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Comparison of Growth Performances of Teak (*Tectona grandis* Linn. f.) and Padauk (*Pterocarpus macrocarpus* Kurz.) by Line Enrichment Planting in Ngalaik Reserved Forest

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ကျွန်းနှင့်ပိတောက်တို့၏ ရှင်သန်ကြီးထွားမှုကို ငလိုက်ကြိုးဝိုင်းတွင် လိုင်းအလိုက် တန်ဘိုးမြှင့် စိုက်ပျိုးခြင်းဖြင့် နှိုင်းယှဉ်လေ့လာခြင်း

သန်းစိုးဦး
ဦးစီးအရာရှိ
သစ်တောဦးစီးဌာန၊ မန္တလေးတိုင်း

စာတမ်းအကျဉ်း

သဘာဝတောများသည် အကြောင်းအမျိုးမျိုးတို့ကြောင့် ပျက်စီးယိုယွင်းလာပြီးတောညံ့များ အဖြစ်သို့ တဖြည်းဖြည်းရောက်လာပါသည်။ အဆိုပါတောများတွင် စီးပွားရေးအရတန်ဖိုးရှိသော အပင်များလုံလောက်ခြင်း မရှိလျှင် (သို့မဟုတ်) အဆိုပါအပင်များ လုံးဝမရှိလျှင် (ဥပမာ–အလွန်အကျွံသစ်ထုတ်ယူထားသောတောများ) ယင်းကဲ့သို့သော သစ်တောများအား ပြန်လည်ပြုစုရာတွင် သစ်တောတန်ဖိုးမြှင့်စိုက်ပျိုးခြင်း (Enrichment Planting) သည် အုပ်မိုးကာဆိုင်းခုတ်လှဲခြင်း (Improvement Felling) နှင့်နှိုင်းယှဉ်လျှင် ပိုမိုကောင်းသော နည်းလမ်းတစ်ခု ဖြစ်နိုင်ပါသည်။ အကောင်းဆုံးအဖြစ်သိထားကြသော သစ်တောတန်ဖိုးမြှင့်စိုက်ပျိုးခြင်း (Enrichment Planting) သည် လိုင်းအလိုက်စိုက်ပျိုးခြင်း (line planting) ပင်ဖြစ်ပါသည်။

ဤစာတမ်းတွင် ငလိုက်ကြိုးဝိုင်း အကွက်အမှတ် (၁၈)၌ တည်ထောင်ထားသော သစ်တော တန်ဖိုးမြှင့် စိုက်ခင်းမှ ကျွန်းနှင့်ပိတောက်တို့၏ အမြင့်ကြီးထွားမှုနှင့် ရှင်သန်မှုတို့ကိုနှိုင်းယှဉ် လေ့လာထားပါသည်။ လေ့လာမှုတွင် သစ်မျိုးတစ်ခုစီအတွက် စမ်းသပ်မှုအဖြစ် လိုင်းအကျယ် (၃)မျိုးထားပြီး ထပ်ကြိမ်ရေ (၃)ခုဖြင့် စိုက်ပျိုးခဲ့ပါသည်။ သစ်တောတန်ဖိုးမြှင့်စိုက်ပျိုးခြင်း မဆောင်ရွက်မီ တော၏သစ်မျိုးဖွဲ့စည်းထားပုံ၊ ရင်စို့အချင်း ပြန့်နှံ့မှု၊ စီးပွားရေးအရတန်ဖိုးရှိသည့် သစ်မျိုးများ၏ပါဝင်မှုအချိုးအစား၊ ရင်စို့အချင်း ပြန့်နှံ့မှုနှင့် သဘာဝ မျိုးဆက်မှုတို့ကို လေ့လာခဲ့ပါသည်။ ကျွန်း၊ ပျဉ်းကတိုး၊ ပိတောက်တို့၏ ပါဝင်မှုအချိုးအစားသည် လွန်စွာနိမ့်ကျနေသည်ကို လေ့လာတွေ့ရှိရပြီး တော၏အရည်အသွေးမှာ များစွာကျဆင်းနေသည်ကို လေ့လာ တွေ့ရှိခဲ့ပါသည်။

လေ့လာတွေ့ရှိချက်အရ ပိတောက်သည် ကျွန်းနှင့်နှိုင်းယှဉ်လျှင် အမြင့်ကြီးထွားမှုနှင့်ရှင်သန်မှုတွင် ပိုမိုကောင်းမွန်ကြောင်း တွေ့ရှိရပါသည်။ လိုင်းအကျယ်(၃)မျိုးတွင် လိုင်းအကျယ် အမှတ် (၂) သည် ယခု လေ့လာမှုအရ ပိတောက်အတွက် အသင့်တော်ဆုံးဖြစ်နေသည်ကို တွေ့ရှိရပြီး ကျွန်းအတွက်မူ လိုင်းအကျယ် အမှတ်(၃)သည် အခြား (၂)မျိုးထက် ပိုမိုကောင်းမွန်သော်လည်း စာရင်းအင်းပညာအရ ထူးခြားမှုမရှိပါ။ အတန်းလိုက်စိုက်ပျိုးနည်းဖြင့် သဘာဝတောတန်ဖိုးမြှင့်စိုက်ပျိုးခြင်းတွင် ရှင်သန်မှုရာခိုင်နှုန်းနှင့် အပင်အမြင့် ကြီးထွားနှုန်းတို့အတွက် အောင်မြင်မှုရရှိရန် အဓိက အရေးအကြီးဆုံးအချက်မှာ အလင်းရောင် ရရှိနိုင်မှုပင် ဖြစ်သည်က တွေ့ရသည်။ ကျွန်းအတွက် အခြားအပူပိုင်းဒေသနိုင်ငံများတွင် အသုံးပြုနေသော သစ်တော တန်ဖိုးမြှင့်စိုက်ပျိုးခြင်းနည်းလမ်းများကို ရှာဖွေလေ့လာရန် လိုအပ်ပါမည်။

ဤစာတမ်းတွင် (၁) လက်ရှိတောအပေါ် ထိခိုက်မှုအနည်းဆုံးနှင့်အလင်းရောင်အများဆုံးပေးနိုင်မည့် လိုင်းအကျယ်ကို ဆက်လက်လေ့လာရန် (၂) သဘာဝတောတန်ဖိုးမြင့် စိုက်ပျိုးရာတွင် ရွှေ့ပြောင်းအနေဖြင့် ပိတောက်ကို အသုံးပြုပြီး လိုင်းအကျယ် အမှတ်(၂)ကို အခြေခံထား၍ ရေမြေအနေအထားတူညီသော ဒေသများ တွင် စမ်းသပ်ဆောင်ရွက်ရန် (၃) ကျွန်းအပါအဝင် အခြားတန်ဖိုးရှိသစ်မျိုးများကိုလည်း လိုင်းအကျယ် အမှတ်(၂)နှင့်(၃) ကို အခြေခံပြီး အလင်းရောင်ပိုမိုရရှိနိုင်သည့် အလင်းဖွင့်ပေးခြင်း နည်းလမ်းများကို အသုံးပြုပြီး သစ်မျိုးနှင့်အသင့်တော်ဆုံး နည်းလမ်းကို သုတေသနပြုရှာဖွေသွားရန် တို့ကို အကြံပြုတင်ပြထားပြီး သဘာဝတော တန်ဖိုးမြင့်စိုက်ပျိုးရာတွင် လိုက်နာဆောင်ရွက်သင့်သည့် နည်းလမ်းများကို တင်ပြထားပါသည်။

Comparison of Growth Performances of Teak (*Tectona grandis* Linn. f.) and Padauk (*Pterocarpus macrocarpus* Kurz.) by Line Enrichment Planting in Ngalaik Reserved Forest

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Abstract

Due to many factors natural forests are being affected and gradually change to degraded forests. In such forests, if there is an insufficient number of economically valuable trees or if there is a lack of (e.g. logged-over forests), then enrichment planting may be a better option than improvement to restore or rehabilitate those forests. The best known enrichment system is line planting.

In this paper, height growth and survival of teak Padauk (*Pterocarpus macrocarpus* Kurz.) are compared in the enrichment plantation established in the compartment No. (8) of Ngalaik Reserved Forest. Each species was given three treatments of different line widths with three replications. Prior to enrichment planting experiment silvicultural stand analysis was conducted to realize species composition, diameter distribution, ratio of economically important species and their DBH distributions and natural regeneration. It was observed that relative abundance of teak, Pyinkado and Padauk were very low and the forest stand investigated was severely degraded.

According to the results obtained, Padauk is better than teak in respect to both height growth and survival. Among three treatments, Treatment 2 is the most suitable for Padauk and as for teak there is no significant difference at 5% level between treatments in spite of the mean height growth and survival of Treatment 3 better performance than that of other two treatments. The main factor for the success of line enrichment planting is found to be availability of overhead light. As for teak, it is needed to study other enrichment planting techniques applied in tropical countries.

In this paper, the followings are recommended and presented;

1. to continue further study on the best line width that will give optimum overhead light with least adverse affect on the existing vegetation;
2. to establish pilot enrichment plantation in regions with similar climatic and edaphic conditions of the study area by using Padauk based on Treatment 2;
3. Based on the Treatments 2 and 3, to do researches on the optimum line width for other commercial species including teak by applying other line opening methods to get more overhead light and the basic rules for enrichment planting with commercial species are also presented.

1. Introduction

Degraded forest areas are increasingly predominant all over the tropical region. The extent of degraded forests is as much as 58% of the present forest cover in the tropics (ITTO, 2002). In spite of reduced productivity and limited biological diversity, these forests still possess important forest functions and development potential. While securing sustainable management of remaining productive primary forests is obviously of prime importance, the need for a proper management of degraded forests in the tropics also become an important priority.

Some 350 millions hectares of tropical forest land have been so severely damaged that forest won't grow back spontaneously, while further 500 millions hectares have forest cover that is either degraded or has regrown after initial deforestation (ITTO, 2002). If properly restored, rehabilitated and managed, ecological as well as economical benefits can be significantly generated from these forests. Properly rehabilitated degraded forests will provide local people with goods and services such as wood and non-wood forest products and will also offset carbon emissions, and other intangible forest functions as well. Consequently, pressure on the primary forests through such forests products will be reduced. Proper restoration approach should encourage natural process to regain ecosystem integrity, i.e.., to recover gradually the structure and composition of original stands. To accelerate the natural restoration process, the degraded stands can be subjected to two basic types of silvicultural treatments, viz., improvement and enrichment.

In Myanmar, 43.34% of total land area (i.e., 293,269 sq. km) is covered with closed forests, 7.53% of the total land area (i.e., 50,968 sq. km) is covered with degraded forests (Anon. 1993; Anon. 2000). The area of degraded forests takes up about 17.38% of the closed forests in the country. Moreover most of the degraded areas are found more or less in the accessible areas and local people living near those forests depend on the forest products for their livelihoods. So the degraded forests should be restored or rehabilitated to take advantage of their high potentials to achieve environmental and economic benefits.

Choice of suitable silvicultural intervention depends primarily on the structural characteristics and regeneration potential of the degraded stand. Therefore, it is essential to conduct the assessment of stand characteristics and existing natural regeneration at the initial stage of restoration process. The essential preconditions for the success of the improvement of the stand are the existence of sufficient regeneration of desirable species and more or less even distribution of these species over the entire area. If the number of economically valuable trees in the initial stand is not sufficient, or there is a complete lack of such trees, then enrichment may be a better option than improvement (LAMPRECHT, 1989). In order to improve economic as well as ecological value of a degraded forest, one of the simplest and most effective methods is enrichment planting that can offer the following advantages:

- any economic trees in the area can easily be integrated;
- conversion is achieved without clear-cutting and elimination of soil erosion through run-off;
- a secondary stratum with high species diversity can be maintained in the understory.

Of two possible types of planting, namely, patch planting and line planting, line enrichment is the common form of enrichment practiced today. Enrichment by irregular spaced groups had been abandoned because of difficulties in control and retracing the groups for tending operations (WEIDELT, 1976).

As the degraded forest areas are expanding with alarming rate throughout the country due to increasing population followed by greater demand for forest products, Forest Department (FD) is now focusing on the restoration and restoration of such forests by encouraging enrichment planting with economically valuable species. To implement and to provide some information on enrichment planting, the present study of enrichment planting was conducted in collaboration with ASEAN-Korea Cooperation Unit (AKECU) with three different light intensities and two economic species, teak (*Tectona grandis* Linn. F) and Padauk (*Pterocarpus macrocarpus* Kurz.).

2. Objectives

Objectives of the study are as follows:

1. To compare the height growth and survival of teak (*Tectona grandis* Linn. F) and Padauk (*Pterocarpus macrocarpus* Kurz.) by enrichment planting of different light intensities;
2. To provide some information on enrichment planting in degraded forest
3. To document the silvicultural parameters of the degraded forest at the time of rehabilitation by line enrichment planting so that the changes with time could be used in the future

3. Study Area

3.1 Location

Study was carried out in a degraded forest stand situated in Compartment No. 18 of Ngalaik Reserved Forest, Pyinmana Township. Geographical location of the area is 19° 56' N and 95° 56' E. The study area is also situated in one of the compartments of natural reserved forests managed by Forest Research Institute (FRI), Yezin.

3.2 Climate

Climatic data was taken from the Pyinmana Weather Station and monthly mean temperature, rainfall and DE MARTONNE'S aridity index of Pyinmana Township are shown in the Table 1.

Table 1: The climatic data (monthly mean) and DE MARTONNE'S aridity index of Pyinmana Township

Month	Jan	Feb	Mar	Apr	May	June	
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 and 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 having lowest av. Rainfall	February (2.6 mm)

Source: Meterological Department, Pyinmana

According to WEIDELT (1999), months with an aridity index below 20 are termed as arid months. The study area shows a pronounced dry season of 5 months from December to April. Rainy season starts in the month of May and ends in November, and 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 and it is shown in the Figure 1.

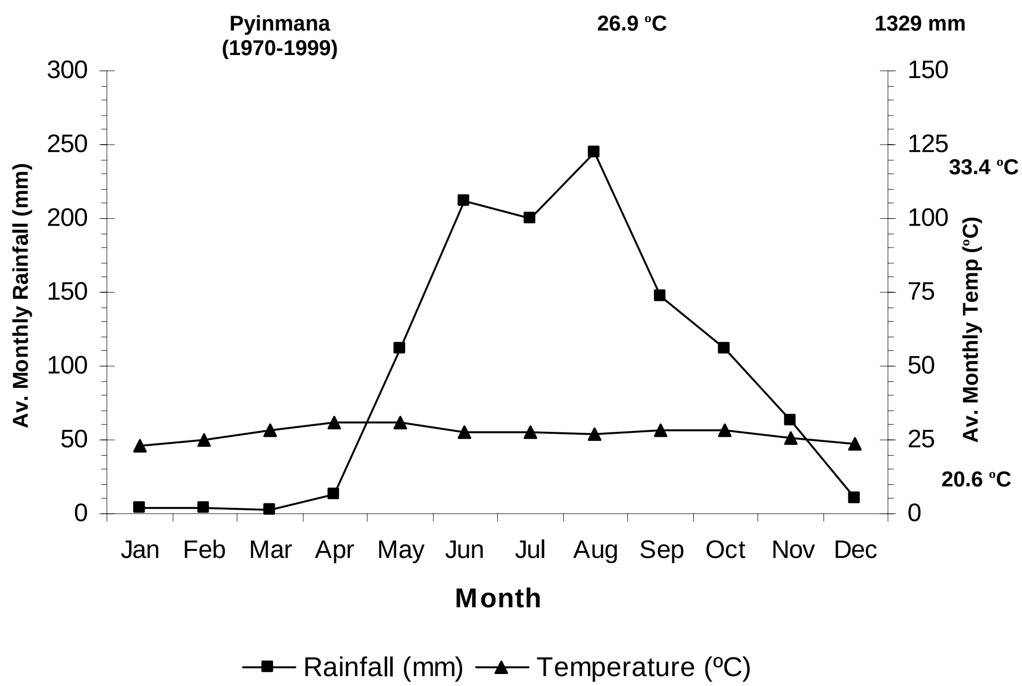

Figure 1: Climatogram of Pyinmana Township

As the prevailing climatic and edaphic conditions are the determining factors for the formation of the forest type of a given area, the study area receiving annual mean rainfall of 1329mm is with 5 pronounced dry seasons having aridity index below 20 and with maximum and minimum temperature of 33.4°C and 20.6°C respectively. Under these edaphic and climatic conditions, according to the climax forest formations in the tropical belt stated by LAMPRECHT, H.[β] (1989), moist deciduous forests can occur, but here to be considered is the rainfall per annum

[β] Climax forest formations in the tropical belt LAMPRECHT, H. (1989): Detailed description is attached to the appendix 1 of the study area is found to be less than mean annual rainfall between 2,045mm and 1,022.5mm. Therefore, the study area will be prevailed by rather dry climatic condition as compared to the area, in which typical moist deciduous forests occur. So the mean annual rainfall of 1329 mm (52.3 inches) may be determining factor to grow slightly (or rather dry) moist deciduous teak bearing forest in the study area.

3.3 Soil

Physical and chemical properties of soil in response to different light opening intensities in the study area are investigated. Four systematically distributed sample points in each experimental plot were selected as shown in the figure 2. Soil samples were taken from three layers: 0-10 cm, 40-50 cm and 90-100 cm. At selected representative point of each replication, soil profile information was collected. Soil physical and chemical properties tested at the soil laboratory of the Forest Research Institute are shown in the table 1a and 1b.

Main Plot

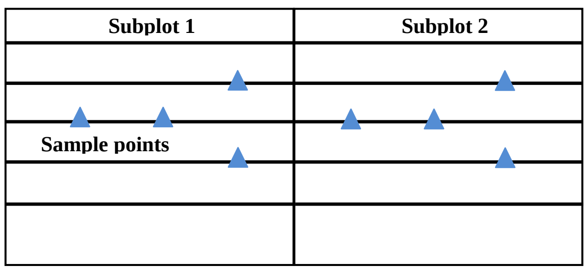

Figure 2: Selected points in each experimental plot for soil sample collection

Table 1a: Physical properties of soil of the study area

Soil Depth	(0-10) cm	(40-50) cm	(90-100) cm
Sand %	34	24	17
Silt %	35	46	63
Clay %	31	29	19
Texture	Clay Loam	Clay Loam	Silt Loam
Moisture Content %	16.31	16.46	16.5

Table 1b: Chemical properties of soil of the study area

Soil Depth	(0-10) cm	(40-50) cm	(90-100) cm
pH	5.65	5.61	6.02
Total N %	0.0599	0.0688	0.0291
Av. P %	0.000029	0.000022	0.000021
K %	0.0124*	0.0073*	0.0064*
Ca %	5.10	4.13	4.06
Mg %	4.33	6.01	6.23
OM %	3.92	3.12	2.46
OC %	6.74	5.37	4.23

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

4. Materials and Method

4.1 Assessment of stand structure and species composition

Prior to the enrichment planting, stand structure and dynamics of the degraded forest in the study area was assessed through a systematic sampling survey. A total of 25 square plots with an area of 400 m^2 (20 m x 20 m) were laid out over the area as shown in the figure 3a. Each plot is divided into four equal subplots that are referred to as compartments A1, A2, A3 and A4 with an area of 100 m^2 (10 m x10 m). In each sub-compartment, another sub-compartments B1, B2, B3 and B4 of 25 m^2 (5 m x 5 m) are built up. There will be 100 sub-compartments of A and 100 of B as shown in the figure 3b.

(a)

(b)

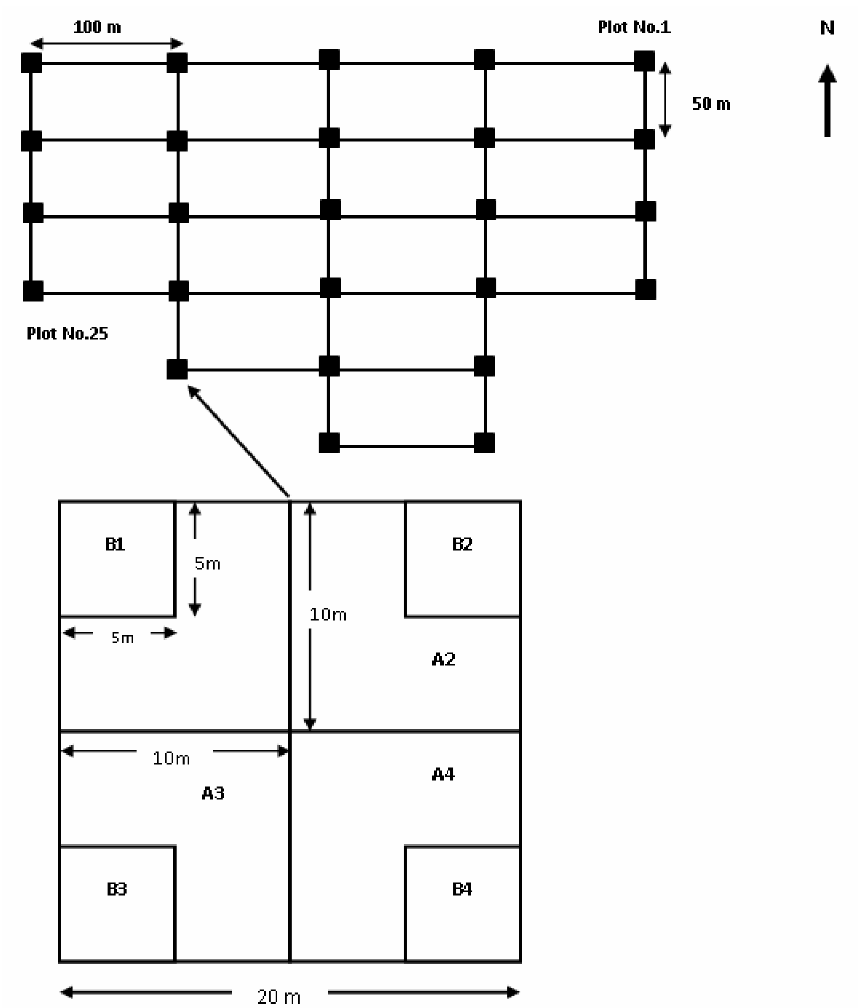

Figure 3: (a) Distribution and (b) Layout of the sample plots for stand structure assessment

The inventory parameters recorded in each sub-plot are given in the table 2.
Table 2: Inventory parameters recorded in each sub-plot 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 - For all trees with a DBH ≥ 5 cm, total height, crown point height and DBH were measured	Compartment A (i.e., A1, A2, A3 and A4)	Breast Height = 1.3 m
2.	Regeneration assessment for all species - No. of seedlings with a height ≥ 30 cm and < 130 cm were recorded.	Compartment B (i.e., B1, B2, B3 and B4)	

4.2 Enrichment planting method and laying out of sample plots

Two economically important species teak (*Tectona grandis* Linn. f.) and Padauk (*Pterocarpus macrocarpus* Kurz.) were selected to test the growth performances of both species with response to different light opening intensities. In the degraded forest to be enriched, parallel lines are cut with an interval of 20 m in an east-west direction and the following treatments were given and is shown in the figure 4.

Treatment 1: On both sides of the axis of each line, a strip of 2 m wide is completely cleared other than economic species

Treatment 2: On both sides of the axis of each line, a strip of 2 m wide is completely cleared and within 5 m width trees ≥ 10 cm DBH cut other than economic species

Treatment 3: On both sides of the axis of each line, a strip of 5 m wide is completely cleared other than economic species

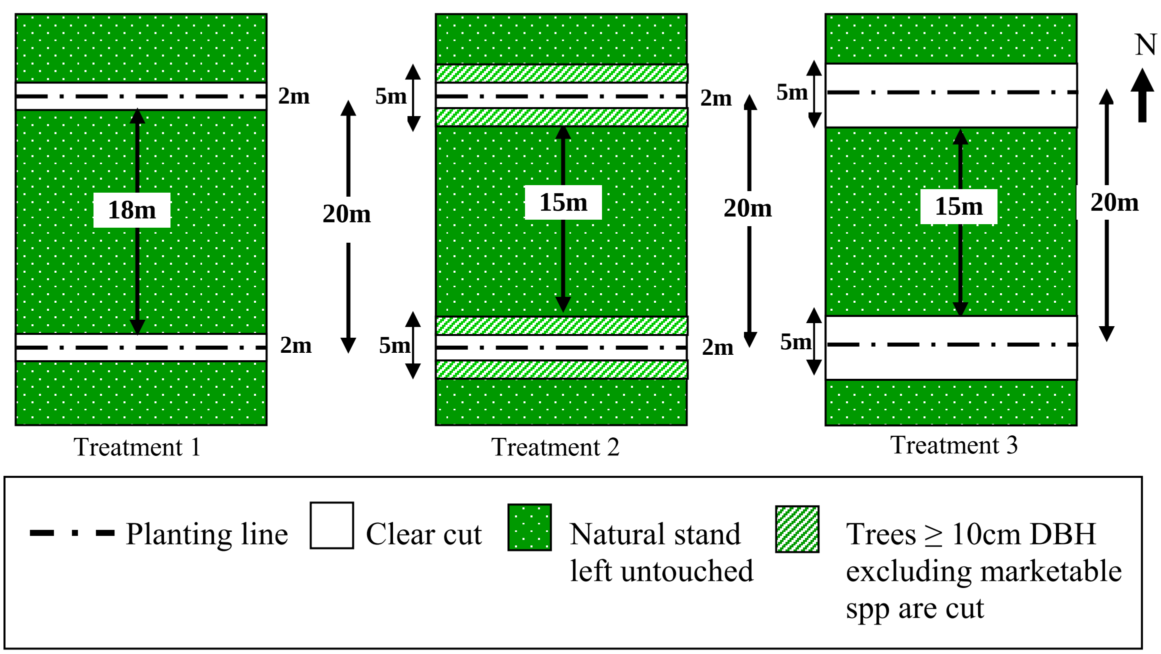

Figure 4: Line enrichment planting with three different intensities

To set the sample plots in the degraded forest to be enriched, the Split Plot Design with three replications and three treatments of different light opening intensities was applied and other tending operations such as weeding and fertilization were equally given to all treatments. Layout of sample plots in the study is shown in the figure 5.

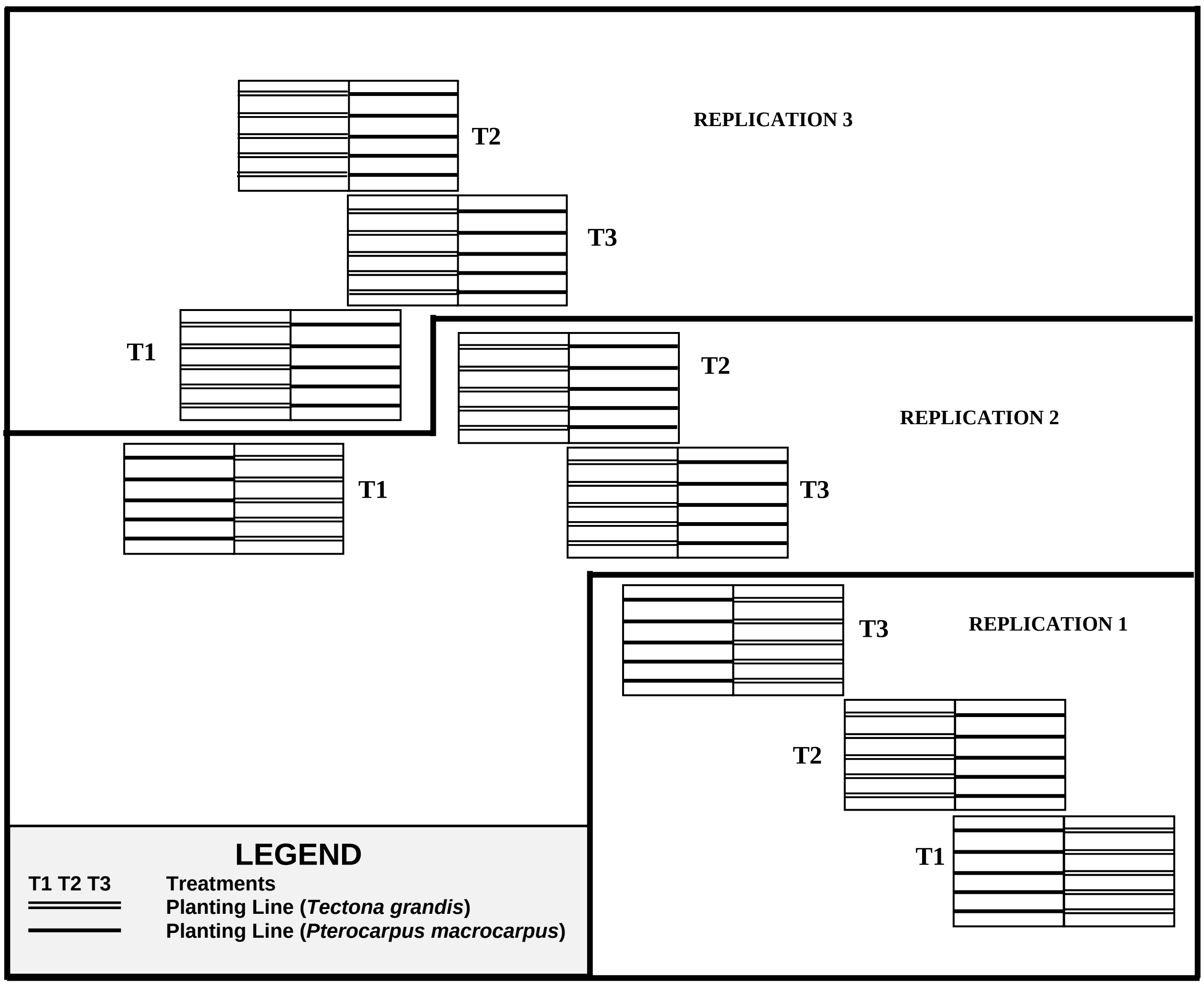

Fig 5: Layout of sample plots in the enriched degraded forest

5. Results and Discussion

5.1 Silvicultural Parameters of degraded forest as compared to typical moist deciduous forest

According to the analysis of stand survey data, basal area per hectare (≥5 cm DBH) of the degraded stand in the study area is 10.7 m^2), indicating very low density and severity of degradation. As shown in the table (1), basal area, in term of meter square per hectare, of the enriched degraded forests is found to be 10.7 m^2 as compared to that of typical mixed deciduous forest flourishing in the Bago Yoma region. It is also an indicator for that forest to conserve for perpetual development and if the economic species are comparatively low it should be enriched with valuable ones by appropriate method.

Table 3: Comparison of some parameters between a typical mixed deciduous stand and the degraded stand under investigation

Parameters	Typical mixed deciduous stand	Degraded stand of the study area
Locality	Kabaung R.F., Compt. 107 Oktwin Township	Ngalaik R.F., Compt. 18 Pyinmana Township
Geographical location	18° 51' N, 96° 01' E	19° 56' N, 95° 56' E
Elevation (m a.s.l)	220-300	170-210
Annual precipitation (mm)	1934	1329
Average mean annual temperature (°C)	27	27
Minimum DBH assessed (cm)	5	5
Number of trees (ha^{-1})	381	411
Number of species (ha^{-1})	44	49
Number of teak trees (ha^{-1})	132	42
Ratio of individual per species	1 : 9	1 : 5
Basal area (m^2 ha^{-1})	33.4	7.42
Species richness index	2.25	2.33
Average DBH of the stand (cm)	28.7	14.1
Average stand height (m)	18.9	9.7

Table 3 also gives information on the mean height and DBH of the stand investigated and it points out that the stand suffers severe disturbances showing low average stand height of 9.7 m and average DBH of 14.1 cm respectively. Lower annual precipitation, loamy clayey soil structure and opened situation of the study area seem to be favourable conditions for occurrence of most of the species growing in the area. It is because number of trees (DBH ≥ 5 cm) per hectare of the degraded stand investigated was found to be higher than that of typical moist deciduous forest, 442 and 381. In consequence, its species richness is also higher than the latter.

It can be concluded that the study area can change the degraded stand into more valuable one in terms of economically and ecologically.

5.2 Abundance, dominance, frequency and important 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 space it occupies. **Frequency** is the occurrence or absence of a given species in a subplot (LAMPRECHT, H. 1989).Total number of species found in the degraded stand investigated is 49 and total abundance, dominance and frequency per hectare were found to be 401, 7.423 m^2 and 287 respectively.

Important Value Index (IVI) is calculated as the sum of relative abundance, relative dominance and relative frequency (WEIDELT, H –J. 1999) and important value indices of all species (≥ 5 cm DBH) found in the investigated stand were made and the species were listed with the descending order according to their important value index (IVI), and ten species with highest IVI values are given in the table 4.

Table 4: Abundance, dominance, frequency and Important Value Index (IVI) for 10 species with highest Important Value Index in the degraded investigated stand with descending order of IVI (sample area = 1 ha, min. 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
	Total	**257**	**5.102**	**166**	**64**	**68.5**	**57.6**	**190.7**
11-49	Other species	144	2.321	121	36	31.5	42.4	109.3
	Grand Total	**4.1**	**7.423**	**287**	**100.0**	**100.0**	**100.0**	**300**

As shown in the table, 10 species take up 64% of total number of trees, 68.5% of total basal area, but it occupies 57.6% of total frequency. It is also an indicator that the degraded forest investigated is heterogeneous and the species growing in the area are more or less evenly distributed and they have chances to occur in the given site. It shows that the study site has not only economic potentials if the forests could be properly restored or rehabilitated but also ability to maintain its ecological integrity.

5.3 Horizontal Distribution of the degraded stand in the study area

Distribution of trees (≥5 cm DBH) in DBH classes shows the fact that most of the individuals accumulate in small diameter classes and large-sized trees are almost lacking despite all tree species are taken in account. The number of individual decreases dramatically from lower to higher diameter classes and the situation is even worse for teak and other important economic species as shown in the figures 7a and 7b.

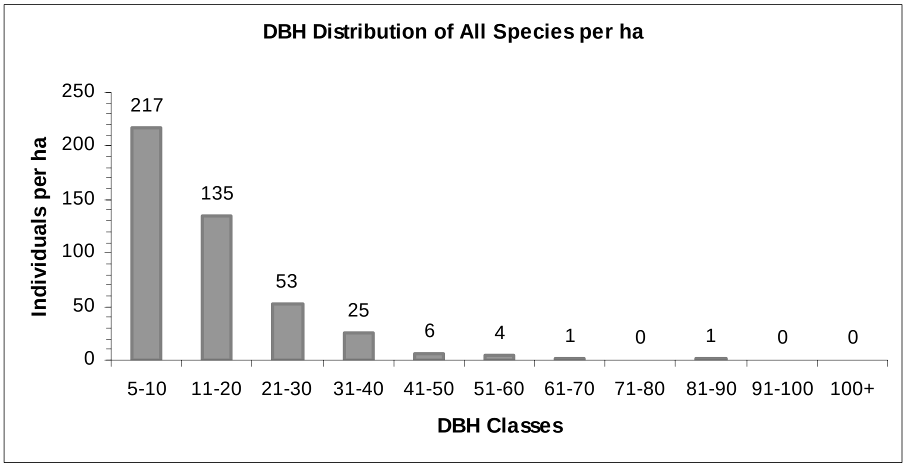

Figure 7a: Diameter Distribution of all species in the investigated degraded stand

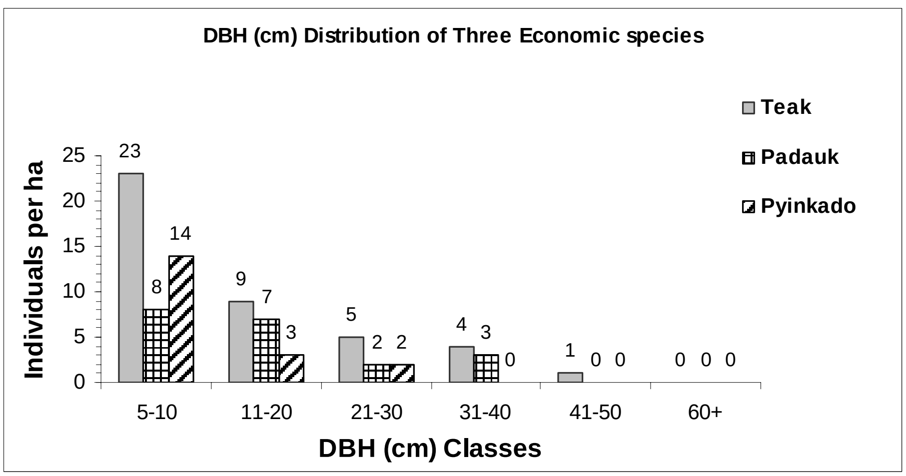

Figure 7b: Diameter Distribution of three economic species in the investigated degraded stand

As shown in the figure (a) and (b), 217 trees (49.1%) and 135 trees (30.5%) of the total number of trees accumulate in the small diameter classes of 5-10 and 11-20 respectively and trees are lacking the higher classes of 70 cm DBH and above. It indicates that the forest investigated is severely degraded and *according to ITTO, 2002 it delivers a reduced supply of goods and services from a given site and maintains only limited biological diversity. It has lost of the structure, function, species composition and/or productivity normally associated with the natural forest type expected at that site*. The only way to conserve the ecological integrity and to get economic benefits of those forests is to enrich again with desirable economically species.

5.4 Frequency diagram of the enriched degraded forest

Frequency is the occurrences or absence of a given species in a subplot and the frequencies give an approximate indication of the homogeneity of a stand. High values in classes I/II indicate a high degree of floristic heterogeneity (LAMPRECHT, H. 1989). The frequency diagram was constructed to examine the floristic heterogeneity of enriched degraded stand of the study area and is shown in the figure 8.

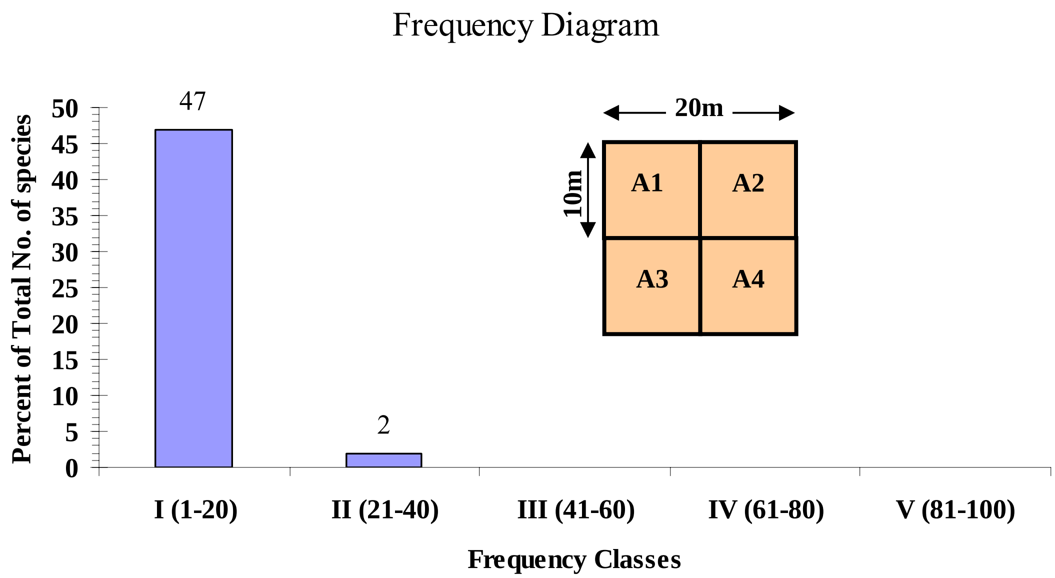

Figure 8: Frequency of the enriched degraded forest (Sample area = 100 subplots x 100 m^2; min.dia = 5cm DBH)

As shown in the figure 8, 47 species (i.e. 96% of the species found in the enriched degraded forest) accumulate in the lowest frequency classes, I (1-20) and only 2 species (i.e. 4% of the species found in the enriched degraded forest) occur in the second lowest frequency class, II (21-40). The higher frequency classes, III to V show the lack of representatives in the area studied.

As stated above high values in class I/II indicate a high floristic heterogeneity and the species composition over the whole area of the enriched degraded forest is, therefore, highly heterogeneous. All 49 species found in the enriched degraded forest are very scattered in the study area.

In case of teak, only 6 trees are present in the DBH class of 10-20 cm and 2 trees in the DBH class of 30-40 cm respectively. Due to their small DBHs and low frequency values could make it uncertain to produce sound and sufficient seeds for successful natural regeneration. Similarly, Padauk (*Pterocarpus macrocarpus* Kurz.) shows lower abundance and frequency percent of 31 trees and 17% respectively. These two species, however, stand 2nd and 3rd positions with regard to IVI (Important Value Index). It indicates that both species play vital role in the forest ecosystem of the investigated stand. It points out that teak and Padauk are very important species not only from the economic point of view but also from the ecological one.

6. Natural regeneration of all species in the degraded stand under investigation

Regeneration density for all species is found to be 920 per 0.25 hectare. Although the figure is apparently large, for the economic point of view, economically valuable species show relatively low regeneration density. Regeneration densities of 10 species with highest values are given in the table 5a. Almost all species in the table (5a) are not economically valuable and it indicates that regeneration potentials of economic species are poor. Teak along with Pyinkado (*Xylia dolaformis* Benth.), another important hardwood species, stands the 16th position with 17 seedlings per 0.25 hectare as shown in the 5b.

Table 5a: Regeneration of 10 species with highest densities

Sr.	**Species** (Local Name)	**Species** (Botanical Name)	**Seedlings per 0.25 ha**	**Ranking**
1	Lettok-gyi	*Holarrhena antidysenterica* Wall.	123	1
2	Madama	*Dalbergia colletti* Prain	88	2
3	Mahlwa	*Markhamia stipulata* (Wall.) Seem.	85	3
4	Yinma	*Chukrasia tabularis* A.Juss.	73	4
5	Bebya	*Cratoxylon nerrifolium* Kurz.	64	5
6	Kinbalin	*Antidesma collettii* Craib	46	6
7	Nagye	*Pteropermum semisagittatum* Ham.	43	7
8	Tayaw	*Grewia polygama* Roxb.	37	8
9	Kyin-nalin	*Premna pyramidata* Wall.	34	9
10	Petthan	*Haplophragma adenophyllum*(Wall.)Dop.	33	10
11-55	**Other Species**		**294**	**11-26**
1-55	**Grand Total**		**920**	**1-26**

Table 5b: Regeneration density of some economic timber species

Species (Local Name)	**Species** (Botanical Name)	**Seedlings per 0.25 ha**	**percent**	**Ranking**
Teak	*Tectona grandis* Linn.f.	17	1.8 %	16
Pyinkado	*Xylia dolarbriformis* Benth.	17	1.8 %	16
Thinwin	*Millettia pendula* Benth.	3	0.3 %	24
Padauk	*Pterocarpus macrocarpus* Kurz.	1	0.1 %	26
Total		**38**	**4.1 %**	
Other Species		**882**	**95.9 %**	

Tables 5a and 5b present natural regeneration of the degraded stand in the study area. Species standing in high ranks are not economically important species and the succession of the forest stand is going to the state of not economic benefit. It can be said that although the forest is satisfactorily floristic heterogeneous, germination and establishment of the economic species could have unfavourable conditions. Moreover, it is also a result of lack of sufficient seed bearers to produce enough seeds. To enrich this type of forests with economically important species followed by maintaining the ecological integrity is to adopt the appropriate forest management system, i.e. adaptive enrichment planting techniques.

7. Growth performances of teak (*Tectona grandis* Linn. f.) and Padauk (*Pterocarpus macrocarpus* Kurz.)

7.1 Comparison of Height growth of the species tested between treatments

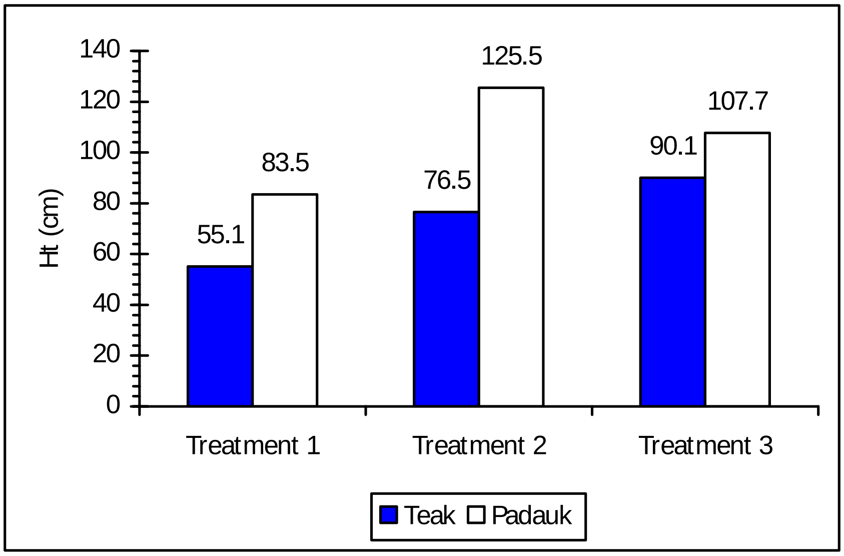

Figure 9: Height growths of teak and Padauk in response to different treatments

As shown in the figure (9), teak shows lower performance in height growth as compared to that of Padauk in all treatments of different light opening intensities under same tending operations such as weeding, fertilizer application and overtopping. *Teak is pronounced light demander; it does not tolerate any suppression at any stage of its life and requires complete overhead light as well as fair amount of side room for its proper development* (TEWARI, D. N., 1992). So teak, in the study, shows better height growth with increasing light intensities it received. It indicates that teak, undoubtedly, requires sufficient overhead light at its young stage i.e., seedling to sapling stages, and it is essential for teak to give silvicultural interventions as liberation thinning[2], refining[3] which are costly and yield only distant future returns and they are, however, important in the initial stage to demonstrate measurable effects from forest restoration, management and rehabilitation efforts (ITTO, 2002).

Table 6: Comparison of Height growth of teak and Padauk between different treatments

Source of variation	d.f.	s.s.	m.s.	Computed F	Tabular F	F pr.
Repl. stratum	2	1177.3	588.7	0.89		
Repl. Treatment stratum						
Species	6	3990.8	665.1	2.95		
Repl.f_ Treatment.*Units* stratum						
Species	1	4505.6	4505.6	17.51*	5.32	***0.003***
Residual	8	2058.0	257.3			
Total	17	11731.8				

* = significant at 5% level CV% = 17.9

[2] A cutting that relieves young seedlings saplings and trees in the C-layer from overhead competition
[3] Refining is the elimination of silviculturally undesirable trees, climbers, shrubs and other plants that will inhibit site occupation by desirable trees

"*Teak seedlings are intolerant of shade and thrive best entirely in the open* (Troups, R.S:1921). In enrichment planting using teak, it is an essential operation to keep teak from side shade and overtopping by cutting bamboo culms and other trees that may impede the development of teak. But it is an all round premier species on the world and so to find out the most appropriate enrichment method for teak under a given site condition is critical important for our country. To achieve both economical and ecological objectives, teak has being used as an enrichment planting species in humid and semi-humid tropics of Southeast Asia including Mekong and semi-arid (and dry) regions of India adopting appropriate methods.

Among three treatments of different light opening intensities, it is observed that there is significant difference with respect to performance in height growths of the species tested and it is illustrated in the figure 9. So it is required to examine which treatments are significantly different between mean heights of the species to each other and whether there will be significant difference in respect to height growths between treatments given to the species tested. Mean height of each treatment between the species tested is statistically analyzed using Genstat Software and the respective height growth responses between species are given in the table 7.

Table 7: Analysis of Variance of mean heights of teak and Padauk between treatments

Species		Teak		
	Treatments	1	2	3
Padauk	1	ns CV% = 25.1 F pr = 0.184	ns CV% = 13.0 F pr = 0.517	* CV% = 0.7 F pr = 0.011
	2	* CV% = 9.0 F pr = 0.003	* CV% = 8.8 F pr = 0.021	ns CV% = 11.8 F pr = 0.079
	3	* CV% = 11.1 F pr = 0.021	ns CV% = 9.1 F pr = 0.051	ns CV% = 16.4 F pr. = 0.317

* = significant at 5% level ns = non significant at 5% level

Table 7 shows there is significant difference in the mean height of teak and Padauk between Treatment 2 and the ANOVA table given above shows the mean height of Padauk in Treatment 2 is significantly different as compared to those of mean heights of Treatments 1 and 2 of teak. Although comparisons of mean heights between Treatment 2 of teak and Treatment 3 of Padauk, and between Treatment 3 of teak and Treatment 2 of Padauk do not show significant difference at 5% level, they are significant different at 5.1% and 7.9% level and moreover their respective F probabilities of 0.051 and 0.079 should be taken into consideration because at 5% level of significance is 18.5 and the respective computed F values are 18.25 and 11.19.

For both species Treatment 3 should be taken into account that it is the best enrichment planting method in the current research and should also be regarded as a basic line with for the degraded primary forests growing in the area having similar climatic and edaphic condition of the study site. Treatment 1 must be abandoned for the future enrichment planting researches based on these two species. As for Padauk, treatments 2 and 3 should be considered as the basic line width and removal of undesirable trees that will inhibit the development of Padauk seedlings enriched.

7.1.1 Analysis of Variance of mean height of treatments in teak

Table 7: Comparison of Height growth of teak between treatments

Source of variation	d.f.	s.s.	m.s.	Computed F	Tabular F	F pr.
Repl. stratum	2	475.9	238.0	1.19		
Repl.Treatment stratum						
Treatments	2	1864.8	932.4	4.68^{ns}	6.94	***0.090***
Residual	4	796.7	199.2			
Total	8	3137.5				

ns = significant at 5% level CV% = 19.1

As overhead light received for teak seedlings are different due to treatments given to them, the development of teak seedlings show different performance between treatments. Therefore, mean heights of the treatments were statistically analyzed using Genstat Software so as to verify whether there will be significant difference at 5% level. In term of mean height of teak seedlings it shows no significant difference between treatments in response to light availabilities. But the value of F probability 0.090 shows teak requires profuse lights for its development because the mean height of teak seedlings between treatments indicated better height growth along with more light conditions they received in spite of no statistically difference at 5% level.

7.1.2 Analysis of Variance of mean height of treatments in Padauk

In case of Padauk, Treatment 2 is found the best in height growth as compared to that of other treatments 1 and 3 within species and also superior than those of teak. TROUPS (1921) stated that *natural reproduction of this species, like that of the Andaman Padauk, cannot establish itself under the suppression of low cover, and require an abundance of light*. ***Low cover, however, appears to favour germination and the early development of the seedling***. Mean height of Padauk for all treatments is statistically analyzed and the result of the analysis of variance between treatments is given in the table 7.

As shown in the table (9), there is significant difference in Padauk between the treatments of different light opening intensities. As stated above, low cover given by Treatment 2 appear to be favourable conditions for the early development of the seedlings and as a result, the mean height growth of Treatment 2 shows the best as compared to those of the other two treatments. The study area is located in the rather dry area as compared to the area in which typical mixed deciduous forests occur. As described in the table 3, while the latter receives mean annual rainfall of 1934 mm, the study area has only mean annual rainfall of 1329 mm with pronounced dry seasons of 5 months (see Fig: 1).

Table 8: Comparison of mean height growth of Padauk between treatments

Source of variation	d.f.	s.s.	m.s.	Computed F	Tabular F	F pr.
Repl stratum	2	714.4	357.2	1.99		
f_Repl *Units* stratum						
f_Treatments	2	2656.7	1328.3	7.40*	6.94	0.045
Residual	4	717.6	179.4			
Total	8	4088.7				

* = significant at 5% level CV% = 12.7

As a rule, Padauk prefers rather dry sites to moister ones, in a moist deciduous forests of the country, it is very common on the upper and drier portions of the hill slopes, and also a common mixture being teak and Padauk on the upper slopes and teak and Pyinkado (Xylia dolabriformis Benth) on the lower and moister slopes (TROUPS; 1921). So it may be assumed that the study site may provide some of the ecological and environmental requirements (i.e., climatic and edaphic conditions) to Padauk seedling. But it must be noted that it is also a light demander with medium height growth and overtopping is critical to create growing spaces or canopy gaps through which it can grow. For this reason, tending operations has to be conducted up to 6 years until the seedlings planted reach the secondary stratum.

7.2 Comparison of Survival percentage of the species tested between treatments

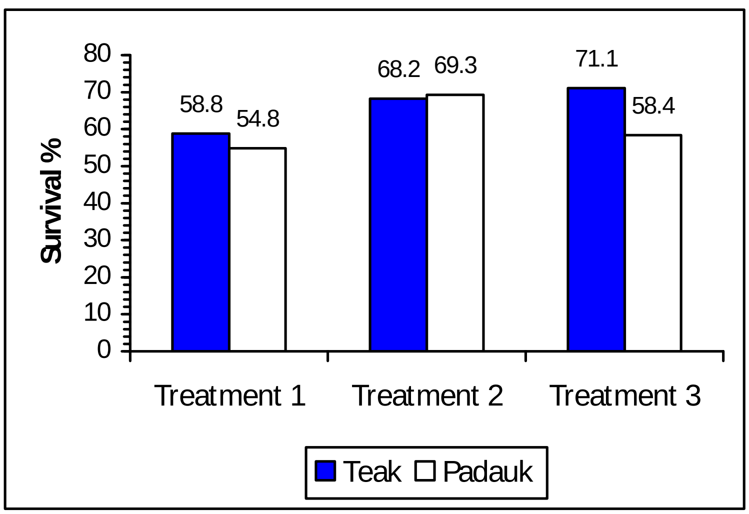

Figure 10: Comparison of mean survival % of treatments between teak and Padauk

The mean survival % of treatments between teak and Padauk are given in the figure (10), Treatment 3 of Padauk shows the highest and Treatment 1 of teak, the lowest. As for teak Treatment 1 gives the lowest survival percent and the Treatment 2 shows the highest in this respect and in Padauk, Treatment 3 is the highest and the Treatment 1 is the lowest. For strong light demander and fast growing species like teak, lowest light opening intensity of Treatment 1 creates great obstacles for the height growth and survival of teak. Meanwhile Treatment 2 of teak shows the highest survival percent as compared to those of the other two treatments. To verify whether there will be significant differences of mean heights of treatment between teak and

Padauk are tested using Genstat Software and the analysis of variances is given in the table 9. As described in the table (9), analysis of variances of over all mean survival % of treatments between teak and Padauk show no significant difference at 5% level.

Table 9: Comparison of mean survival % of treatments between teak and Padauk

Source of variation	d.f.	s.s.	m.s.	Computed F	Tabular F	F pr.
f_Repl stratum	2	25.88	12.94	0.12		
f_Repl. f_Treatments stratum						
	6	653.43	108.91	1.13		
f_Repl. f_Treatment. *Units* stratum						
f_Species	1	120.88	120.88	1.26^{ns}	5.32	0.295
Residual	8	769.69	96.21			
Total	17	1569.87				

ns = significant at 5% level CV% = 15.5

The mean survival % of Padauk between treatments shows increasing with light opening intensity from Treatment 1to 3 (see Figure 10). So availability of light is an important factor for the survival of Padauk and teak as well. Existing condition of the degraded forest, in which large trees with dense crowns are comparatively less and as a result top height of the forest is low, seems to be favourable for the survival of Padauk seedlings planted. In natural forests, similar condition is essential prerequisites for the successful establishment of Padauk and TROUPS, R.S. (1921) stated that "*As a rule natural reproduction is reported to be good only in the rather dry open forests, and is scanty or absent in moist forests where the cover is denser*". Although survival of Padauk is found to be higher with increasing light opening intensity in the present study, but *the past experiment of this species mixing with teak by taungya system had proved a failure and where Padauk and teak have also been tried together in plantations the latter has outgrown the former* (TROUPS, R.S; 1921).

Table 10: Analysis of Variance of Survival % of teak and Padauk between treatments

Species	Teak			
	Treatments	1	2	3
Padauk	1	ns CV% = 23.2 F pr = 0.747	ns CV% = 16.9 F pr = 0.262	***** **CV% = 5.4** **F pr = 0.023**
	2	ns CV% = 20.3 F pr = 0.307	ns CV% = 15.4 F pr = 0.908	ns CV% = 4.0 F pr = 0.656
	3	ns CV% = 20.3 F pr = 0.793	ns CV% = 9.0 F pr = 0.242	**ns** **CV% = 7.9** **F pr. = 0.094**

* = significant at 5% level ns = non significant at 5% level

Therefore Padauk should be managed carefully in enrichment planting though it shows highest growth and satisfactory survival when comparing with teak at the young stage. Great care is required for Padauk to give appropriate silvicultural interventions such as liberation thinning, refining, weeding, fertilizer application, canopy opening and etc., up to the seedlings well established to meet the economic benefits and ecological ones as well. Mean survivals of all treatments between teak and Padauk are also compared and the analysis of variances was made using Genstat Software and the results obtained are given in the table 10.

According to the table 10, all of the analysis of variance of mean heights of all treatments between both species other than that of Treatment 3 of teak and Treatment 1 of Padauk are non significant at 5% level. So Treatment 3 of teak shows significant difference in both mean height and survival of Padauk Treatment 1. Removal of all trees (DBH ≥ 10 cm) and 9.7 m of means height of the stand seems to create more favourable conditions for the growth and survival of teak and so Treatment 3 should be regarded as fundamental line width for teak when enrichment planting is selected to restore and rehabilitate degraded forests which occur in the area of teak natural range.

7.2.1 Analysis of variance of mean survival of teak between Treatments

As shown in the figure (10), Treatment 2 shows highest survival percent followed by Treatments 3 and 1, 69.3%, 58.1 and 52.9 respectively. According to the ANOVA table for the comparison of mean survival of teak between Treatments, there is no significant difference between mean survival percent of treatments.

Table 11: Comparison of mean survival % of teak between treatments

Source of variation	d.f.	s.s.	m.s.	Computed F	Tabular F	F pr.
f_Repl stratum	2	233.37	116.69	1.35		
f_Repl. f_Treatments stratum						
f_Repl. f_Treatment. *Units* stratum						
f_Species	2	247.66	123.83	1.43^{ns}	5.32	0.339
Residual	4	345.45	86.36			
Total	8	826.48				

^{ns} = significant at 5% level CV% = 14.1

Table 12 b: Comparison of mean survival % of teak between treatments

Treatments	1	2
2	ns = significant at 5% level CV% = 12.2, F pr = 0.207	-
3	ns = non significant at 5% level CV% = 17.1, F pr = 0.308	ns = non significant at 5% level CV% = 12.5, F pr = 0.718

In respect to survival of teak, Treatment 1 of the narrowest in line width of 2 m as compared to that of other two treatments shows the lowest. It is also a proof that teak cannot tolerate overhead and side shades and sensitive to interspecies competition for light. It can be concluded that narrow line width is needed to be avoid for teak when restoration, rehabilitation and management of primary degraded forests.

Only treatments 2 and 3 should be taken into account to restore and rehabilitate degraded forests as silvicultural interventions. However, it needs to modify the treatments to be compatible with existing condition of the forest to be enriched especially species composition, horizontal and vertical structures of a particular forest.

7.2.2 Analysis of variance of mean survival of Padauk between treatments

Padauk shows no significant differences between treatments of different light opening intensities at the young stage as seen in the table 12. Treatment 2 shows the highest survival percent of 69.3, followed by Treatment 3 and 1 with 58.4% and 54.8% respectively. As treatment 2 is medium light opening intensity leaving trees with DBH < 10 cm, partial shade might be assumed as favourable condition for the development of Padauk seedlings at the young stage. Moreover, Treatment 2 in Padauk is the best performance not only in survival percent but also in height growth in comparing with other two treatments.

Padauk is also an enlisted species for restoration and rehabilitation activities in the semi-humid (dry) regions of the tropics. It is suggested that Treatment 2 of Padauk should be tried in enrichment planting as a pilot scale at the landscape level.

Table 12 a: Comparison of mean survival % of Padauk between treatments

Source of variation	d.f.	s.s.	m.s.	Computed F	Tabular F	F pr.
f_Repl stratum	2	84.74	42.37	0.86		
f_Repl. f_Treatments stratum						
f_Repl. f_Treatment. *Units* stratum						
f_Species	2	247.66	123.83	3.44^{ns}	6.94	0.135
Residual	4	345.45	86.36			
Total	8	826.48				

ns = non significant at 5% level CV% = 11.6

Table 12 b: Comparison of mean survival % of Padauk between treatments

Treatments	1	2
2	* = significant at 5% level **CV% = 6.4, F pr = 0.047**	-
3	ns = non significant at 5% level CV% = 17.1, F pr = 0.695	ns = non significant at 5% level CV% = 9.7, F pr = 0.165

Mean heights of treatments in Padauk are also statistically analyzed and the results obtained are shown in the table 12 (b). Mean survival percent of Treatment 2 is higher than that of Treatment 1 and show significant difference at 5% level. There are no significant difference between mean survival percent of Treatment 1 and 3, and Treatment 2 and 3. It is indicated that Padauk, the young stage, requires partial shade for its survival and it can withstand side-shade to some extent. Padauk is a very branchy species with short boles developing spreading crown in the open although it develops long and relatively straight boles in closed forest and so it is required side-shade at the young stage of Padauk to produce long straight bole for the economic benefits.

8. Recommendations and Conclusion

To achieve more success and so as to apply some enrichments plantings methods in the country, the following recommendations would like to be given.

1. Intensive tending operations such as weeding, refining, liberation thinning are essential requirements for enrichment planting until the seedlings planted can establish without interfering every stage of their development. Tending operations are required up to 6 years and plantation maintenance should be principally adopted as shown in the table.

   The cost of line enrichment for 20 meter spacing between the lines can be estimated as follows (CATINOT, 1965: cited in H. J. WEIDELT, 1976).

		man days/ ha
1st Year:	Selection of area, marking of blocks and lines,	2
	Clearing of lines, poisoning of trees between lines	11
	digging of planting holes	3
	production of planting stock	5
	planting and replanting, incl. transport of planting stock	4
	weeding	2
2nd Year:	Weed control, climber cutting, further poisoning	3
3rd Year:	-ditto-	3
4th Year:	-ditto-	3
5th Year:	-ditto-	3
6th Year:	-ditto-	3
	Total	42

2. Bamboo culms are the most troublesome for line opening and very costly to clear them and then bamboo culms growing beside lines bend over the seedlings planted and make great obstacles for the seedlings to receive overhead light. Therefore, it should be taken advantages from bamboo flowering for enrichment planting.
3. As enrichment planting requires intensive cares it should be implemented only in landscape level and not extensively. When planting commercial species, the following basic rules are needed to be applied (DAWKINS, H. 1958: quoted in ITTO, (2002).
   - *(i) use close spacing along lines;*
   - *(ii) align the lines east-west in order to maximize access to light;*
   - *(iii) use only species capable of fast height growth in their juvenile stage;*
   - *(iv) close the area to timber harvesting;*
   - *(v) tend the whole area, not just the planted lines;*
   - *(vi) liberate the planted trees from overhead and lateral shade and root competition;*
   - *(vii) monitor the behaviour of wildlife, because lines can become game tracks and the planted trees can attract the attention of wildlife*

4. According to the results obtained from the study, it is uncertain the survival and height growth of teak and Padauk unless sufficient overhead light can be created for them. Treatment 2 shows the highest in height growth and stand in the second position for survival percent. It is predominant timber specie and has been enlisted in promising species for restoration, rehabilitation and management of secondary and degraded forests. So Padauk should be used as enrichment planting species in pilot scale based on the line width and light opening intensity as described in the Treatment 2.
5. In case of teak, all round premier species and pronounced light demander, the research on enrichment purpose need to continue and Treatment 3 should be basic line width and light opening intensity. According to WEIDELT (1976), line width and light opening intensity shown below should be tried for commercial species of the country for enrichment planting.

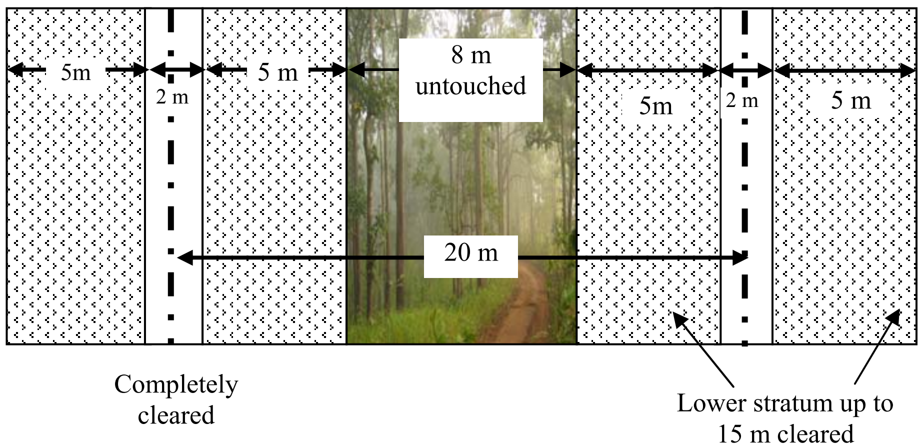

Figure: Line enrichment with shade tolerant species

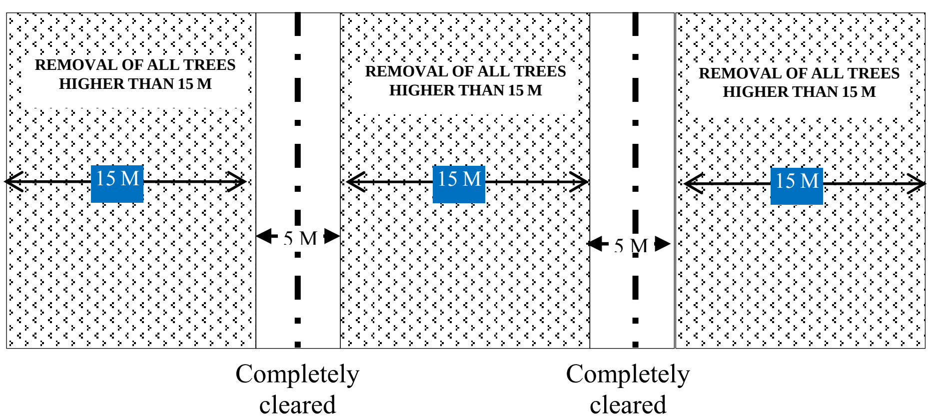

Figure: Line enrichment with light demanding species

6. Pyinkado (*Xylia dolaformis* Benth. Syn *X. kerri* Craib & Hutchinson. Syn *X. xylocarpa* DC. I. lignose Grah) also includes in open-ended list of promising species for enrichment planting in the restoration of degraded primary forests and it has been tried in the enrichment of degraded primary forests in semi-arid (and dry) tropics of India. In Myanmar, It should take the economic importance and shade tolerance ability of this species for restoration and rehabilitation of degraded primary forests.

7. Silvicultural stand analysis is prerequisite for enrichment planting activities in order to realize dynamic of the forests, regeneration and distribution pattern of desirable species.
8. Other commercial species such Tamalan (*Dalbergia oliveri* Gamble), Thinwin (*Millettia pendula* Benth.), Thitya (*Shorea obtuse* Wall.), Ingyin (*Pentacme siamensis* (Miq.) Kz), should also be tried in enrichment planting in accordance with their ecological requirements.
9. Other economic potential species suitable for enrichment planting should also be explored and other enrichment planting methods applying in other tropical countries should be introduced in the country.
10. As the trees enriched have to compete severely against existing vegetation, at least one year seedlings need to be used to ascertain survival and height growth. Fertilizer application also plays in important role for the rapid growth.

9. Conclusion

Restoration and rehabilitation activities by enrichment planting with desirable species is not an easy one as it not only needs to investigate the existing condition of a given degraded forest by conducting diagnosis sampling survey to realize dynamic of the forest but also to understand development potentials of the species that want to be enriched, and at the same time it needs not be lost sight of the main objectives of maintaining ecological status of the given forest and to achieve economical benefits. Enrichment planting has commonly been used for the restoration of logged primary forests and for increasing the wood volume and economic value of secondary forests. The experience with enrichment plantings in secondary forests has generally been more favourable than when applied in primary/logged-over forests.

The success of enrichment planting has been variable and sufficient overhead light availability of the seedlings of light demanding species is determining factor for their establishment. Some of the reasons for enrichment planting in the tropics are difficulties to supervise in planting works, costly and labour demanding. In general, failures are attributed to poor selection of species and/or the lack of adherence to sound planting and tending practices, improper selection of planting stocks, insufficient canopy opening prior to planting, insufficient follow-up tending and pest attack.

Therefore, enrichment planting should be managed carefully and adequate funding is essential for the success.

References:

Anon., 1993: Forestry Fact Sheets, Forest Resources Division, Forest Department, Ministry of Forestry, Union of Myanmar.

ITTO, 2002: ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. ITTO Policy Development Series No. 13, International Tropical Timber Organization.

Lamprecht, H., 1989: Silviculture in the Tropics: Technical Cooperation - Federal Republic of Germany, Eshborn.

Tewari, D. N., 1992: A Monograph on Teak. International Book Distributors, Dehra Dun - 248006 India.

Troup, R. S., (1921): The Silviculture of Indian Trees, Volume II, Leguminosae (Caesalpiniaceae) to Verbenaceae, Claredon Press, Oxford.

Weidelt, H. -J., 1976: Establishment, Maintenance and Protection of Forest Plantation. Manual of Reforestation and Erosion Control for the Philippines. German Agency for Technical Cooperation, Ltd. (GTZ), Eshborn.

Weidelt, H. -J., 1999/2000: Tropical Silviculture: Provisional Lecture Notes, Institute of Tropical Silviculture, Goettingen University (Unpublished)

Appendix 1

Climax forest formations in the tropical belt

General characteristics: Daily thermal regime: daily and annual averages fluctuate between 28° and 10° C according to the elevation. Occurrence of occasional frost only in high montane forests.

Nomenclature	Physiognomy	CLIMATE — a = aridity index acc. to DE MARTONNE; T_a = mean annual temperature; N_a = mean annual precipitation
1. Moist evergreen forests a. Low elevation b. Montane c. High montane (cloud forests)	Evergreen, 3-to multi-storied, rich in tree species Multistoried, cauliflory, buttresses Generally, 3-storied, few buttresses 3-storied, very rich in epiphytes, tree ferns	No more than 1 month a<20, N_a>5(T+14) cm Hot (T_a ca. 22-28°C; N_a>1800 mm) Temperature (T_a ca. 14-22°C; N_a>1400 mm) Moderately cold and moist (T_a ca. 10-14°C; N_a>1200 mm)
2. Moist deciduous forests a. Lowland b. Montane	± many periodically deciduous species, 2-to 3-storied, rich in tree species Rainy season: appearance ± the same as moist evergreen forests Dry season: at least the upper story is semi-deciduous, few buttresses, fewer epiphytes	Max. 4 months a<20, Min. 6 months a>40; N_a between 5 (T+14) cm & 2½(T+14) cm Hot (T_a ca. 22-28°C) Temperate (T_a ca. 14-22°C)
3. Dry deciduous forests	Periodically bare for longer periods, 1- to 2-Dornenedstoried, ± poor in species, many thorned species, xeromorphous structure	The length and intensity of the dry season is more decisive than the temperature 6-8 months a<20, ca. 3 months a>40 N_a <2 (T+14) cm

Comments: 1. Although the tropical forest is dominated by broad leaved trees, conifers occasionally occur in all formations (mainly due to extreme soil conditions), in particular in Southeast Asia and Central America. Most widespread genera are, among others:

1a: *Agathis, Dacrydium, P. merkusii*

1b: *Abies, Agathis, Araucaria, Cupresses, Dacrydium, Pinus,Podocarpus*

2a: *Callitris, Pinus*

2b: Up to the tree line *Abies, Cephalotaxus, Cunningghamia, Juniperus, Pinus, Podocarpus*

2. Apart from climatic formations, edaphic forest types also occur, e.g. gallery, peaty, freshwater swamp forests, mangrove forests, etc.

Appendix 2

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

Ranking	Species	Scientific Name	Total			Relative			IVI
			Ab. N/ha	Dom. m^2/ha	Freq. %	Ab. %	Dom. %	Freq. %	
1	Yinma	*Chukrasia tabularis* A. Juss	55	0.612	34	13.7	8.2	11.8	33.8
2	teak	*Tectona grandis* Linn. F	61	0.464	29	15.2	6.2	10.1	31.6
3	Padauk	*Pterocarpus macrocarpus* Kurz.	31	0.595	17	7.7	8.0	5.9	21.7
4	Bebya	*Cratoxylon neriifolium* Kz.	28	0.633	17	7.0	8.5	5.9	21.4
5	Seikchi	*Bridelia retusa* (L.) Spreng	23	0.729	16	5.7	9.8	5.6	21.1
6	Thadi	*Protium serratum* Englar.	6	0.961	5	1.5	12.9	1.7	16.2
7	Didu	*Bombax insigne* Wall.	22	0.276	19	5.5	3.7	6.6	15.8
8	Pyinkado	*Xylia dolabriformis* Benth.	14	0.271	13	3.5	3.6	4.5	11.7
9	Kyetyo	*Vitex pubescens* Vahl.	10	0.265	9	2.5	3.6	3.1	9.2
10	Thitpagan	*Dalbergia lanceolaria* L.	7	0.296	7	1.7	4.0	2.4	8.2
11	Tayaw	*Grewia polygama* Roxb.	9	0.194	9	2.2	2.6	3.1	8.0
12	Dawni	*Eriolaena candollei* Wall.	12	0.139	8	3.0	1.9	2.8	7.7
13	Magyibauk	*Sapindus mukorosis* Gaertn.	13	0.086	9	3.2	1.2	3.1	7.5
14	Petwun	*Mallotus nepalensis* Muell.	8	0.150	8	2.0	2.0	2.8	6.8
15	Kuthan	*Hymenodictyon excelsum* Wall.	10	0.085	7	2.5	1.1	2.4	6.1
16	Petthan	*Haplophragma adenophyllum* Wall.	9	0.070	8	2.2	0.9	2.8	6.0
17	Gwe	*Spondias pinnata* (L). Kz.	4	0.245	4	1.0	3.3	1.4	5.7
18	Nabe	*Lannea grandis* Ehgl.	8	0.071	8	2.0	1.0	2.8	5.7
19	Pokthinma-myetkauk	*Derris robusta* Benth.	3	0.272	3	0.7	3.7	1.0	5.5
20	Gyo	*Schleichera oleosa* Merr.	7	0.082	6	1.7	1.1	2.1	4.9
21	Lettok_gyi	*Holarrhena antidysenterica* Wall.	5	0.026	5	1.2	0.3	1.7	3.3
22	Sawbya	*Pterocymbium tinctorium* Merr.	1	0.192	1	0.2	2.6	0.3	3.2
23	Unidentified		8	0.064	1	2.0	0.9	0.3	3.2
24	Kyun-nalin	*Premna latifolia* Roxb	4	0.038	4	1.0	0.5	1.4	2.9
25	Hnaw	*Adina cordifolia* Hk. f.	2	0.111	2	0.5	1.5	0.7	2.7
26	Yinzat	*Dalbergia fusca* Pierre.	2	0.105	2	0.5	1.4	0.7	2.6
27	Binga	*Mitragyna rotundifolia* Ktze.	2	0.088	2	0.5	1.2	0.7	2.4
28	Madama	*Dalbergia ovate* Grah.	4	0.024	3	1.0	0.3	1.0	2.4
29	Mayanin	*Acrocarpus fraxinifolius* Wt.	3	0.026	3	0.7	0.3	1.0	2.1
30	Thetyingyi	*Croton roxburghianus* Bal.	3	0.023	3	0.7	0.3	1.0	2.1
31	Chinyok	*Garuga pinnata* Roxb.	3	0.011	3	0.7	0.1	1.0	1.9
32	Linyaw	*Dillenia parviflora* Griff.	3	0.009	3	0.7	0.1	1.0	1.9
33	Nagye	*Pterospermum semisagittatum* Ham.	3	0.027	2	0.7	0.4	0.7	1.8
34	Yon	*Anogeissus acuminate* Wall.	2	0.025	2	0.5	0.3	0.7	1.5
35	Leza	*Lagerstroemia calyculata* Kz	1	0.042	1	0.2	0.6	0.3	1.2
36	Thanat	*Cordia dichotoma* Forst.	1	0.042	1	0.2	0.6	0.3	1.2
37	Kinbalin	*Antidesma diandrum* Roth.	2	0.004	1	0.5	0.1	0.3	0.9
38	Wetshaw	*Erythropsis colorata* Roxb.	1	0.015	1	0.2	0.2	0.3	0.8
39	Kathit	*Erythrina arborescens* Roxb.	1	0.006	1	0.2	0.1	0.3	0.7
40	Kyaungsha	*Oroxylum indicum* Vent.	1	0.009	1	0.2	0.1	0.3	0.7
41	Lein	*Terminalia pyrifolia* Kz.	1	0.009	1	0.2	0.1	0.3	0.7
42	Phalan	*Bauhinia recemosa* Lam.	1	0.006	1	0.2	0.1	0.3	0.7
43	Sa-thange-ohnauk	*Cratoxylon prunifolium* Dyer & Kz	1	0.006	1	0.2	0.1	0.3	0.7
44	Thande	*Stereopermum grandiflorum* Cubitt.	1	0.005	1	0.2	0.1	0.3	0.7
45	Yindaik	*Dalgergia cultrate* Grah.	1	0.005	1	0.2	0.1	0.3	0.7
46	Zaungbale	*Lagerstroemia villosa* Wall.	1	0.005	1	0.2	0.1	0.3	0.7
47	Hingut	*Dolichandrone spathacea* K. Schum	1	0.001	1	0.2	0.0	0.3	0.6
48	Taung-magyi	*Albizzia odoratissima* (L. f.) Benth	1	0.003	1	0.2	0.0	0.3	0.6
49	Thabut-gyi	*Miliusa velutina* Hk. f. & T	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 3

Regeneration density of species found in the degraded forest investigated arranged in descending order

Sr.	Common name	Scientific name	No. of seedlings/0.25 ha
1	Lettok_gyi	*Holarrhena antidysenterica* Wall.	140
2	Petthan	*Haplophragma adenophyllum* Wall.	96
3	Yinma	*Chukrasia tabularis* A. Juss	82
4	Kyun-nalin	*Premna latifolia* Roxb	80
5	Bebya	*Cratoxylon neriifolium* Kz.	72
6	Seikchi	*Bridelia retusa* (L.) Spreng	39
7	Yon	*Anogeissus acuminate* Wall.	39
8	Tayaw	*Grewia polygama* Roxb.	35
9	Madama	*Dalbergia ovata* Grah.	34
10	**Teak**	***Tectona grandis* Linn. F**	**30**
11	Didu	*Bombax insigne* Wall.	20
12	Gyo	*Schleichera oleosa* Merr.	20
13	Kinbalin	*Antidesma diandrum* Roth.	19
14	Pyinkado	*Xylia dolabriformis* Benth.	15
15	Kuthan	*Hydnophytum formicarium* Jack.	14
16	Thabut-gyi	*Miliusa velutina* Hk. f. & T	14
17	Thadi	*Protium serratum* Englar.	13
18	Binga	*Mitragyna rotundifolia* Roxb.	12
19	Kyetyo	*Vitex pubescens* Vahl.	12
20	Mahlwa	*Markhamia stipulata* (Wall) Seem	12
21	Sathange-ohnok	*Cratoxylon prunifolium* Dyer & Kz	12
22	Thitpagan	*Dalbergia muliflora* Heyne.	12
23	Kyaungsha	*Oroxylum indicum* Vent.	11
24	Petwun	*Mallotus nepalensis* Muell.	9
25	Dwani	*Eriolaena candollei* Wall.	8
26	Linyaw	*Dillenia parviflora* Griff.	8
27	Thitsein	*Terminalia bellerica* Roxb.	8
28	Leza	*Lagerstroemia calyculata* Kz.	7
29	Padauk	*Pterocarpus macrocarpus* Kurz.	7
30	Yinzat	*Dalbergia fusca* Pierre.	7
31	Magyibauk	*Randia dumetorum* Lam.	6
32	Thetyingyi	*Croton roxburghianus* Bal.	6
33	Dwabok	*Kydia calycina* Roxb.	5
34	Okshit	*Aegle marmelos* (L.) Correa.	5
35	Yindaik	*Dalbergia cultrate* Grah.	4
36	Chinyok	*Garuga pinnata* Roxb.	3
37	Thande	*Stereopermum grandiflorum* Cubitt.	3
38	Hingut	*Dolichandrone spathacea* K. Schum	2
39	Lein	*Terminalia pyrifolia* Kz.	2
40	Pokthinma-myetkok	*Derris robusta* Benth.	2
41	Pyinma-ywetkyi	*Lagerstroemia macrocarpa* Kz.	2
42	Zaungbale	*Lagerstroemia villosa* Wall.	2
43	Gwe	*Spondias pinnata* (L.) Kz.	1
44	Hnaw	*Adina cordifolia* Hk.f.	1
45	Nabe	*Lannea grandis* Ehgl.	1
46	Taung-thayet	*Swintonia floribunda* Griff.	1
47	Zibyu	*Emblica officinalis* Garten.	1
	Total		**439**