# Report of Pre-Feasibility Survey

on

# Reforestation in Brunei

July 1982

Japan International Cooperation Agency

# PREFACE

It is with great pleasure that I present Report on Pre-Feasibility Survey for Forestry Development in Brunei to the Government of Brunei.

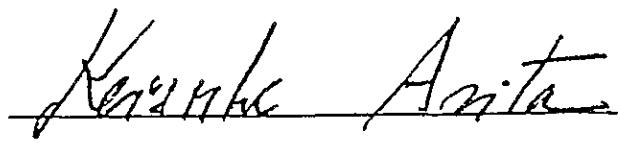
This report embodies the result of a pre-feasibility survey which was carried out from 25th March to 9th May 1982 by a Japanese survey team commissioned by the Japan International Cooperation Agency.

The survey team, headed by Mr. Hisashi Oya had a series of discussions with the officials concerned of the Govenment of Brunei and conducted an extensive field survey and data analyses.

I hope that this report will be useful as a basic reference for forestry development of Brunei.

I wish to express my deep appreciation to the officials concerned of the Government of Brunei for their close cooperation extended to the survey team.

June 1982



Keisuke Arita
President

Japan International Cooperation Agency

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# Report of Pre-Feasibility Survey on Reforestation in Brunei

## 1. Summary

(1) This report is the result of the "pre-feasibility survey on reforestation in Brunei" which was carried out from March 25 to April 9, 1982 for the purpose of forest development in Brunei, particularly for the implementation of a trial reforestation project.

(2) Brunei is endowed with large conservation areas of virgin forests. By conserving indigenous tree species such as Meranti, Kapur, Agathis, and others, and by conducting natural regeneration trials, the Government of Brunei is acting on forest resources conservation with enthusiasm. Accordingly, the conditions of natural forests are extremely good.

These activities are highly commended at the present time when forests are decreasing rapidly in various regions of Southeast Asia. It is also important that these forests will continue to provide forest tree genes and seeds in the future.

(3) Artificial reforestation trials with exotic tree species have been carried out in Brunei since 1960s, though on a samll scale and nearly 30 species have already been tested. Nevertheless, this experimental reforestation is as yet insufficient and is still inadequate to provide information and data to develop a system of reforestation techniques.

Trial reforestation over a much larger area with a systematic plan would be necessary in the future.

(4) In carrying out reforestation trials, selection of sites is quite important. Before launching the trial project, a survey must be made of soil, topography, vegetation, water supply and road conditions, together with availability of manpower.

(5) A reforestation trial project would require two-phases.

In Phase 1, trial reforestation on a small-scale, including nursery trials, would be carried out, primarily as a "species elimination test".

In Phase 2, medium-scale trial reforestation would be carried out as a "stand growth test".

After reforestation and management techniques are developed through these tests, industrial tree plantation would be started.

(6) Since these trial projects will cover a long period of time, there is a need to conduct them with adequate organization and planning.

The result of the trial reforestation carried out jointly by the Forestry Department and National Paper & Pulp Co., (N.P.P.), seems to be promising, therefore, it would be effective to introduce the activities of the private sector for the expansion of trial reforestation.

## 2. Introduction

(1) Purpose of Survey

Purpose of the team is to carry out a pre-feasibility study on forestry development especially on setting up the silvicultural techniques in Brunei.
The establishment of the re-afforestation works ensures the sustained yield of forest products and promotes the environmental functions of forests.
From those points of view, the team has studied the natural and economic conditions for the re-afforestation by an on-the-spot survey in cooperation with the forest department of Brunei from 30th March to 3rd April.

(2) Members

| | | |
|---|---|---|
| Hisashi Oya | Team Leader | President, Japan Forest Civil Engineering Consultants Foundation |
| Niro Namura | Experimental planning | Executive Director, Japan Overseas Forestry Consultants Association |
| Hatsuo Hashimoto | Cooperation Planning | Assistant Director, Personnel Division, Forestry Agency, M.A.F.F. |
| Isamu Yamada | Reforestation | Chief, Breeding Lab, Kanto Forest Tree Breeding Institute, M.A.F.F. |
| Seiichi Yonekawa | Project Planning | Research & Development Manager, Settsu Paperboard Mfg. Co., Ltd. |
| Hideya Kitagori | Coordinator | Vice Head, Finance Cooperation Division, Forestry & Fisheries Development Cooperation Dept., J.I.C.A. |

(3) Itinerary

| | |
|---|---|
| March 26 Fri. | Arrival at Burunei (MH 520) |
| 27 Sat. | Courtesy call to the Brunei governmnent concenrned.<br>Forest Dept.<br>Diplomatic Service Dept.<br>Agriculture Dept.<br>Immigration Dept.<br>Land Dept.<br>Economic Development Board<br>State Secretariat; Information Dept.<br>Economic Planning Unit |
| 28 Sun. | |
| 29 Mon. | Discussion with the Forest Dept.<br>Visit to Lamunin test plantation site of Forest Dept. |
| 30 Tue. | Visit to Badas Forest Reserve, Ulu-Badas test plantation site and Sungai Liang Forest Research Institute. |
| 31 Wed. | Sungai Liang Forest Research Institute. |

| | | |
|---|---|---|
| April | 1 Thu. | Helicopter survey; Ladan Forest Reserve, Ulu-Tutong forest, Ulu-Belait peat swamp forest, Andulau Forest Reserve and Labu Forest Reserve.<br>Visit to Jerudong test plantation site. |
| | 2 Fri. | Visit to experimental plantation sites of N.P.P.; Bt. Kukub, Lurong 10 Timor, Bt. Perumpong and Mcfarm Giant Ipil-Ipil site. |
| | 3 Sat. | Visit to logging camp of Lutong Sawmill. |
| | 4 Sun.. | |
| | 5 Mon. | Making a interim report. |
| | 6 Tue. | Discussion with relevant government authorities.<br>Reception at Horitage in Sheraton-Utama Hotel. |
| | 7 Wed. | Leave Burunei (MH 521) |

### 3. Possible Cooperation in Forestry

The forests of Brunei occupy about 75% of the entire land (576,500 ha). The use of forest resources has been limited to meeting domestic demand and the forests have been comparatively well conserved.

The economy of Brunei is supported by the petroleum and natural gas industries. Aside from petroleum and natural gas, forests are significant natural resources in Brunei.

However, forestry activities are being carried out at the moment without firm medium or long-term forest development plans.

To promote effective use of forest resources on the basis of long-term plans, and to further enrich the existing forests is an important subject for Brunei, not only for the conservation of land and environment but also for a stable economic development and creation of more employment opportunities.

For this purpose the Government of Brunei and N.P.P. are implementing experimental reforestation on a small scale. As it was started only a few years ago, the result is as yet uncertain, and a request has been sent to JICA for cooperation this field.

It will be important for Japan to cooperate with Brunei in re-afforestation and other development activities. In doing so, it is essential to undertake trial reforestation first before launching a large-scale re-afforestation programme.

To start a reforestation trial, aquisition of lands and to set up an implementing organization would be important.

Land: Shifting agriculture is still practised though decreasing rapidly; the government is reportedly intending conversion of forests into agricultural lands; these two factors, coupled with other types of land use, may cause certain limits in selecting lands for a reforestation trial. However, as forests are all state-owned and the Forest Department is eager to cooperate, no substantial problems are foreseen in finding out a suitable site for the trial.

Implementing body: Reforestation trials will have to be carried out systematically and for a longterm. Particularly in Brunei, an insufficient number of forestry professionals and technicians is a serious constraint. Therefore, it is required to increase and train the staff and upgrade its competence. A practical and realistic approach to meet this requirement would be to introduce and expand activities of the private sector in reforestation trials in view of the initial success, though on a small-scale, shown by the joint project between the Forest Department and N.P.P.

## 4. Reforestation Trial

(1) Outline of Trial Reforestation

The aim of trial reforestation is to obtain basic technical and management data for future industrial large scale reforestation.

Accordingly, importance should be attached to the following items as the basic character of trial reforestation:

① It should be useful in maintaining and increasing qualitatively and quantitatively the outstanding forest resources that will become the foundation of Brunei's forest industries in the future.

② It should be useful in the development of intensive forest management and wood processing industries that will promote the establishment of employment opportunities and the training of capable persons.

③ It should be useful in developing and improving of forest management technology that will promote the public interest functions of forests such as soil conservation, protection of the natural environment, and reservation of water resources.

Under the foregoing understanding, it is believed that the means of advancing definite cooperation for reforestation will go through the following stages:

① Preparatory Stage – Construction and establishment of facilities and system.

② Trial Reforestation, Phase 1 – Species elimination test (including nursery test).

③ Trial Reforestation, Phase 2 – Stand growing test.

④ Reforestation Project for Industrialization – Industrial tree plantation test.

The period of the foregoing ① Preparatory Stage will be set at two years. During this time, the system for facilities, personnel and organization, such as nursery, roads and others, will be established, the materials and equipment purchased, seeds procured, and the production of seedlings carried out.

In ②, Trial Reforestation, Phase 1 four years will be allotted after the Preparatory Stage as the period for planting and three years as the period for observation of progress, a total of seven years. During this time, from among tree species planted in the past or in other regions, the species considered promising will be planted based on the design referred to later. In this way, a study will be made of the survival, vigor and crown cover of each species by site conditions. The target for the size of the plantation will be about 110 ha in four years (10 ha → 20 ha → 30 ha → 40 ha).

Trial Reforestation, Phase 2 ③ will set a period of five years following the above four-year period. A study will be made of the conditions of growth (tree height, diameter, tree volume) of the tree species selected in Phase 1 as suitable, by the method of planting (spacing, nutrition and stand). The target for the size of the plantation will be about 1,000 ha in three years (100 ha → 140 ha → 180 ha → 220 ha → 360 ha).

In addition, in this Phase 2, both line-planting and natural regeneration tests (including enrichment-planting) will be carried out together in hill and swamp forests.

Next, the Reforestation Project for Industrialization 4 is not included in this survey for the Trial Reforestation, but it is a project to study the forest management system (forestry execution system linking reforestation and yield) that is necessary for nationwide development of

the reforestation works in the future.

It is believed that in this phase, cooperative relationship between the Brunei side and Japanese side are necessary in funds, organization, land and other pahses. This period will begin after the ending of Trial Reforestation, Phase 2, and at least ten years are scheduled to obtain the thinning yield of fast growing species. The target for the size of the planting area is an average 250 ha to 300 ha annually.

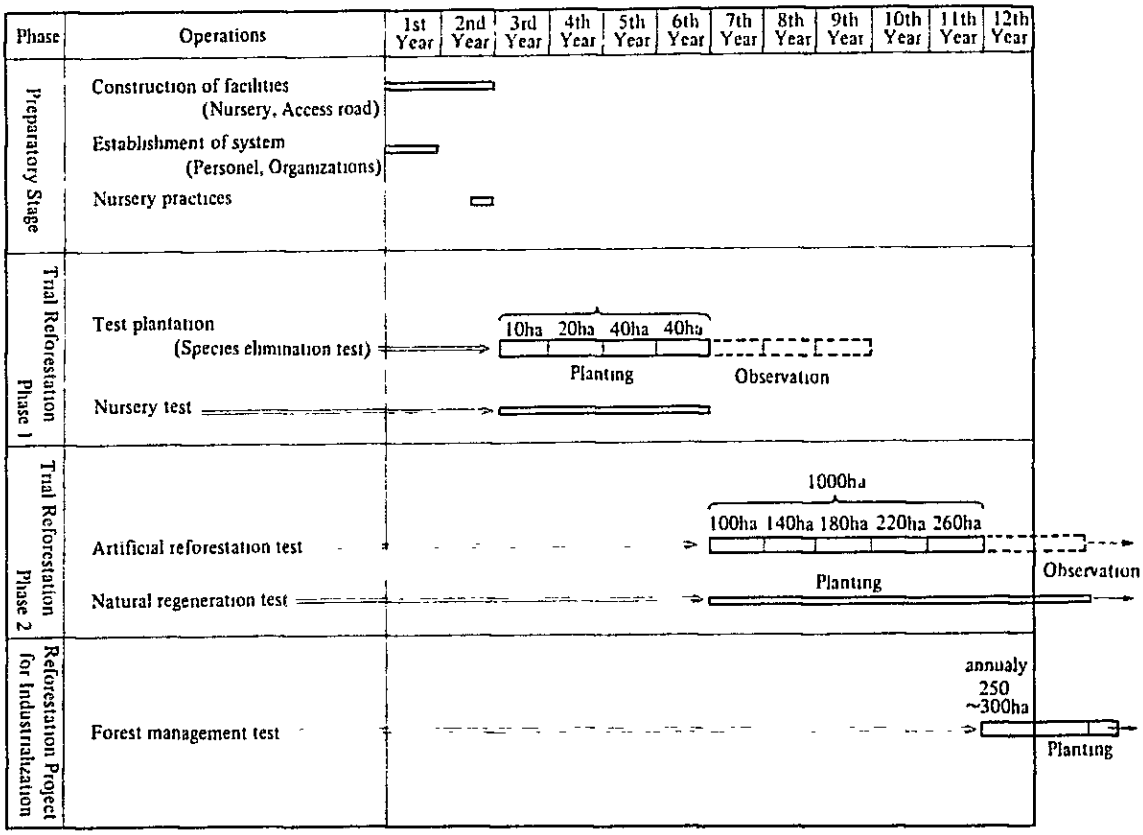
Since each phase (including industrial project for industrialization) is a technical and management test aimed at re-afforestation for future industrial use, it would be desirable for these tests to be carried out by the cooperation of the Brunei side and with the participation of a private sector on Japanese side.

In the stages of ① Preparatory Stage to ③ Trial Reforestation, Phase 2, it would be appropriate that a Japanese private sector is responsible for the funds and organization to be procured and arranged, as well as being the implementation body to carry out the work with cooperation of Brunei in terms of institutional advice and providing of sites.

It is also desirable for the Reforestation Project for Industrialization ④ to be carried out by a Japanese enterprise and a Brunei organization united as one.

The foregoing stages are summarized in Table 4-1.

**Table 4-1. Schedule for Cooperative Reforestation**



(2) Studies To Be Undertaken

① Trial Reforestation, Phase 1

This stage will consist of test plantation for species elimination and nursery test for establishment and improvement of nursery practice.

Test plantation for species elimination will be mainly carried out on fast growing species which are regarded as promising from past results. These include foreign species (Alibizzia falcata, Acacia mangium, Eucalyptus deglupta, Pinus caribaea and others) and indigenous species to be tested in view of the results in other countries or their utilization (Anthocephalus cadamba, Endospermum malaccense, Cratoxylon arborecesn = GERONGGANG, Octomeless sumatrana, Campnosperma auriculate = TERENTANG, Gonystylus Spp. = RAMIN, Dyera Spp. = JERUTONG and others.

The study will cover:

(a) Measurement of survival rate – Survival rate after one dry season.

(b) Rate of dead trees – rate of dead trees by cause, annually after planting.

(c) Rate of unhealthy trees – Rate of unhealthy trees by cause, annually after planting.

(d) Height growth – Annual height growth after planting.

(e) Diameter growth – Annual diameter growth after planting.

(f) Weeding – Estimation of the closing period of weeding.

(g) Crown covering – Estimation of the completion period.

The above subjects will be measured and analyzed by site conditions.

In addition, besides fast-growing species, test plantation on slow-growing saw timber species (Araucaria hunsteinii, Swietenia macrophylla, cordia Spp. Peronema canescens and others) will be carried out in parallel from the third year of this stage onward.

In the following nursery test, measurement and analysis will be conducted by provenances of the abovementioned species:

(a) Seed storage test.

(b) Germination test.

(c) Material soil test.

(d) Mycorrhiza and fertilizer test.

(e) Disease analysis.

(f) Calculation of sound seedlings percentage.

(g) Slipping test.

② Trial Reforestation, Phase 2

In contrast to the Phase 1, which was to study the growth result of individual trees, the purpose of the Phase 2 is to find out volume increments, growing course, yield volume/ha and yield age by each forest stand.

The Phase 2 will consist of artificial reforestation test and natural regeneration test.

Artificial reforestation will be carried out mainly with fast-growing species selected in the earlier Phase 1 as promising species. Medium-growing species will be secondary. When future industrial tree plantation is taken into consideration, inclusion of a large number of tree species is not deemed in practical. They should be limited to about five to seven species.

The following tests will be carried out for each species by stand site. The tree height and D.B.H. will be measured annually from full five years after planting.

(a) Land preparation test – Burning and non-burning separately.

(b) Specing test – Sparsity and density separately.

(c) Density control test – Drawing up of density control curve.

(d) Site class investigation – Preparation of site class index.

(e) Nutrition test – Fertilized and non-fertilized separately.

(f) Line planting test – Work to finally remove shade trees and make it an entirely clear cut condition.

Next, in the natural regeneration test, a fixed experimental area will be set up to investigate natural regeneration and stand growth of slow-growing species in hill and swamp forests. The following tests will be conducted:

(a) Flowering and fruiting study – Time, perennial nature, etc.

(b) Germinationand survival study – Effects by felling, changing of light intensity, clearing, land treatment, etc.

(c) Increment and mortality study – In accordance with selective cuts, improvement cuts, etc.

(d) Enrichment-planting test – Management system in which shade trees will finally remain.

(e) Test for seed tree system – Regeneration test when seed trees are left.

③ Industrial Tree Plantation

As mentioned in the foregoing, this is outside the scope of this survey for the time being. The following can be assumed to be the test subjects:

(a) Formulation of yield table.

(b) Determination of forest management system.

(c) Calculation of forest management revenue and expenditure.

For reference, the growth conditions of man-made forests in tropical rain forest areas are shown in Table 4-2.

## Table 4-2. Results of Artificial Reforestation

| Country / Regions | Species | Age (Year) | Average growing stock per ha ($m^3$) | Number of trees per ha (tree) | Average DBH (cm) | Average tree height (m) | Average annual increement ($m^3$) | Spacing | Remarks | |
|---|---|---|---|---|---|---|---|---|---|---|
| P.N.G | Eucalyptus deglupt | 20 | 226 | 100 | 39.6 | 40.8 | 11.3 | 4.6 x 4.6 m | 1981 Nov. measured | |
| (New Britain, | deglupta | 20 | 261 | 100 | 43.8 | 40.2 | 13.3 | | 1982 Mar. JOFCA Report | |
| Keravat) | | 10 | 229 | 240 | 28.8 | 31.3 | 22.9 | | | |
| | | 15 | 417 | 270 | 34.6 | 39.1 | 27.8 | | | |
| | | 25 | 576 | 150 | 49.2 | 48.5 | 23.0 | | | |
| | | 11 | 231 | 310 | 24.7 | 26.8 | 21.0 | | | |
| | | 5.8 | 142 | 420 | 20.7 | 22.6 | 24.7 | 4 x 4 m | | |
| | | 5.7 | 120 | 430 | 17.8 | 21.4 | 21.2 | 3 x 3 m | | |
| | | 5.0 | 116 | 340 | 19.5 | 22.8 | 23.2 | 4 x 4 m | | |
| | | 4.7 | 77 | 450 | 15.3 | 17.6 | 16.4 | 3 x 4 m | | |
| | | 3.8 | 73 | 480 | 15.0 | 17.9 | 19.6 | 3 x 3 m | | |
| | | 3.8 | 72 | 530 | 14.0 | 17.7 | 19.0 | 3 x 3 m | | |
| P.N.G | Eucalyptus | 5.4 | 64 | 344 | 16.5 | 19.6 | 11.8 | 4 x 4 m<br>3 x 3 M | *Average of 12 blots* | *flat land hill side* |
| (Madang) | deglupta | | | | | | | | | |
| | | 4.7 | 94 | 561 | 16.5 | 19.8 | 20.2 | ~~6 x 2 m~~<br>4 x 4 m<br>3 x 3 m | Average of 5 blots | foot of hill & hill side |
| | | 3.5 | 38 | 409 | 13.0 | 16.0 | 10.2 | 4 x 4 m | Average of 2 blots | hill side |
| | | estimated | | | | | | | | |
| *Indonesia* | *Peronema* | 5 | | | 3.0 | 2.2 | | | 1979 measured JICA Report | |
| (South | canescens | 5 | | | 3.9 | 2.6 | | | | |
| Sumatera) | | 6 | | | 9.8 | 6.1 | | | | |
| | | 4 | | | 4.9 | 3.1 | | | | |
| | | 5 | | | 3.1 | 4.5 | | | | |
| | Parus | estimated. | | | | | | | | |
| | merkusii | 17 | 143 | 362 | 27.0 | 20.0 | 8 | | | |
| | | 12 | 63 | 350 | 20.0 | 18.0 | 5 | | | |
| | | 12 | 266 | 575 | 24.0 | 22.0 | 22 | | | |
| | | estimated | | | | | | | | |
| | | 12 | 325 | 159 | 33.0 | 33.0 | 27 | | | |
| Fiji | Swietenia | 14 | 87.18 | 355 | 22.3 | | 6.22 | | 1975 measured | |
| (Nukurua) | macrophylla | 13 | 54.05 | 161 | 24.6 | | 4.16 | | 1977 JICA Report | |
| | | 12 | 51.83 | 162 | 25.1 | | 4.32 | | | |
| | | 11 | 32.06 | 134 | 23.0 | | 2.98 | | | |
| | | 11 | 21.05 | 113 | 20.1 | | 1.91 | | | |

(3) Proposed Area for Trial Reforestation

Even in the case of a trial, land for artificial reforestation is located in Forest Reserve in most countries. For example, the Technical Cooperation Project of Reforestation in Pantabangan, Philippines, is located in state-owned land excluding A & D area (Allied & Disposal Area). The Cooperative Reforestation Project in Madang, Papua New Guinea, is located in forest land for which the timber right has been purchased from the government.

The policy of the Brunei Government, however, is that land outside the Forest Reserve would be preferable for artificial reforestation. For the time being, land adjacent to Forest Reserve will be considered. The Brunei side will be requested to consider artificial reforestation in Forest Reserve in the future.

Even if the project site is outside the Forest Reserve, a place with second growth would be desirable. Grassland that has resulted from many years of shifting cultivation is undesirable.

In regard to the natural conditions of topography, soil and other factors, hilly terrain and slightly eluvial Acrisol (Red Yellow Podzolic soil) or Luvisol would be preferable for the artificial reforestation site. On the other hand, depending on the test subject (such as artificial reforestation of swamp forest), Histosol or Gleysol sites in swampy ground or lowland will be inevitable.

Candidate sites for trial reforestation that meet the abovementioned conditions are:

① Near Lamunin Test Plantation Site
② Vicinity of Sungai Liang (such as Bukit Perumpong)
③ Near Bukit Kukub
④ Vicinity of Ulu-Badas
⑤ Badas lowland
⑥ Lutong swampland } for natural regeneration test

Next, the conditions for nursery site are that it is near a test reforestation site (from the standpoints of seedlings transportation cost and damage), good drainage of top soil, no fear of flood, convenient water supply, gentle terrain (only a small amount of earth work necessary), nearby supply source of soil, sand and humus to be put into pots, and good locality for control and management (site with short access road and sufficient electric power supply .)

When these conditions and the earlier mentioned proposed area for Trial Reforestation are considered together, it is desirable that the proposed nursery site be selected from one of the following two area:

① Sungai Liang district.
② Lamnin district.

As mentioned in the next section, about 2 ha will be necessary for the nursery including an office, workship, storehouse and others.

(4) Design for Trial Reforestation

1 Design for Preparatory Stage

(a) The minimum composition of the organization and personnel in the Preparatory Stage can be considered as follows:

Manager – 1

Assist. Manager – 1
Staff (Female) – 1

Field Manager – 1

Permanent Laborers
(for nursery practices and weeding.
To be increased according to increase
of work volume)

Casual Laborers
(for land preparation and planting.
To be recruited according to increase
of work volume)

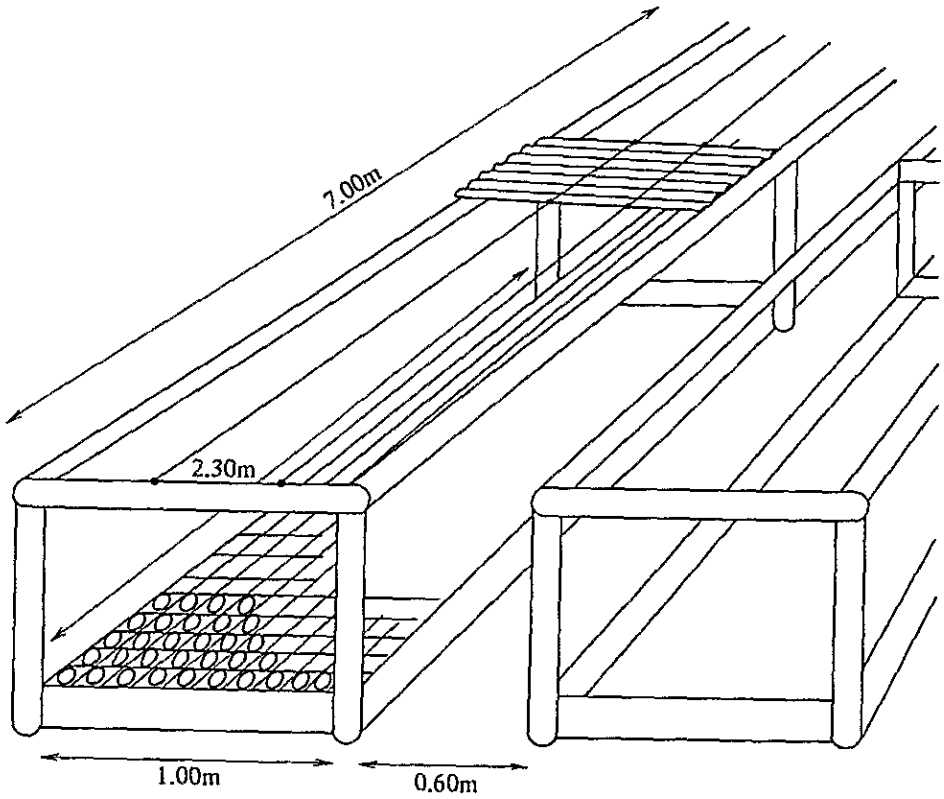
Brunei people should assume the posts of either Field Manager or Assist. Manager and Staff. Nearly all of the Permanent Laborers should be Brunei people. Employment of foreigners (Malaysians) as Casual Laborers can be considered.

(b) The nursery work in the Preparotory Stage will consist of ensuring the site, earth working, construction of facilities, etc. These will be completed during the two years of the Preparatory Stage. Expansion of seedling beds will be carried out during the next Trial Reforestation Stage according to the production of seedlings adapted to the amount of plantation work. Presented here is a summarized design of the whole:

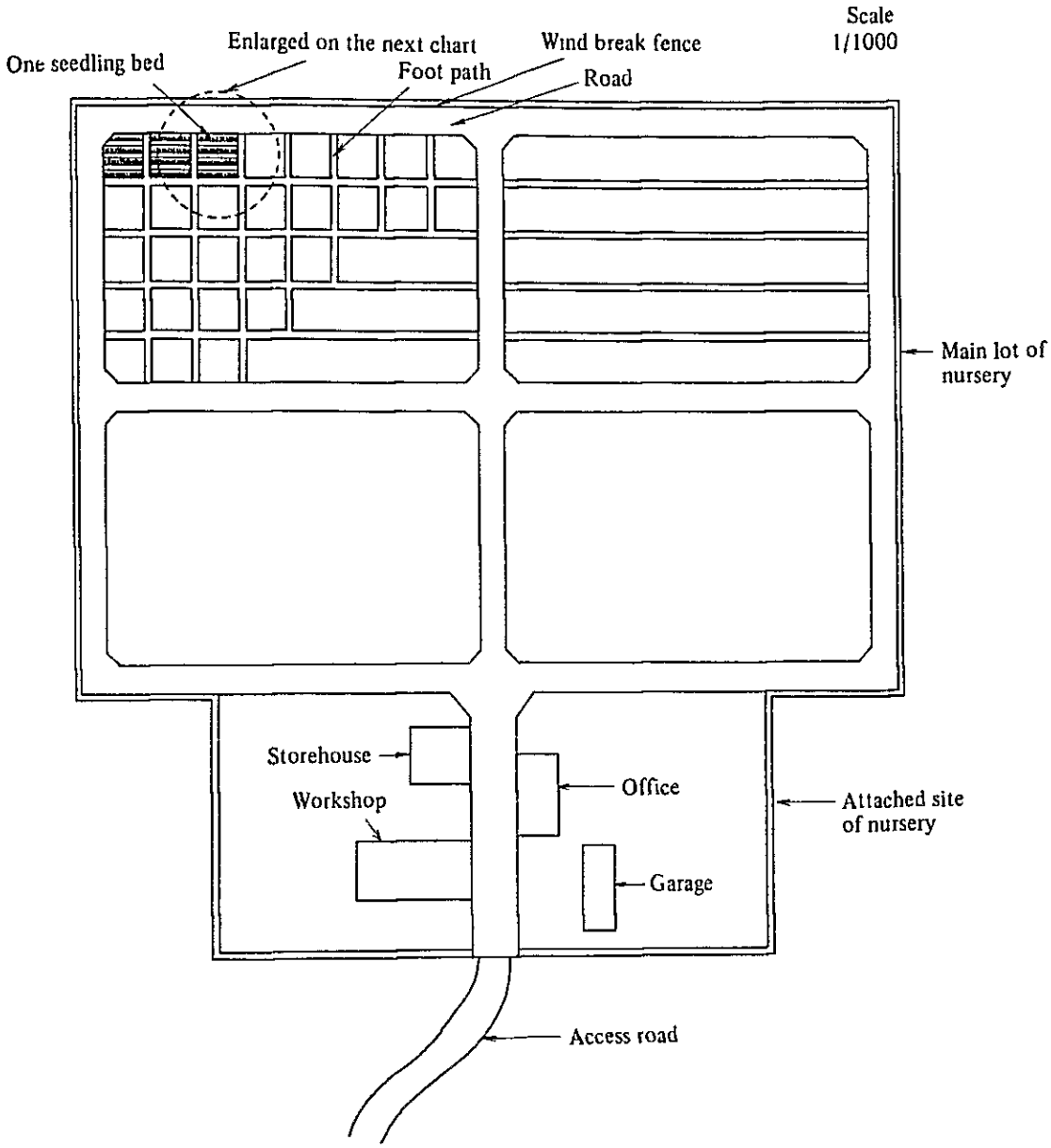
* Pot of 8 cm diameter = 3 in. to be used.
* Space of seedling beds per pot = 8 cm x 8 cm = 64 $cm^2$ ≒ 100 $cm^2$. (space between pots taken into account)
* Number of pots per 1 $m^2$ of seedling beds = 1 $m^2$ ÷ 100 $cm^2$ = 100 pots.
* Spacing of planted trees = 2.5 m x 2.5 m ≒ 8 ft x 8 ft.
* Number of planted trees = average of various species per one ha = 1,600 trees.
* Maximum area of annual planting in future = 300 ha.
* Number of seedlings for out-planting in each year = 1,600 seedlings x 300 ha = 480,000 seedlings.
* Number of seedlings to be produced in each year (20% will be rejected) = 480,000 ÷ 0.8 = 600,000.
* Total area of seedling beds = 600,000 seedlings ÷ 100 seedlings = 6,000 $m^2$.
* Total nursing area (50% space estimated between seedling beds) = 6,000 $m^2$ x 1.5 = 9,000 $m^2$
* Area of main lot (50% estimate for foot path, road) = 9,000 $m^2$ x 1.5 = 13,500 $m^2$ ≒ 1.5 ha.
* Area of attached site = 0.5 ha will be estimated as the lot for office, workshop, soil deposit, storehouse and other structures, and outdoor place for materials, empty lot and wind break fence.

* Grand total area of nursery = 1.5 ha + 0.5 ha = 2.0 ha.
* Position of seedling beds and one example of seedling bed are shown in Charts 4 - 1 to 3.

**Chart 4-1. Design of Seedling Bed**



## Chart 4-2. Total Design of Nursery



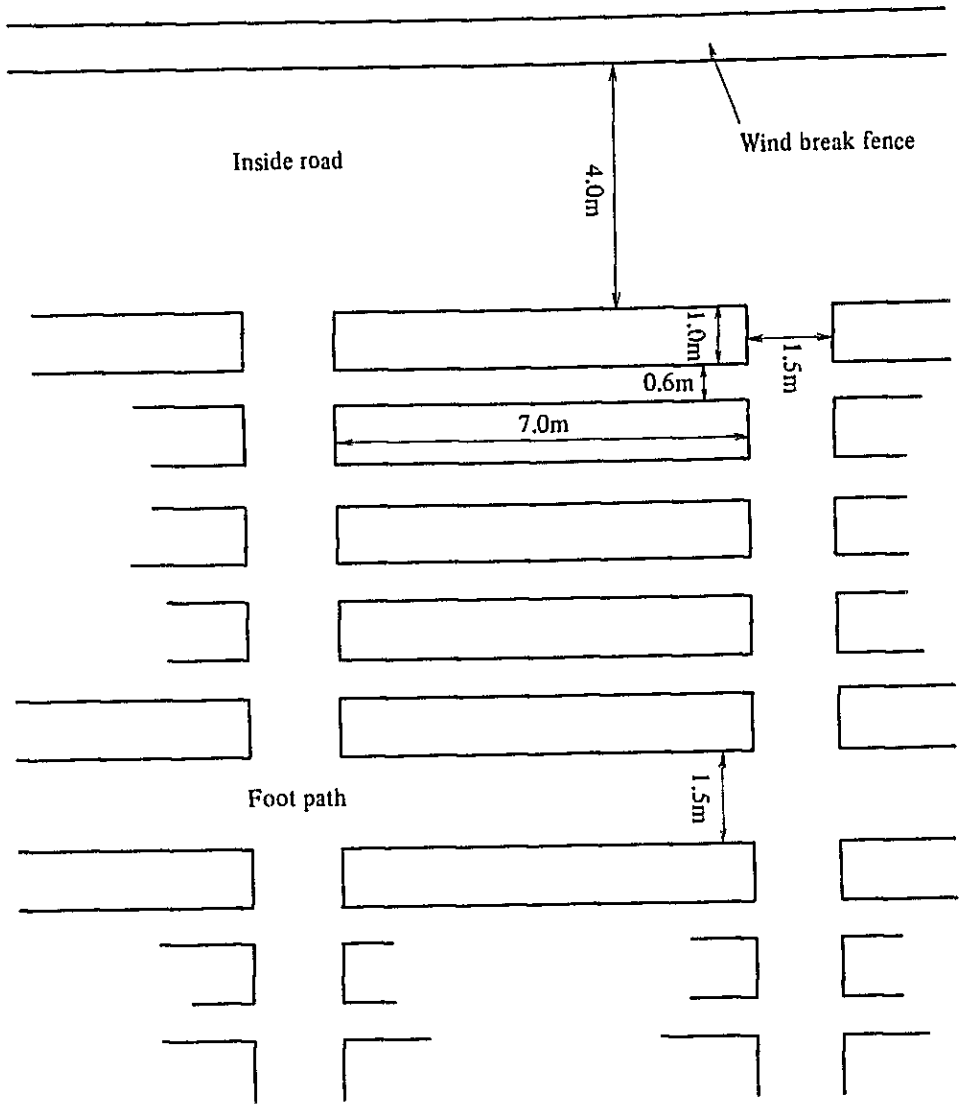



**Chart 4-3. Allocation of Seedling Beds** Scale 1/1000

(c) Laying of roads in the Preparatory Stage will consist of an access road from the public road to the nursery, footpaths inside the nursery, and access roads to the test plantation sites. It will suffice for the road inside the test plantation site to be completed in the year before planting during the Trial Reforestation Stage.

The main machinery, materials and facilities that should be purchased or installed in the Preparatory Stage are as follows:

* Small truck (2 t, pick-up type) – 1
* Jeep – 1
* Chain saw – 2 or 3
* Bush cutter – 2 or 3
* Materials for watering facility (vinyl chloride pipe, valve, pump, etc.)
* Materials for seedling beds (lumber, cement, vinyl sheet, shade sheet etc.)
* Structures (office, workshop, storehouse, etc.)

In the Preparatory Stage, machines and vehicles for engineering work will be chartered or hired. But in the next Trial Reforestation Stage, purchase of a small bulldozer and increased installation of the abovementioned machines to meet the expansion of the work volume will be necessary.

The present local prices of the foregoing materials are as follows:

* Vinyl chloride pipe – 3/4 inch x 20 feet = B$7.50 each, 1/2 inch x 20 feet = $5.80 each
* Lumber – B$450–470/hoppers ton
* Cement – B$200–240/ton
* Construction cost of wooden house – B$25/sq. ft.
* Bulldozer hired charge (Caterpillar D6 class) (inc. fuel) – B$480/day
* " " pay for driver – B$55/day
* Dump truck hired charge (6-ton class) (inc. fuel) – B$170/day

② Design of Trial Reforestation, Phase 1

The detailed design for this stage will be drawn up to match local conditions after the site has been determined. Only the basic design will be described here.

First of all, the policy for the test plantation design will be based on:

(a) With a small catchment area as one parcel, this will be enclosed by a road on the main ridge and surrounded by firebreak zone.

(b) A footpath will be set up on the small ridge running out from the main ridge.

(c) The hillside will be divided into 0.3-0.8 ha blocks. One species will be planted in each block.

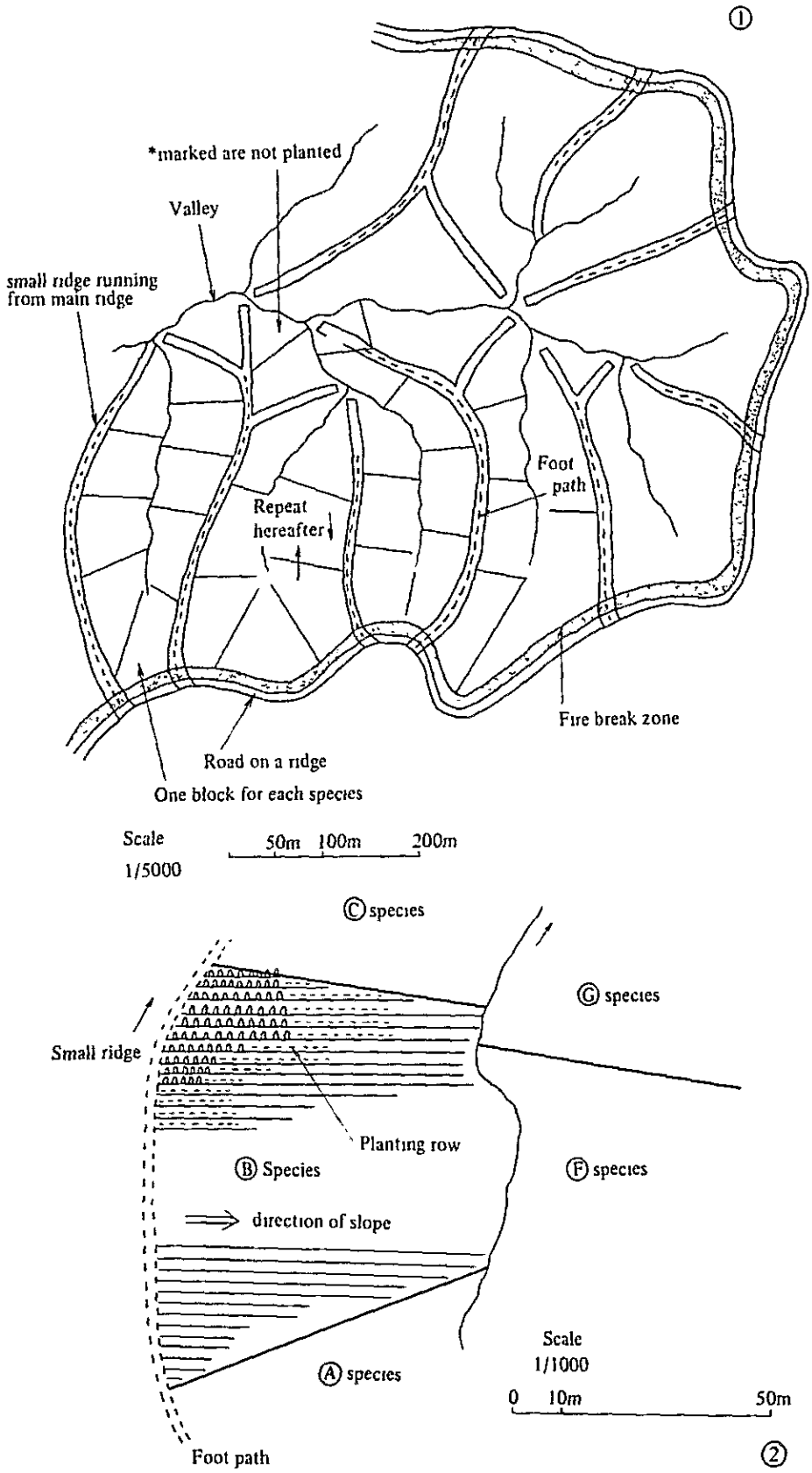
(d) The planting rows will be made parallel along the inclination of the slope from the small ridge in the direction of the dale.

(e) Among the tree species to be planted, besides testing many promising species they will be arranged to be several "repetitions" in the parcel.

(f) The site conditions inside the block will be studied so that the relationship with the growth will be made clear.

Based on the fovegoing policy, the model map of test plantation in the small catchment area of a standard hilly topography is shown in Charts 4-4,①and②.

## Chart 4-4. Model Map for Test Plantation (Phase 1) in Small Catchment Area



③ Design of Trial Reforestation, Phase 2

Since the design in this stage should also be formulated in detail after the site has been decided, the basic design will be mentioned here.

As described in the previous "Subjects of Trial Reforestation," the purpose of the artificial reforestation test in this stage is to obtain growth data by a forest stand of five to seven selected species by working methods. In other words, after making clear "site conditions and suitable species" in Phase 1, the main aim here is to clarify "working methods and stand growing" of suitable species.

The main points in the design of artificial reforestation test in this phase can be enumerated as follows:

(a) Each tree species is independent in terms of stochastics. (The species is not a matter of combination)

(b) In the artificial reforestation test, one species will be planted on a same slope of hillside within a small valley basin (15 to 20 ha will be the lot for one species).

(c) Inside the abovementioned lot, a Latin square test block will be set for the purpose of spacing and nutrition test at more than three places (repeating are more than three times).

(d) By combining spacing and nutrition, a Latin square will be made to enable a stochastic analysis. (Repetition more than three times of four combinations of sparsity and density of spacing, and fertilized and non-fertilized).

(e) The land preparation method (burning, non-burning) and line-planting test will be separate test subjects. They will not be combined.

(f) Density control test and site class investigation will be carried out during the growth of the man-made forest and after naturity.

(g) In order that the Latin square block will not be influenced by unforeseen circumstances, a distance of at least 20 meters will be kept from the ridge, valley, and boundary of plantation.

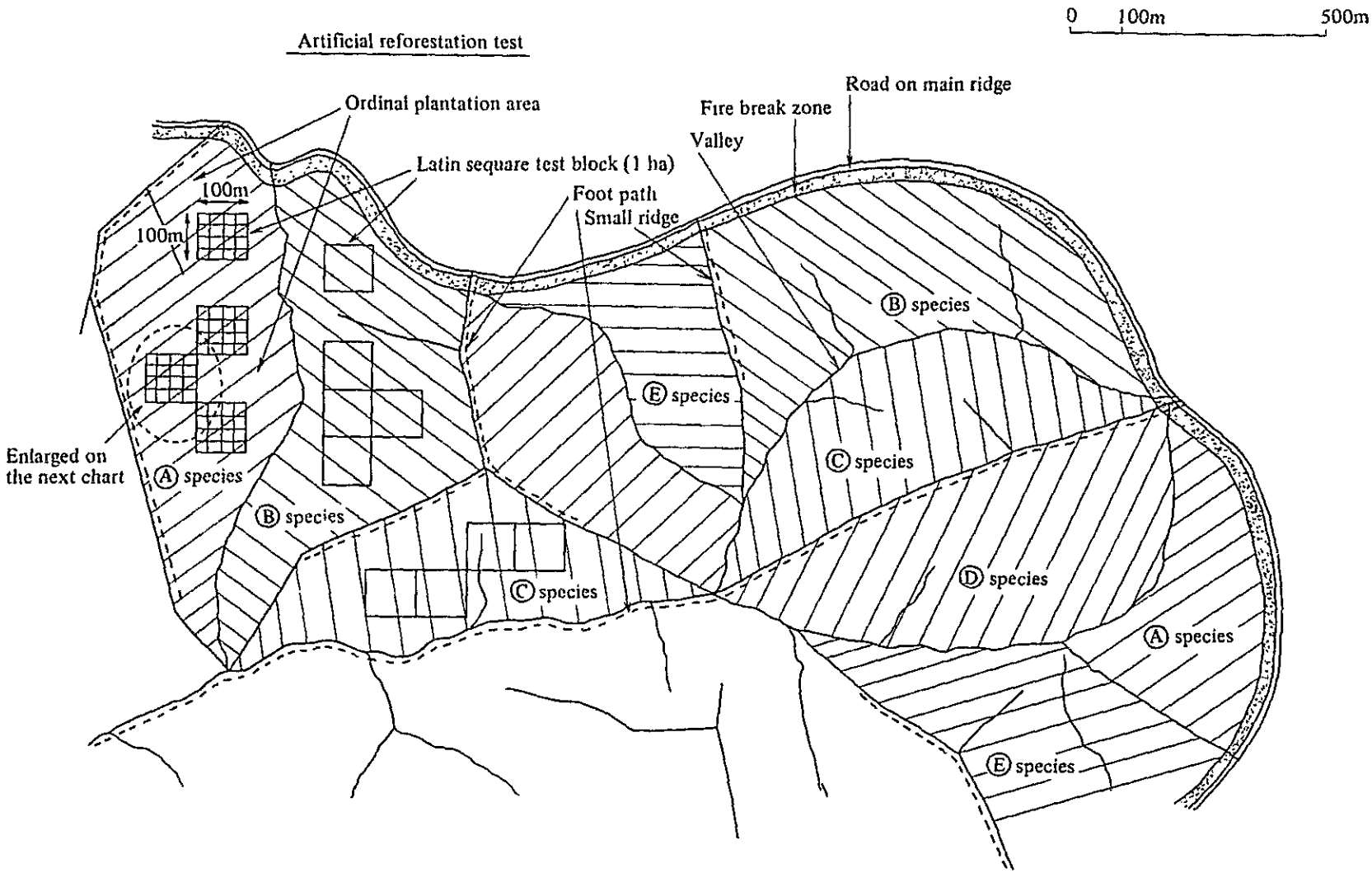
(h) Plantation of outside the Latin square block will follow the ordinal plantation method and will be treated as a stand for density control test and site calss investigation.

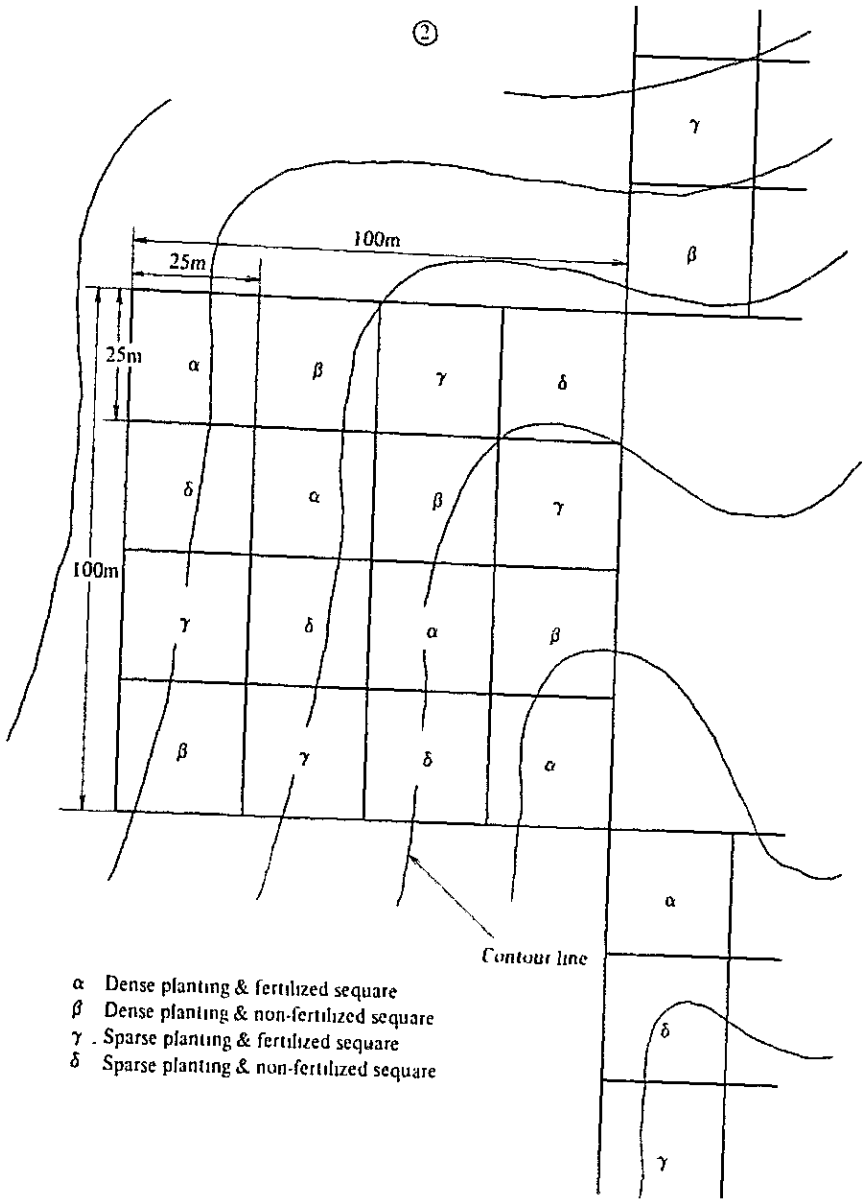
(i) In the planted area not including the Latin square block, land preparation method tests or line-planting tests will be conducted.

Based on the foregoing policy, the model map of the artificial reforestation test, taking the small catchment area of a standard hilly topography is shwon in Chart 4-5, ① and ②.

## Chart 4-5. Model Map for Trial Reforestation Phase 2

Scale 1/1000






The next natural regeneration test is conducted in a fixed experimental area. Among the subjects of this test, a stochastic analysis will be carried out regarding felling strength, clearing of undergrowth and soil surface treatment with the same method as for artificial reforestation test by dividing 4 to 9 combinations in a Latin square block. Aside from this, studies will be made in a fixed experimental area of flowering and fruiting, increment and mortality study, test for enrichment-planting and seed tree system.

(5) Schedule of Trial Reforestation

Tables 4-5 and 4-6 will be the time schedule for the work of ① Preparatory Stage, ② Trial Reforestation, Phase 1, and ③ Trial Reforestation, Phase 2.

## Table 4-5. Schedule for Preparatory Stage

| | 1st Year | | | 2nd Year | |
|---|---|---|---|---|---|
| | High precipitation season | Low precipitation season | High precipitation season | Low precipitation season | High precipitation season |
| Preparation of personel & organization | 3 months | | | | |
| Design & cost estimation | 3 months | | | | |
| Construction of access road to nursery | | 3 months | | | |
| Civil engineering work at nursery site | | | 2 months | | |
| Construction of building in nursery | | | 3 months | | |
| Construction of nursing area | | | 3 months | | |
| Purchase of equipment and materials | | | 6 months | | |
| Construction of access roads to the test plantation site | | | | 6 months | |
| Preparation of nursery operation | | | | 2 months | |
| Recruiting of laborers for nursery work | | | | 2 months | |
| Sowing & nursery practice | | | | Nursing period is depend on the sp usualy 4 to 6 months<br>6 months ( + 2 months) | |
| Land preparation on a test plantation site | | | | | 2 months |

## Table 4-6. Schedule for Trial Reforestation Phase 1 and Phase 2

| | 1st Year | | | 2nd Year | | 3rd Year | | 4th Year | |
|---|---|---|---|---|---|---|---|---|---|
| | Hps | Low precipitation season | High precipitation season | Low precipitation season | High precipitation season | Low precipitation season | High precipitation season | Low precipitation season | High precipitation season |
| Land preparation | | 3 months | | | | | | | |
| Planting | 2 months | | 1 months | 2 months | | | | | |
| Weeding | | 6 months + α | | | | | | | |
| Fire protection etc. | | 6 months + α | | | | | | | |
| Measurement & survey | | | | 2 months | | | | | |
| Nursery practice | (+ 2 months) 6 months | | | | | | | | |
| Nursery test | | Year | | | | | | | |
| Extension of road on main ridge | | 2 months | | | | | | | |

## 5. Technical Details of Tree Species Recommended

(1) Outline

In carrying out trial reforestation, attention is required, first of all, in selecting tree species suitable for Brunei's climate of humidity and high precipitation. The result of the findings shows that tree species originated in the monsoon zone are unsuitable, in principle. The conclusion reached is that tree species originated in the humid tropical zone should be selected as much as possible. According to the data in Sabah and Sarawak, the tree species that are believed to be suitable for Brunei in the future are the following:

① Exotic species tested in Brunei:
Acacia auriculiformis (even in poor soil), Acacia mangium, Albizzia falcata, Araucaria hunsteini (just after clear cutting), Eucalyptus deglupta, Pinus caribaea

② Indginious fast growing species:
Anthocephalus, Campnosperma, Casuarina, Cratoxylon, Dyora, Endospermum, Gonystylus, Octomelus

③ Non-fast growing species:
Agathis, Cordia, Dryobalanops, Shorea, Shorea albida and Swietenia macrophylla

A summary of these tree species has already been published in various forms but a brief explanation will be given in the following:

(2) Exotic Species Tested in Brunei:

* Acacia auriculiformis

Grows naturally on an island off the north coast of Australia where the annual precipitation is about 1,600 mm. The period of the dry season is six months. The annual mean temperature is about 28°C. With a tree height of nearly 20 m and diameter of 60 cm, it is a species of poor tree shape but since it grows fast even in poor soil, it is suitable for land after shifting cultivation. In Indonesia it is ordinarily planted on dry land or barren up to 400 m above sea level.

The fruiting season is July-November and bears every year. The seed volume is 56,000/kg. After advance processing in boiling water, the seeds are soaked in running water for 24 hours. The seeding is spaced 5 cm apart. A sunscreen is necessary. Potting is done when the seedling height is 4 cm (20-25 days after seeding). It is desirable to plant out the seedlings three months after potting and just before the rainy season, with planting space of 2.5 × 1 m or 3 × 1 m.

The tree height in five years has been recorded to 14 m in Indonesia, 9 m in Manaysia and over 10 m in Zanzibar. Because of its poor tree shape, the only uses are as firewood and pulp wood but it is important as a species because it will grow even in poor soil. It is planted in various regions.

* Acacia mangium

This species is distributed from Maluku islands Indonesia to the western part of Papua New Guinea and northeast Queensland Australia. In Queensland, it appears in the vicinity of mangrove association and tropical rain forests along coastal areas. The tree height is up to 30 m and DBH is up to 25 cm. The trunk is straight and the branches are small and horizontal. The branch-shedding is good. One year after planting, the tree crown covers the stand.

In Sabah, this species was introduced in 1966. It grows well even in poor soil such as the grassland, tractor road, felling road, and land after shifting cultivation. In Sabah, 10-year trees, planted 2.4 m spacing will be 23 m in height and 20 cm in DBH. This species grows 439 $m^3$/ha in growing stock and the mean annual growth is 44 $m^3$/ha. Even in poor soil, the mean annual growth is $20^3$/ha.

Because the flowering season overlaps that of Acacia auriculiformis, hybrids can be seen. They have heterosis (hybrid vigor) but their tree shapes are poor. Flowering and fruiting are successive. The volume of seed production is abundant. The sprout from stump is successive. It can be planted directly in eroded soil. The disease should be avoid by the botanical quarantine.

In the nursery, the seedlings harmed by a kind of scale insect grasshopper but this cannot be seen in a forest stand. This species is so sensitive to herbicides, that the phenomenon of falling leaves and canker arises. The sap wood is creamish white and its width is narrow. It is differentiated from the light brown heart wood. The grain is straight. The wood is easy to process and the finishing is good. It is suitable for general construction, furniture, box material, wooden frames, particle board and pulp.

* Albizzia falcata

The origin of this tree species is Maluku, Indonesia, and distributed at altitudes from 0 to 1,500 m above sea level. It is planted in the Philippines and Indonesia, and other various regions. A fast growing species with a height of 45 m, the fruiting season in Indonesia is June-December. Dry seeds number about 40,000/kg or 36,000/liter, and the germination rate is about 80%. On the seeding bed with shade, the seeds are sown at 5 cm interval, with depth 1 cm. From 220 g of seeds, 6,300 seedlings are produced. Boiling water processing and 24-hour steeping in water are necessary. Germination begins 2-3 days after seeding. In the case of seedling by stump shoot, it is desirable that, the diameter of the seedling stem at the botom is 0.2-2.5 cm, upper end of seedling is cut off at a height of 5-20 cm and the root length is 20 cm. Spacing is 3 x 2 m.

Growth during the first five years will be 4 m annually but this declines to 1 m in 10 years. The cutting age is after 10 years.

Lumber is white to light yellowish in color. It is light wood and the air-dried specific gravity is 0.24-0.49. It has little resistance to injurious insects and fungi.

The timber is easily dried and processed. Suitable for pulp, packing material, matches, furniture and interior.

* Araucaria hunsteinii (Klinki Pine)

Distributed in mountainous regions of New Guinea at an altitude of 600-1,500 m above sea level and in fertile soil with an annual precipitation of 1,270-1,780 mm. This is a gigantic

tree with a height exceeding 80 m and DBH of 2 m. The trunk is straight and cylindrical. This species can grow over 40 m in bole height. In Papua New Guinea, the suitable time for seed collecting is from the latter part of September through the first part of October. The seeds collected from registered elite trees should be sown as soon as possible. The seeds are generally short-lived and die within eight weeks but it is possible to preserve them for one year sealed in humid and low temperature of 3.3°C. The sowing season is October-November. The 100% shade immediately after sowing. The shade should be reduced to 50% four months later. Thinning out to make seedlings 132/$m^2$ four months later. When the height of the seedlings becomes 15-25 cm, they are transplanted into pots. They are watered every day and kept in the shade until they reach a height of 30 cm. Seedlings of about 40 cm are out-planted with a spacing of 3 m x 2.5 m. Weeding should be done until the third year.

The first pruning is carried out when 75% of the trees exceeds 6 m in height. The second pruning will be done when it goes over 13 m. The first thinning is done at a tree height of 15.2 m with the number of remaining trees are 865/ha. The second time is 18.3 m and remaining trees are 718/ha, and the third time 21.3 m and 420/ha. The growth of Klinki Pine while young, is inferior to Hoop Pine but is superior after 16 years. At 8 years a height of 13 m and DBH of 14 cm is reached, and 17-year-old trees have a height of 28 m and DBH of 25 cm.

The timber is similr to Hoop Pine but somewhat harder with an air-dried specific gravity of 0.45 but less strength. It is used as structural interior joinery, furniture, packing material, plywood and pulp.

* Eucalyptus deglupta

Distributed from Papua New Guinea and its surrounding islands to Sulawesi, Indonesia, and West Irian, and the southern Philippines. Grown in various soil conditions with an average annual precipitation of 3,000 mm and a temperature of 27° – 31° C. A giant tree with a height of 75 m and DBH of 2.5 m. Planted not only in New Guinea but also in other regions. This is a most promising tree species for reforestation in rain forest area.

In Papua New Guinea, flowers can be seen the whole year. Seeds are produced annually. From November to May is the seed collecting season. Fruits are collected in bunch. After natural drying, the seeds are sifted out. The seeds number 12,000/g. They can be stored for four years under cool sealed conditions.

Sowing is carried out by scattering in a seeding pan mixed with sand. Germination begins in 3 to 8 days. The shade is gradually removed. Seedlings of 5 to 6 cm in height are transplanted into pots with a diameter of 5 cm and a height of 20 cm. The potted seedlings are completely screened from the sun. After the seedlings take root, they are gradually exposed to the sun and placed in full sunlight about one month before out-planting. They are planted out in four months. Spacing is more than 4 x 4 m for saw timber and 2.5 x 2.5 m for pole timber.

The growth is very fast, averaging 4.5 m a year. In 20 years a height of 52 m is reached, with growing stock of 500-640 $m^2$/ha. Weeding, vine cutting and other maintenance work is necessary. There is also need to cope with damage by fire, snails and termites. Cutting age for pulp wood takes in 8 to 12 years and for saw timber takes 25-30 years. The color of the timber is reddish brown to light rosy brown. Although lacking in earthing durability, it is hardy in exposure to weather. Easy to process and suitable for interior, furniture, flooring and pulp.

* Pinus caribaea

There are three varieties. Var. hondurensis is distributed in Central America – British Honduras, Guatemala, Honduras and Nicaragua – at an altitude of 0 to 1,000 m above sea level. Var. bahamensis is distributed in the Bahamas and Caicos Islands, and var. caribaea in Cuba and Pine Island.

The Var. hondurensis is used the most for reforestation. The suitable site is a area with a precipitation of 1,200-1,700 mm inland and 2,300-3,900 mm along the coastal area. It prefers loam with good drainage and sandy soil. Generally it has a straight trunk with a height of 25-30 m and DBH of 30-60 cm. The seed volume is 70,000/kg. Seeds can be stored for one year under ordinary conditions. Storage for a longer period is possible in a cool sealed room.

Seedlings raised in a seedling bed are transplanted into pots. They are then planted out when the seedlings are 20-30 cm in height which take 6 to 8 months after seeding. The growth is fast. The timber is colored light brown to brown. The air-dried specific gravity is 0.75. It is quite strong and suitable for structural, interior joinery, construction material, boxes, and pulp.

(3) Indigenous Fast Growing Species

* Anthocephalus cadamba

Distributed widely from the continental part of South and Southeast Asia to the islands of Indonesia and Papua New Guinea. As the pioneer of secondary forests at an altitude of 0-900 m, it makes pure stand on the area after shifting cultivation, by the roadside and on the eroded land. It is fully a intolerant tree and shows deciduous characteristics.

With a tree height of 30 m and DBH of 60 cm, the trunk is straight and the bole-height is high. The growth is very fast. It prefers a land where precipitation is comparatively high and soil with good drainage. The regeneration by sprout is active. Flowering and fruiting take place from the fifth year. The fruit collecting season is October-November in the Philippines, and June-August in Indonesia. The fruit is placed in water immediately after collecting. Then remove its pulpish material. If keep it under the cool and sealed condition after being air-dried for two days, it can be stored for one year.

The seeds are very small and number 174/g (in the case of the Philippines). The germination rate in the Philippines is 30-70%. Germination begins in 3 to 4 weeks after being placed in a seeding pan. Transplanting into pots takes place after four young leaves have sprouted. For two weeks after transplanting, partial shading is carried out for two weeks.

In Indonesia, germination begins in 11 to 15 days. Transplanting into pots takes place 1 to 1.5 months after sowing when the seedlings have become 5 cm in height. When the height of the seedlings is 10-15 cm (3 to 4 months after sowing), they can be planted out. In the Philippines, the size of seedlings at the out-planting time is 20-30 cm and the spacing is 2 x 2 m to 4 x 4 m. It is 3 x 1.5 m or 3 x 2 m in Indonesia. Planting takes place at the start of the rainy season. Weeding and vine cutting are carried out as carefully as possible. A fire break zone and spraying of insecticide is also necessary. Growth is fast during the first three years. It is said that from the fourth year, tha Albizzia falcata becomes bigger than this species. This species has a

tendency for growth to slow down because of insect damage. In Indonesia, a tree height of 22 m and DBH of 28 cm in nine years can be seen.

The timber is creamish yellow in color. It is light wood with an air-dried specific gravity of 0.3-0.6. It is easy to process but lacks earthing and weathering durability. It is used for provisional construction, sandals, toys, matches, packing boxes and pulp.
a girth of 90 cm. The tree shape is good reaching 30 m in height and 2.4 m in girth. The trunk is cylindrical and the buttress is very small. At times small prop roots appear. After first showing coniform, it turns into an umbrella form and from a distance it somewhat resembles Kapur. The timber is brown in color and has a long straight groove. There are green phyllodes and small scaly leaves. The flowers are very small forming a conical spike. This species is a gynodioecious plant. The fruit is also coniform or nearly spherical, with a diameter of 1.9 cm. At the best site, the growth of this tree shows an annual 3 cm increase of girth. Fruiting starts from 12 to 15 years old and it takes place in successive years. If the growth conditions are not good, the fruiting will be sterility and the regeneration by sprout is poor. At a place where dissolution of acidic humus is slow, litters accumulate on the ground surface. Because the humus disturbs roots of natural seedlings going deep below the humus, natural regeneration becomes difficult. In addition, because the cones open up on the tree, collecting the small seeds is difficult. Therefore the cones should be collected before opening and will be observed about every two days and when the tip of the scale part turns yellow, it should be dried in the sun. The fallen seeds should be put to sowing at once. Germination will be somewhat slow and irregualr.

When natural seedlings can be easily obtained, they should be trans planted in a pan and kept in the nursery for several months. Those of good shape and vigor should be selected and after replanting into pots, they should be planted with a spacing of 2.1 x 2.1 m. The best plantations sites will be those where land preparation has been thoroughly carried out. Weeding will be necessary during the first two years.

Thinning can be carried out for ten years with profit. Twigs can also be used. The upper part of the trunk can be used as a Christmas tree.

The timber is extremely hard and heavy with an air-dried specific gravity of 1.14. The grain is either straight or wavy and the structure is small. The sap wood is clear and yellowish brown in color with pink spots. The heart wood is reddish brown in color with black stripes appearing at times. A wavy grain of the kind often seen in oak timber becomes apparent. Sawing is hard but finishing and drying are well. Suitable for wood carving, firewood, and charcoal.

* Cratoxylon arboreseens

This appears as an old secondary growth on poor soil, dryland, swampland, and sites of cut-over land and burned land in Peninsula Malaysia, Sumatra, Borneo and Java. This species belongs to mesophanerophyte or magaphanerophyte with DBH of about 70 cm. Without buttress. The tree crown is round.

The bark is dark brown with straight ridges and rough. When the tree becomes old, the bark turns into long irregular flakes that drop off. The sap is white to yellow in color, a viscous liquid. The leaf is hard, single leaf and grows distichous. The top of leaf is a wider oval than the bottom and has many small veins. The petiole is 0.6 cm in length.

Both the flower and fruit are small. The capsule fruit with pointed tip is partially wrapped in the sepal. It is a considerably intolerant tree. There is a record in Malaysia of a tree that grew to a 1 meter in DBH.

In the year after dry weather, the flowers sometimes bloom twice a year. Flowers and fruit appear from young age, are often sterility. Natural regeneration on a open space is active and the tree is so abundant in the area after heavy cutting. It is a fast growing tree. In a swampy forest, 11 year-old trees will grow 4 cm up to a maximum 6.5 cm in annual girth growth. It becomes a big tree in 60 years.

Collecting of seeds is difficult and the germination rate is low but this species is suitable for reforestation use even in poor soil. The timber is light and soft. The air-dried specific gravity is 0.43-0.62. It is low in strength and contains silica. Although processing and drying are easy, durability is low. It may be damaged by termites under the earthing condition but it is not harmed by fungus. Infusion of a preservative is easy. Good for cabinet work, furniture, box material, lumber, blackboards, drawing boards, plywood and pulp.

* Dyera spp.

The species distributed in the humid zone from southern Thailand to the Peninsula Malaysia, Sumatra and Borneo. It is generally called Jelutong.

Dyera costulata appears on dry soil in Dipterocarpaceae forests has of Peninsula Manaysia, Borneo and Sumatra. Dyera lowii appears in peat swamp and on strongly acidic soil in Sarawak and Brunei. The tree has a straight, circular trunk without battress. Dyera costulata grows to a height of 60 m and DBH of 2m. Dyera lowlii is smaller with a height of about 30 m.

In the case of D. costulata, the bark is glassy and is dark in color. It has plenty of sap. The leaves are verticillate. Just after the dry season, the leaves fall in several days. Flowering is irregular but the flowers generally bloom all at once a few weeks after the leaves change. The flowers bloom at night and fall at dawn. The condition of bloom continues for about ten days and the upper part of the trunk turns white with a profusion of white flowers. The fruit ripens in two to three months. The sheath bursts open and numerous light seeds are scattered in the wind.

The growth of the tree is fast. The girth increases 3.8 cm annually until 1.2 meters is reached. The girth becomes 1.8 meters in 60 years. Until then the amount of sap is small. When the girth becomes 3.6 m, the annual growth begins to decline.

This species is distict intolerant tree. Although resistant to insect while young, its vigor bigins to decline when the girth becomes 3 to 3.6 m, and insect damage is suffered. The path of the insects is followed by termites and fungus, and the tree withers and dies.

Natural regeneration and regeneration by sprout are both good. There is a need to collect seeds before the podded fruit opens, however it is a difficult to climb up the tree. When the fruit opens, the seeds are blown away by the wind. Germination is irregular and it takes from 10 to 90 days. The timber is light with an air-dried specitic gravity of 0.45. The not too strong wood is easily processed. Preservatives can be infused easily. Durability is low and tend to crack along the sap canal.

Used for matches, packing material, toys, board, casts and wood carving. The latex is used for chewing gum. The latex is collected in the same way as rubber tapping. About 8 pounds

of letex can be collected per month from a good tree.

D. lowlii, which grows in swampland, is important in Sarawak and Brunei. It grows one tree per 2 to 3 acres of peat swampland. Aside from swampland, it also appears on heavy acidic soil. In both cases, since the big trees are generaly withered by tapping, not so many huge trees can be seen. Although the amount of latex is more plenty than D. costulata, this species is smaller in size and tapping begins after a girth of 1 m is gained. Until the girth reaches 1 m, the annual girth growth is 2.5 cm. The results of reforestation up to now have been not succeeded. In this case, the girth is 60 cm to 95 cm (max.) at 7 years old. Therefor it takes to begin tapping about 30 to 35 years.

The timber is somewhat lighter in comparison with the D. constulata but the other characteristics are the same.

* Endospermum peltatum

Distributed widely in Luzon, Mindoro, Palawan and Mindanao, the Philippines. It appears on both lowlands and hilly area. This species best suitable for an area with high precipitation the year round but the tree grows fairly well even on dry land. It is mesophanerophyte with DBH of nearly 80 cm and a intolerant tree that appears often on cut-over land. Seeds amount to 6,300/ liter and the maximum period of storage is one month. After being steeped in running water for 24 hours, sowing takes place. They are transplanted into pots 20 days after germination.

The timber is somewhat bright yellow to light yellow. The air-dried specific gravity is 0.48. It is easily processed but durability and resistance to insects are low. Infusion of preservative is extremely easy.

It can be used for provisional construction, interior, concrete panel, box material, match-sticks, low quality veneer and pulp.

* Gonystylus bancanus

Distributed in the swampy forests of Sarawak and Brunei, it also appears in acidic and poor soil with poor drainage. It can become a big tree and reaches a maximum girth of 3.3-3.6 m but it is generally much smaller. The crown is thick and round. The trunk is straight and perpendicular. Although there is no battress, the base may have an edge at times.

The bark is dark grayish brown in color. There may be small fissures which fall off in rectangular flakes. The sapwood is white in color. The flower is small and grows in terminal panicle. The fruit is spherical and woody with diameter of 2.5 cm and it open to five peaces. The seeds are rather small.

The leaves of young trees are of larger size than matured trees and are not very conspicuous in a forest. Among the same genus, this species is the most prevalent and appears widely in Peninsula Malaysia and the Philippines. In Sarawak and Brunei, it is the protruding species in mixed swamp forests but also appears in other swamp forests. It may also appear abundantly in part of the dry Kerangas forests. The tree with more than 1.5 m in girth appears less than one per acre. Sometimes 4 to 5 trees and seldom 10 may be seen. In mixed swamp forests, auxiliary species include Shorea uliginosa and Dactylocladus stenostachys. In some places the latter may be more numerous than Gonystylus bancanus. At a Shorea alibida type of swamp forest, this species

is reduced to half.

This is an evergreen tolerant tree and in young stage shade is needed. But in matured stage, sufficient sunshine is better. The fruiting period is irregular but shorter than Dipterocarpaceae. The natural regeneration is good but growth is slow in a natural forest. Under the selective logging system, the annual girth growth is less than 1.3 cm. Appropriate sunlight is believed necessary same as Iron wood to anticipate ordinary growth.

The timber is of medium hardness and weight. The air-dried specific gravity is 0.67. The color of the timber is from white to yellowish white. There is no differentiation between sapwood and heartwood, and the grain is straight. In order to avoid damage by fungus, rapid log extraction is essential. The tree is also susceptible to termites. It is used for light structural, furniture, toy, plywood and sole.

* Octomeles sumatrana

This tree can be seen in Borneo, Sumatra, the Philippines, Sulawesi, New Guinea and even in the Solomon Islands. It appears abundantly as second growth. The growth is the best on a river embankment. It is a tree that is conspicuous along the large rivers of Sarawak and Brunei.

This tree is a megaphanerophyte and rises to 60 m in height with DBH of 90-100 cm. The trunk is well shaped and the bole height is long. The crown spread out in small scale and the branches extend like a ring form. A battress is seen only on big trees. The bark is white or yellowish gray and irregular fissures appear. The fruit is attached to a thread hanging down vertically. Contained inside is a very large number of seeds (20,000/g). This is a intolerant and a fast growing tree. Deep and fertile soil is desirable. There is a record of a annual girth growth of 37 cm for four years. The timber is hard with an air-dried specific gravity of 0.27-0.42. The color of the timber is light yellow. The defferentiation between sapwood and heartwood is not clear. The strength is equivalent to that of lightest Meranti. Used for veneer, matchboxes, coffins, and pulp. It is susceptible to insect damage and lacks durability. The infusion of preservative is easy.

(4) Non-fast Growing Species

* Agathis dammara

Three varieties are distributed from Peninsula Malaysia to Sumatra, Borneo, the Philippines, Sulawesi, Maluku and New Guinea. It prefers extremely rich soil in the tropical humid zone but it is not suitable on grassland. In Java it has been used as roadside trees since the 19th Century. Since the growth is good, it is used for reforestation. It is a coniferous tree with a height of 60 m and DBH reaching 2 m. The trunk is straight and conical. The bole height is high. It produces a resin called copal. The seed is obovate form and having a wing. The length is 10-16 mm with a width of about 8 mm. In Indonesia, flowring and fruiting begin when the tree is 15 years old. Vigorous seeds can be obtained from the 25th year. The flowers can be seen throughout the year. The seeds are collected in February-April and August-October. About 6,000 seeds

are contained in one kilogram. The germination rate of new seeds is 90-100% but this declines with the passage of time and drops to absolute zero in six weeks. In storing seeds, charcoal powder moistened with water containing 1% of salt is mixed with the seeds in a proportion of 4/3 litter of powder to 1 kg of seeds. These seeds are kept in a bag or tinbox with a hole. After being soaked in cool water for one day, the seeds are sown in a seeding bed with spacing of 5 x 5 cm or 10 x 5 cm. The germination start about 10 days after sowing. It takes about 20 days to germinate of 80%. Seeds processed with cool water are faster than non-treatiment in germination. Shaded immediately after germination, the surface of the bed is covered and sprinkled with water. When the seedlings grow to 7 cm, the seedlings are replanted for a spacing of 12 x 12 cm. Seedlings of 1 to 1½ years with a length of 25-50 cm are planted out. In Tumpang Sari, planting takes place during the December-January of rainy season with a spacing of 1 x 3 m or 1.5 x 3 m. The first thinning takes place in the sixth to eighth year. After that, it is every three years up to the 20th year and every fifth year up to the 40th year. It becomes every ten years from then on. A height growth of 6 m in the fifth year has been recorded.

The timber is yellowish brown in color. It is lustrous and has an air-dried specific gravity of about 0.45. A rather soft timber, it is suitable for interior and exterior, cabinet work, structual, furniture and pulp.

* Cordea alliodora

Distributed in Central and South America, and the West Indies. An evergreen with a height of 45 m and DBH of 70 cm, the trunk is straight having a battress. The production of seedlings from seeds is easy. This species is somewhat fast growing tree. It is used in reforestation in various tropical regions. The timber is coffee colored that is somewhat greenish. The air-dried specific gravity is 0.45-0.57. Strong in durability and also strong against termites, processing is easy and good finishing can be obtained. This is a high grade tree used for high quality furniture, cabinet work carving, boat building and musical instruments.

* Dryobalanops spp.

Five species appear in Sarawak and Brunei. All are megaphanerophyte with good shape. The trunk is straight and conical with a battress. The crown of young trees is conical but becomes umbrella shaped in the case of old trees. The leaves hang down from small branches like a bunch. The bark of young trees is smooth but as the tree grows old, the bark easily peels and old trees become rough in texture. The smell of camphor issues from a cut. The timber is yellowish brown in color. The fruit is somewhat larger when compared with other Dipterocarpaceae. With the exception of one species, there are five long wings of equal length.

This is an evergreen with positive intolerant tree. The growth is fast and under ordinary conditions a girth of 1.8 m is reached in 60 years. An exceptionally fast growth of 12.7 cm in annual girth growth has been recorded.

The flowering interval is irreguair. Natural regeneration is abundant after flowering. Young trees are very vigorous and when appearing in abundance, they make pure stand. The problems facing reforestation are the irregular flowering period and the short period of the germination of seeds. The sprouting from young trees is vigorous but this vigor is soon lost.

The timber is of medium hardness and weight. The air-dried specific gravity is 0.56-0.84. The differentiation between sap and heart wood is clear and the sapwood is white tinted with yellow. The heartwood is a dark reddish brown color. Depending on the species, the smell of camphor continues permanently. After felling, it is prone to be harmed by ambrosia bettles Dried wood will not bear insect damage other than termites. It is strong against fungus. Aside from one species, it is a sinker. Silica is contained. The infusion of preservative into the heartwood is difficult.

The timber is good for interior. It is stronger than teak for pillars and beams. Used for flooring, walls, pillars, beams, sleepers and body materials of lorry.

The five species appearing in Sarawak and Brunei are as follows (appearing in Brunei except for No. 4):

1. Dryobalanopus aromatica Gaertn. f.
   (Kapur peringgi)
2. D. beccarii Dyer
   (Kapur bukit)
3. D. lanceolata Burck
   (Kapur paji)
4. D. oblongifolia Dyer
   (Kapur empedu)
5. D. Rappa Becc.
   (Kapur paya)

* Shorea albida

This species forms vast association extending for 200 square miles in the peat swamp of Brunei and Sarawak. The closer to the boundary of the swamp, the larger the trees which become smaller upon going centor of it. In sarawak the trees appear even in sandy areas at an altitude of 60 m. In northeast Sarawak there is a record of its appearing at an altitude of 1,200 meters. It also appears in Kerangas forests.

There are many different sizes from small to giant trees. The largest reach 70 m in height with a girth of 6 m. The trunk is straight and conical in shape. Thick, round surface roots expand on the surface. The bark is purplish red and at times it becomes white or greyish pink. Deep fissures are seen over a length of 2 m. The sapwood is pink and the heartwood redish brown.

Regeneration is extensive in the central part of Bunga forest but few in the fringe of Alan forest. In Alan forest, 8 trees per acre appear at good places and it may be as many as 20. Nearly all appear as the pure stands. Often their leaves are completely damaged by caterpillars. When seen from the sky, the eaten part in a practically round form can be seen here and there among the uniform crown cover. Although the most important species among the dark red Meranti grown in Brunei, damage by hollow, brittle heart or ambrosia beetles is easily sustained. The air dried specific gravity is 0.32-0.91. It is easy to process and dry but hard to preservation. The timber used for pillars, flooring, boat building and heavy construction material. In addition, low quality resin is collected.

* Shorea spp.

There are 17 species of the Selangan Batu group, 10 of the Yellow Meranti group, 5 of the White Meranti, and 43 species of the Red Meranti group in Brunei. The selection from among them of tree species suitable for natural regeneration or artificial reforestation in the future will require a basic silvicultural investigation. But if the selection aiming at a target of large diameter, tall trees, straight and conical trunk and capable of abundant regeneration, the following can be listed as candidates:

Selangan Batu group

S. geniculata Sym. ex Ashton

S. laevis Ridl.

Yellow Meranti group

S. faguetioides Ashton

S. laxa V. Sl

Red Meranti group

S. albida Sym.

S. amplexicaulis Ashton

S. beccariana Burck

S. leprosula Miq.

S. leptoclados Sym.

S. mecistopteryx Ridl.

S. parvifolia Dyer

S. pilosa Ashton

* Swietenia macrophylla

Distributed in Central and South America from 30° to 18° South Latitude. Mainly seen at altitudes of 0-450 m and localities with precipitation of 1,500-5,000 mm, the growth is slow in places with little rain but good timber is produced. The tree has wide adaptability to soil but prefers a slope with sandy clay and good drainage.

Tree height of 30-40 m and girth of 3-4 m. The largest rise to 60 m. The trunk is straight and conical, with a battress which is thick, round and 5 m in height. It expands as a surface root. In Indonesia, about 2,300 seeds are obtained per kg. If not processed, vigor is lost within 2-3 months. If mixed with sawdust and sealed hermetically, the seeds can be stored for one year. Reforestation is carried out directly by sowing or sprout seedling. Spacing for planting is 3 x 1 m. In the Philippines it is 2 x 2 m. The heartwood is pink to reddish brown in color and has a golden sheen. This is important material for cabinet and construction use.