 1 | 1 | | | | | | | | | 10 |
| 13 | Kyaungsha | | 1 | | | | | | | | | | 1 |
| 14 | Kyetyo | 4 | 4 | 1 | 1 | | | | | | | | 10 |
| **15** | **Kyun (teak)** | **53** | **6** | | **2** | | | | | | | | **61** |
| 16 | Kyun-nalin | 3 | 1 | | | | | | | | | | 4 |
| 17 | Lein | | 1 | | | | | | | | | | 1 |
| 18 | Lettok-gyi | 4 | 1 | | | | | | | | | | 5 |
| 19 | Leza | | | 1 | | | | | | | | | 1 |
| 20 | Linyaw | 3 | | | | | | | | | | | 3 |
| 21 | Madama | 3 | 1 | | | | | | | | | | 4 |
| 22 | Magyi-bauk | 9 | 4 | | | | | | | | | | 13 |
| 23 | Mayanin | 2 | 1 | | | | | | | | | | 3 |
| 24 | Nabe | 5 | 3 | | | | | | | | | | 8 |
| 25 | Nagye | 1 | 2 | | | | | | | | | | 3 |
| 26 | Padauk | 15 | 11 | 4 | 1 | | | | | | | | 31 |
| 27 | Petthan | 7 | 1 | 1 | | | | | | | | | 9 |
| 28 | Petwun | 6 | | 2 | | | | | | | | | 8 |
| 29 | Phalan | 1 | | | | | | | | | | | 1 |
| 30 | Pokethinma-myetkok | 1 | 1 | | | | 1 | | | | | | 3 |

Appendix. 2. (continued):

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Pyinkado | 8 | 2 | 4 | | | | | | | | | 14 |
| 32 | Sa-thange-ohnauk | 1 | | | | | | | | | | | 1 |
| 33 | Sawbya | | | | | 1 | | | | | | | 1 |
| 34 | Seikchi | 13 | | 6 | 4 | | | | | | | | 23 |
| 35 | Taung-magyi | 1 | | | | | | | | | | | 1 |
| 36 | Tayaw | 7 | | 1 | | 1 | | | | | | | 9 |
| 37 | Thabut-gyi | 1 | | | | | | | | | | | 1 |
| 38 | Thadi | 2 | | | | 2 | 1 | | 1 | | | | 6 |
| 39 | Thanat | | | 1 | | | | | | | | | 1 |
| 40 | Thande | 1 | | | | | | | | | | | 1 |
| 41 | Thetyingyi | 2 | 1 | | | | | | | | | | 3 |
| 42 | Thitpagan | 6 | | | | | 1 | | | | | | 7 |
| 43 | Unidentifiable | 7 | 1 | | | | | | | | | | 8 |
| 44 | Wetshaw | | 1 | | | | | | | | | | 1 |
| 45 | Yindaik | 1 | | | | | | | | | | | 1 |
| 46 | Yinma | 38 | 12 | 4 | 1 | | | | | | | | 55 |
| 47 | Yinzat | 1 | | | 1 | | | | | | | | 2 |
| 48 | Yon | | 2 | | | | | | | | | | 2 |
| 49 | Zaungbale | 1 | | | | | | | | | | | 1 |
| **Total no. of individuals** | | **259** | **87** | **33** | **12** | **5** | **4** | | **1** | | | | **401** |
| **No. of Species** | | **41** | **26** | **14** | **8** | **4** | **4** | | **1** | | | | **-** |

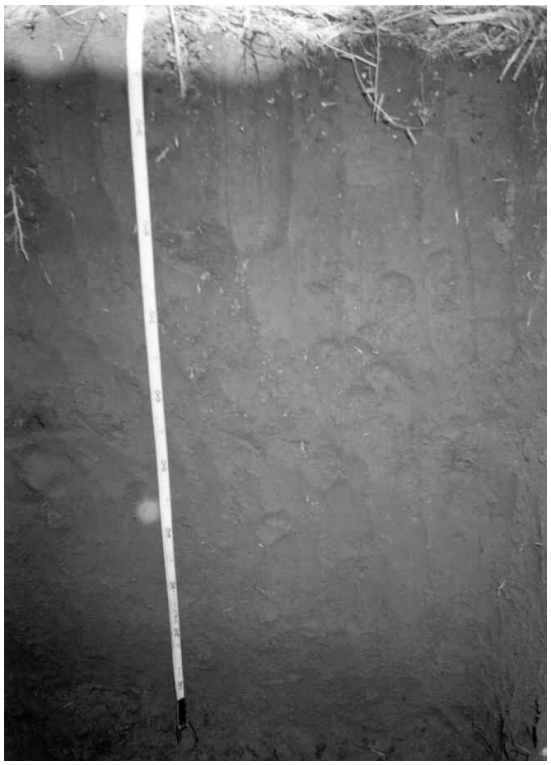
**Appendix.3**

Regeneration Density of species found in the enriched degraded forest, arranged in decending order of regeneration density.

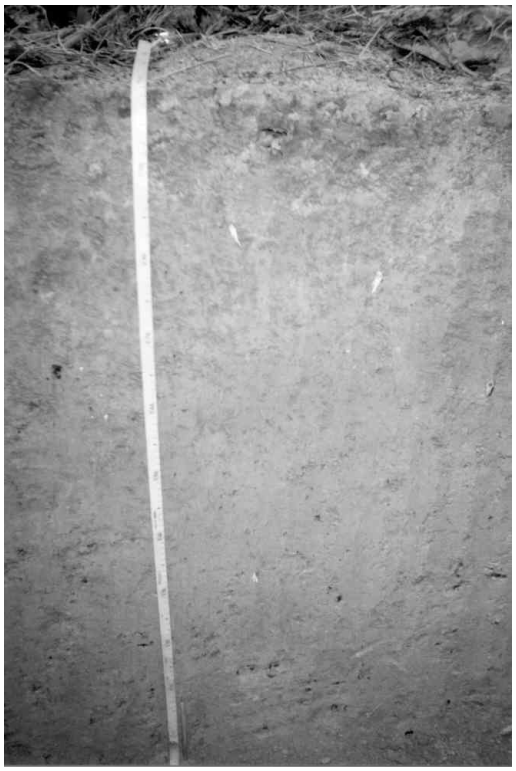
| Sr. | Species | No. of seedlings/0.25ha | Sr. | Species | No. of seedlings/0.25ha |
|---|---|---|---|---|---|
| 1 | Lettokkyi | 140 | 25 | Dwani | 8 |
| 2 | Petthan | 96 | 26 | Linyaw | 8 |
| 3 | Yinma | 82 | 27 | Thitsein | 8 |
| 4 | Kyun-nalin | 80 | 28 | Leza | 7 |
| 5 | Bebya | 72 | 29 | Padauk | 7 |
| 6 | Seikchi | 39 | 30 | Yinzat | 7 |
| 7 | Yon | 39 | 31 | Magyibauk | 6 |
| 8 | Tayaw | 35 | 32 | Thetyingyi | 6 |
| 9 | Madama | 34 | 33 | Dwabok | 5 |
| **10** | **Kyun (teak)** | **30** | 34 | Okshit | 5 |
| 11 | Didu | 20 | 35 | Yindaik | 4 |
| 12 | Gyo | 20 | 36 | Chinyok | 3 |
| 13 | Kinbalin | 19 | 37 | Thande | 3 |
| 14 | Pyinkado | 15 | 38 | Hingut | 2 |
| 15 | Kuthan | 14 | 39 | Lein | 2 |
| 16 | Thabutkyi | 14 | 40 | Pokethinma-myetkok | 2 |
| 17 | Thadi | 13 | 41 | Pyinmaywetkyi | 2 |
| 18 | Binga | 12 | 42 | Zaungbale | 2 |
| 19 | Kyetyo | 12 | 43 | Gwe | 1 |
| 20 | Mahlwa | 12 | 44 | Hnaw | 1 |
| 21 | Sathanghe-ohnok | 12 | 45 | Nabe | 1 |
| 22 | Thitpagan | 12 | 46 | Taung-thayet | 1 |
| 23 | Kyaungsha | 11 | 47 | Zibyu | 1 |
| 24 | Petwun | 9 | - | **Total** | **439** |

**Appendix. 4**

Soil Profiles



Pure teak plantation (estd. 1999)
Compartment no. 8
Kaing Reserved Forest



Enriched degraded forest (estd. 1999)
Compartment no. 18
Ngalaik Reserved Forest

**Appendix. 5**

Pure teak plantation with good height growth of teak.

**Appendix. 6**

**Enrichment planting teak with unsatisfactory light condition**

**Appendix. 7**

**Enrichment planting teak with unsatisfactory light condition under the shade of a bamboo clump which is growing on the edge of the cleared planting line.**

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