FEASIBILITY STUDY
FOR
TRIAL REFORESTATION PROJECT
IN
BRUNEI

APRIL 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

(JICA)

PREFACE

It is my great pleasure that I present the Report on Feasibility Study for Trial Reforestation Project in Brunei to the Government of Brunei.

This report embodies the result of a feasibility study which was carried out from 22nd. November to 9th. December 1982 by a Japanese study team organized by the Japan International Cooperation Agency.

The study team, headed by Mr. Niro Namura had a series of discussions with the officials concerned of the Government of Brunei and conducted an extensive field survey and data analysis.

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

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

April 1983

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1. INTRODUCTION

1-1 Background and Objectives of Study

The territory of Brunei is mostly covered with forests, and timber constitutes the main natural resourse of the country.

However, because of expanding forest exploitation, forests have been declining in recent years. The Government of Brunei was desirous of launching a large-scale re-afforestation project in order to restore its forest resource base for continued timber production. The development of re-afforestation operations ensures the sustained yield of forest products and promotes the environmental functions of forests.

Japan International Cooperation Agency (JICA), an executing agency of governmental international cooperation in Japan, carried out a pre-feasibility study in March 1982 and confirmed the economic and technical feasibility of the forest development especially to develop silvicultural techniques.

As a follow-up to the above, a study team has been sent to make a detailed design for the reforestation project at the experimental plantation area proposed by the Government of Brunei.

1-2 Composition of the Study Team

Assignment	Name	Position
Team Leader	Niro NAMURA	Executive Director, Japan Overseas Forestry Consultants Association
Cooperation Planning	Keizo ASAI	Auditor, Audit Division, Forestry Agency, Ministry of Agriculture, Forestry and Fisheries
Soil Survey	Nobuyoshi HASHIMOTO	Chief Researcher, Japan Forest Technical Association
Reforestation Planning	Kunio HIGUCHI	Overseas Cooperation and Information Section, Research Cordination Division, Forestry and Forest Products Research Institute, Ministry of Agriculture, Forestry and Fisheries
Nursery Planning	Yukitoshi HINO	Chief Forest Engineer, Japan Overseas Forestry Consultants Association
Forest Road Planning (Surveying)	Akio MORI	Forest Engineer, Japan Overseas Forestry Consultants Association
Liaison	Manabu AIBA	Financial Cooperation Division, Forestry and Fisheries Development Cooperation Department, Japan International Cooperation Agency

1-3 Itinerary of the Study Team

Table	Date	Day of week	Movement	Contents of Survey	Stay
1	Nov.22	Mon.	Kota kinabalu → Bander Seri Begawan	Arrival in Brunei (BI 822)	Bander Seri Begawan
2	Nov.23	Tue.		Visit to the Brunei governmental agencies concerned Forest Department Land Department Economic Planning Unit (EPU) Agriculture Department	"
3	Nov.24	Fri.		Economic Development Board (EDB) Visit to Lamunin test plantation site of Forest Dept.	"
4	Nov.25	Thu.	Bander Seri Begawan → Kuala Belait	Visit to Sungai Liang Silviculture Office Field Survey at Sungai Liang District	Kuala Belait
5	Nov.26	Fri.		Team consultation Visit to experimental plantation sites of N.P.P. (Lurong 10 Timor, Bt. Kukub)	"
6	Nov.27	Sat.		Helicopter survey, Ladam Forest Reserve, Ulu-Tutong Forests, Ulu-Belait Peat Swamp Forest, Andulau Forest Reserve, Labi Forest Reserve	"
7	Nov.28	Sun.		Visit to proposed area for the experimental plantation at Sungai Liang	"

Table	Date	Day of Week	Movement	Contents of Survey	Stay
8	Nov.29	Mon.		Visit to Shifting Cultivation area at Labi and proposed area for experimental plantation at Sungai Liang	Kuala Belait
9	Nov.30	Tue.		Field survey of proposed afforestation area at Sungai Liang (Soil and Vegetation Survey, Road Surveying, Nursery Surveying)	"
10	Dec. 1	Wed.		"	"
11	Dec. 2	Thu.		"	"
12	Dec. 3	Fri.		Team consultations	"
13	Dec. 4	Sat.		Visit to Natural Forest of Agathis at Sungai Liang and Test Plantation of Caribean Pine at Sungai Liang	"
14	Dec. 5	Sun.	Kuala Belait → Bander Seri Begawan	Data analysis	Bander Seri Begawan
15	Dec. 6	Mon.		Preparing an interim report	"
16	Dec. 7	Tue.		"	"
17	Dec. 8	Wed.		Discussion with Forest Department	"
18	Dec. 9	Thu.	Bander Seri Begawan → Kota Kinabalu	Departure from B.S. Begawan (BI 821)	

2. SUMMARY

2-1 The Project

The project should be defined as a "trial reforestation project" which would be implemented by a private firm. This is based on the recommendation made by the previous JICA team (Ref: PP 4-6, Report of Pre-feasibility Survey on Reforestation in Brunei, July 1982). The above recommendation indicated that implementation by a private firm would contribute to (1) promotion of employment, (2) industrialization by utilizing commercially viable forest resources, (3) regional development, (4) transfer of practical forestry.

The project would be carried out according to the following stages;

(1) Preparatory stage (one year):
  Construction of nursery
  Assignment of persons and establishment of organizations
  Procurement of facilities and equipment

(2) The first stage of trial reforestation (four years):
  Choice of suitable species
  Construction of a wood chip plant

(3) The second stage of trial reforestation (five years):
  Investigations into clear cutting and artificial reforestation, line planting, etc.

(4) Commercial reforestation project:
  Experiment for forest management

In this study, however, (1) to (3) as mentioned above have been examined.

2-2 Outline of Project

The trial reforestation project consists of nursery construction, nursery operation, reforestation (site preparation, planting, weeding including vine), improvement cutting, thinning, protection, etc.) and road construction. Brief explanations follow.

(1) Construction of nursery is to be completed in the first half of the first year (preparatory stage), in an area of about 2 ha where a state road and Lumut River intersect between Sungai Liang and Labi. The construction cost of the nursery (including buildings and vehicles) is about Brunei Dollars (B$) 361,000 which is equivalent to US$180,000 (which includes the construction costs of following years).

(2) The purpose of nursery operation is to produce all the seedlings required for this project. Namely, during the first stage of trial reforestation, about 130 thousand seedlings are to be produced (12∿48 thousand per year). During the second stage, about 960 thousand seedlings (including those for line planting) are to be produced (115∿270 thousand per year). The cost is B$ 17,000∿33,000 per year during the first stage and B$ 57,000∿83,000 per year during the second stage. This cost includes overhead costs and operational costs, but excludes the initial cost of the nursery construction. Therefore average cost per seedling is about B$ 0.42 and the direct production cost, excluding overhead and operational costs, is B$ 0.20 per seedling.

The reforestation is to be carried out in two areas. The first is Area A (about 600 ha) mainly composed of shifting cultivation area after burning and secondary forest extending east from a point 3 km southeast of Sungai Liang. The second is Area B (about 510 ha) which has been selectively logged, 10 km to the south of Sungai Liang.

(3) The reforestation would be carried out in two stages. The planting area for the four years of the first stage is about 110 ha (including line planting), increasing gradually from 10 to 40 ha per year. The planting area for the five years of the second stage is about 1,000 ha (including line planting of 250 ha) increasing from 120 ∿ 280 ha per year. The total cost of reforestation is about B$ 1,349,000 for the first stage and about B$ 3,726,000 for the second stage, in total B$ 5,075,000 (including costs of mechanical equipment, management and operational costs). Dividing this total by the planting area of 1,110 ha, the average cost of reforestation per ha is about B$ 4,500. The required labor power increases annually from 770 man/days (the first year) to 15,400 man/days.

(4) Principal forest roads, branch forest roads, feeder roads and footpaths would be constructed, but in this study, only forest roads and feeder roads (except footpaths) have been planned and their costs calculated. A total distance of roads to be constructed during the first stage would be 11,200 m (principal forest roads: 1,800 m, branch forest roads: 4,200 m, feeder roads: 5,200 m, cost: about B$ 141,000). The distance to be constructed during the second stage would be 50,000 m at a cost of B$ 629,000. Average construction costs per meter are B$ 19.6/m i.e. for principal forest roads, B$ 13.1/m for branch forest roads, B$9.8/m for feeder roads. The density of forest roads per ha would be 112 m/ha in the first stage, and 50 m/ha in the second stage. In this study, the route map of the proposed area of the first stage was actually surveyed. As in the proposed area of the second stage, however, the required road distance to be constructed has been decided based only on topographic maps.

Table 2-1 indicates the total costs of the project.

Table 2-1 Total Cost of the Project

Unit : {1,000 Yen / B$ 1,000}

Operation	Total	Preparatory Stage + 1st Phase		2nd Phase	
		Subtotal	per year	Subtotal	per year
Nursery Construction	43,286 (361)				
Nursery Operation	55,407 (462)	15,064 (126)	3,013 (25)	40,343 (336)	8,069 (67)
Reforestation	609,060 (5,075)	161,891 (1,349)	32,378 (270)	447,169 (3,726)	89,434 (745)
Road Construction	92,423 (770)	16,912 (141)	3,382 (28)	75,511 (629)	15,102 (126)
Grand Total	800,176 (6,668)	193,867 (1,616)	38,773 (323)	563,023 (4,692)	112,605 (938)

Note: Conversion from Yen to Brunei Dollars in 1B$ = 120 Yen.

2-3 Project Implementation

The proposed areas consist of Area A (grasslands resulting from shifting cultivation, bushes, etc.) and Area B (high forests remaining after selective logging).

The soil condition of Area A is slightly worse than Area B. The site preparation in Area A for clear cutting and artificial reforestation is much easier and less expensive because of its vegetative conditions. However, it is not advisable from considering both site preparation costs and effective utilization of forest resources, to cut and burn existing trees in Area B. It would be appropriated in Area B to continue, for the time being, line planting of non-fast growing species (Agathis, Mahogany, Cordia, etc). Technical and managerial studies would be needed to make a cost/benefit analysis over a 30∿50 year period required for these species to reach maturity.

There is another possibility. If a wood chips plant is constructed in Brunei, existing residual trees could be effectively exploited and site preparation costs would be reduced. Clear-cutting and artificial reforestation with fast-growing species could possibly be implemented in Area B. However, construction of the wood chips plant requires such a large investment that it becomes imperative to carefully study its feasibility and possibilities for the export of wood chips. This study would require close cooperation of the Government of Brunei.

The study team recommends that the Government of Brunei provide enough socio-economic and institutional support during the implementation of this project, particularly for acquisition of land and labor and promotion of trade of the end products.

3. Plan of Trial Reforestation

3-1 Conditions of the Proposed Areas (Location, Area and Vegetation)

3-1-1 Location and Area

The proposed reforestation areas are located to the east of the road between Sungai-Liang and Labi in central Brunei as shown in Fig. 3-1. Area A of the trial reforestation is found about 3 km to the southeast of Sungai-Liang, while Area B is situated about 10 km to the south of Sungai-Liang. Area A is 600 ha including both the 1st and 2nd phase areas and Area B is 512 ha. Table 3-1 gives the annual reforestation areas.

3-1-2 Vegetation

The forest stand surveyed consists of mixed Dipterocarp forest and its secondary forest after selective cutting, burned area, and Agathis forest. Descriptions of the vegetation in the survey area are given below.

(1) Dipterocarp Forest in Andulau Forest Reserve

The forest stands in the area scheduled for planting during the 2nd phase (6th∿10th years of trial reforestation. Table 3-2 shows the tree species found there in order of the size of diameter breast height (D.B.H.). Measurements of D.B.H. and tree height were recorded for the trees of more than 10 cm D.B.H. Asterisk marks (*) denote trees whose names such as Madang and Nyatoh are ambiguous. Minus signs (-) denote those of which scientific names are unidentified. It is noted in the table that Serraya (Shorea curtisii) is the most voluminous tree with 132.0 cm D.B.H. and 48 m height. For the trees with more than 10 cm D.B.H., the average D.B.H. is 31.1 cm and the average height is 28.8 m. The number of trees per ha is 355. Dipterocarpocea family is predominant with occasional distributions of Resak (Vatica sp. or Dipterocarpus sp.), Madang, Rengas (Melanorrhoea spp.) and Kelat.

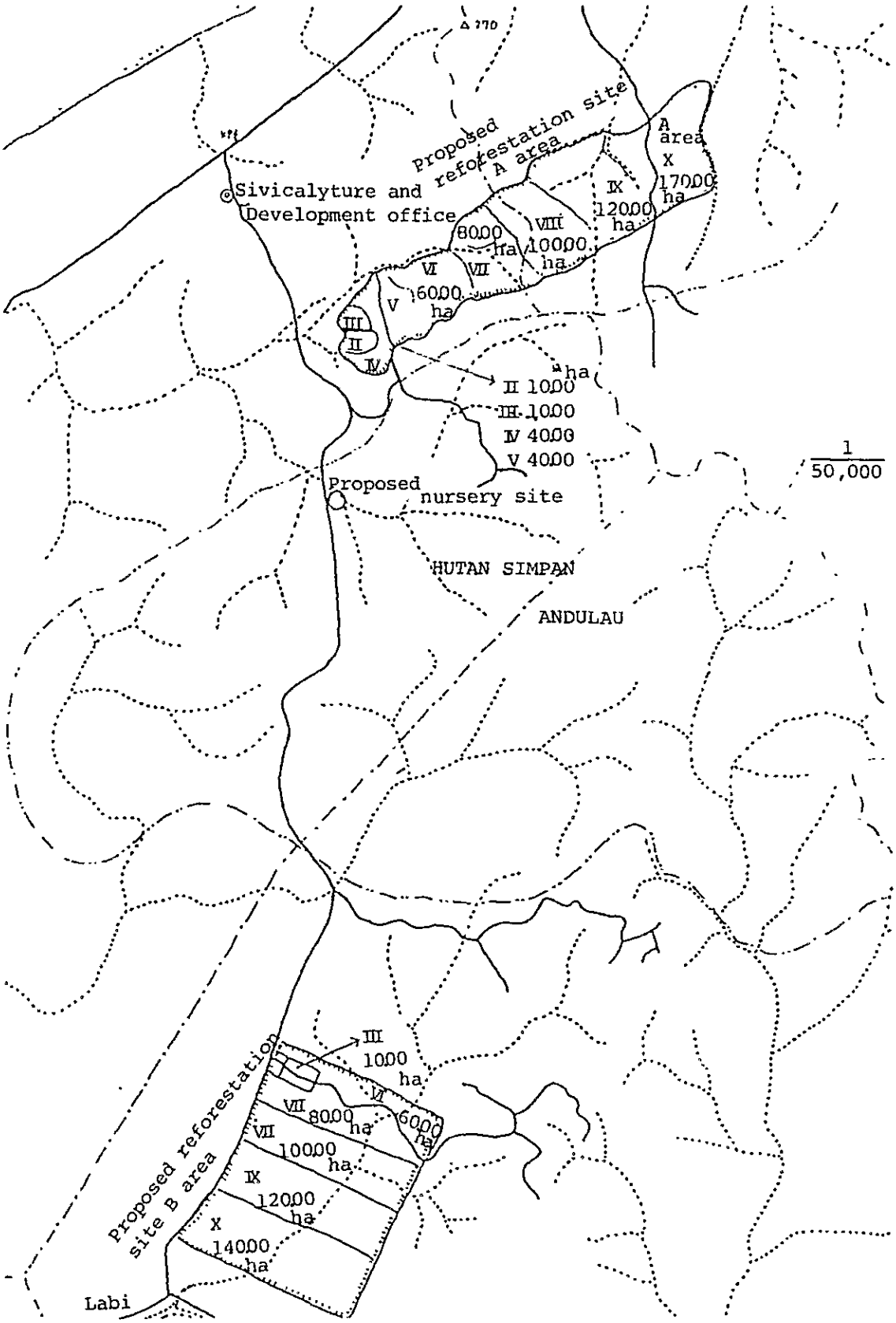


Fig. 3-1 Yearly Reforestation Programme

Table 3-1 Annual Planting Area

Unit: ha

Item \ Year		Year 1	Year 2	Year 3	Year 4	Year 5	Sub total
Clear-cutting & planting	A Area		10.00	10.00	40.00	40.00	100.00
	B Area			10.00			10.00
Line planting	B Area			2.00			2.00
Total			10.00	22.00	40.00	40.00	112.00

Item \ Year		Year 6	Year 7	Year 8	Year 9	Year 10	Sub total	Total
Clear-cutting & planting	A Area	60.00	80.00	100.00	120.00	140.00	500.00	600.00
	B Area	30.00	40.00	50.00	60.00	70.00	250.00	260.00
Line planting	B Area	30.00	40.00	50.00	60.00	70.00	250.00	252.00
Total		120.00	160.00	200.00	240.00	280.00	1000.00	1112.00

Table 3-2 Tree Species in Andulau Forest Reserve

unit: D.B.H cm
Height m

Local name	Scientific name	D.B.H.	Height
Serraya	Shorea curtisii Dyer	132.0	48
Kuruing Buah Bulat	Dipterocarpus Globosus Vesque	91.2	42
Rukedundon	-	65.5	39
Resak	Vatica sp or Dipterocarpus sp	58.2	38
Resak	Vatica sp or Dipterocarpus sp	55.2	36
Unknown	-	53.4	37
Keruing	Dipterocarpus sp	51.5	39
Madang	*	51.0	38
Resak	Vatica sp or Dipterocarpus sp	46.0	33
Rengas	Melanorrhoea spp	43.0	38
Shorea merantie	Shorea sp	39.0	34
Unknown	-	37.0	32
Kayumulm	-	36.2	32
Rengas	Melanorrhoea spp	34.0	34
Kelt	-	34.4	26
Mempisang	*	33.2	30
Resak	Vatica sp or Dipterocarpus sp	32.2	35
Terapikal	-	32.5	32
Resak	Vatica sp or Dipterocarpus sp	31.4	28
Rengas	Melanorrhorea spp	31.0	22
Balgas	-	31.0	34
Kedong	Garcinia sp	29.5	33
Unknown	-	27.1	34
Madang	*	25.0	32
Bayor	*	24.1	32
Resak	Vatica sp or Dipterocarpus sp	23.2	29
Meranti merantai	Shorea macroptera Dyer	22.0	26
Malam	Diospyros sp	22.0	25
Nyatoh	*	21.2	24
Panakran	-	21.0	31
Panakran	-	20.0	28
Tangkauang	-	19.0	28
Unknown	-	18.0	26
Kedang	Pentace spp	17.2	24
Unknown	-	16.1	23
Tulang	Allantospermum borneensis Forman	16.0	19
Bintangor	Callophllum spp	16.0	24
Resak	Vatica sp of Dipterocarpus sp	15.0	13
Kedondong	*	15.0	22
Tulang	Allantospermum borneensis Forman	15.0	22
Kelt	-	14.0	22
Unknown	-	13.4	22
Unknown	-	13.0	12
Unknown	-	12.2	23
Tulang	Allantospermum borneensis Forman	12.2	22
Tulang	Allantospermum borneensis Forman	11.5	18
Banging	-	11.4	21
Bangkoh	Xylopia spp	10.0	17
Tampoi	Baccaurea spp	10.0	21
(Note) *: Local name is ambiguous.	(average)	31.1	28.8

(2) Secondary Forest (Slope) in the Proposed Reforestation A (Area A)

Table 3-3 gives the survey results. This stand consists of secondary forests after selective cutting of mixed dipterocarp forests. The remaining trees are approximately 30 m in height. As there were difficulties in determining the diameter and height of the trees, the forest stand was divided into three layers and then the species in each layer were identified. The dominant layer was 30∿35 m in height, generally trees of dipterocarpaceae family.

(3) Secondary Forest (Valley) in the Proposed Reforestation Area (Area B)

The survey results are shown in Table 3-4. This forest stand is located in the valley of Area A. In contrast, little selective cutting had been done in the dominant layer of this stand. The trees are 40∿45 m in height, generally trees of the dipterocarpaceae family. Remaining trees of secondary forest with 30∿50 m in height would be too costly for site preparation and weeding.

(4) Vegetation after Shifting Cultivation in the Proposed Areas

Table 3-5 and 3-6 show the survey results. The ridge and slope of the area are covered with scattered shrubs of about 2 m in height of Simpor (Dillenia sp.) and other species, with few floor plants due to burning. As shown in Table 3-6, scattered forest stands are found in the valley along the creek. These forest stands in the valley should be preserved for the purpose of soil conservation at the time of site preparation.

(5) Proposed Area (Secondary Forest in Area B)

Table 3-7 gives the survey results. Area B, in contrast with Area A, is flat, with many trees of more than 40 cm D.B.H. and 40 m height including Kapur Bukit (Dryobalanops sp.), Resak (Vatica sp. or Dipterocarpus sp.) and Keruing-Buah-Bulat (Dipterocarpus globosus). Average D.B.H. and height of the trees (more than 10 cm D.B.H.) are

Table 3-3 Tree Species in Area A (Slope)

	Local name	Scientific name
Dominant layer	Rengas	Melanochyla sp
	Nyatoh	*
	Kedondong	*
	Putat	Barringtonia sp
	Selangan	-
	M_dang	*
	Tulang	Allntospermum borneensis
	Kapur	Dryobanops sp
	Damar Hitan	Shorea sp
Subdominant layer	Kismantok	-
	Meranti sarangpunai	Shorea sp
	Kenbang samangkoh	Shorea sp
	Ubah	*
	Durian	Durio sp
	Malunak	-
	Marpisang	*
	Keruing Buah Bulat	Dipterocarpus sp
	Resak	Vatica sp or Dipterocarpus sp
Lower layer	Bintangor	Calophyllum sp
	Melunak	Pentace sp
	Merbau	Insia palembanica Miq.
	Pendarahan	*
	Rotan	Calamus Rotang L.
	Mangkulang	-
	Uponbapu	-
		-
	Gampanas	-
		-
	Ribu Ribu	-
	Kampas	-
	Tambusu	-
	Meranti Merantei	Shorea sp
	Tarap	-
	Madangsisik	-
	Pulai	Alstonia sp

Table 3-4 Tree Species in Area A (Valley)

	Local name	Scientific name
Dominant layer	Ubah	Eugenia sp
	Bandarahan Penarahan	-
	Resak	Vatica sp and Dipterocarpus sp
	Damar Hitam	Shorea sp
	Madangsik	Artocarpus odoratissimus
	Melunak	Pentace sp
	Madang	Artocarpus odoratissimus
	Keruing Bueh Bulat	Dipterocarpus Globosus Vesque
	Kayu Malam	-
	Meranti Sarang Bual	Shorea sp
	Sepetir	Sindora sp
	Kapur Bukit	Dryobalanops beccarii Dyer
Subdominant layer	Kendudong	-
	Ubah	Eugenia sp
	Damar Hitam	Shorea sp
	Tulang	Allantospermum borncensis
	Damar Hitam	Shorea sp
	Kendudong	-
	Bintangor	Calophyllum sp
	Tulang	Allntospermum borneensis
	Meranti Merantei	Shorea sp
	Rasak	Eugenia sp
	Resak	Vatica sp
	Rengas	*
	Ubah	Eugenia sp
Lower layer	Rotan	Calamus Rotang L.
	Marpisang	-
	Matatunan	-
	Meranti merantei	Shorea sp
	Kambang samangkok	-
	Mangkulang	-
	Nirik	-
	Silat	-
	Durian	Durio sp
	Simpor laki	Dillenia sp
	Karangi	-
	Putat	Barringtonia sp
	Madangsisik	Artocarpus sp
	Rasak dunpangang	Vatica sp
	Bintewak	-
	Tulang	Allantospermum borneensis Forman
	Unknown	-
	Binchaloi	-
	Tambusu	-
	Pisang Pisang	*
	Tismantok	Shorea multiflora
	Madang Pewas	Artocarpus sp
	Putat	Barringtonis sp
	Nyatoh	*

Table 3-5 Vegetation in the Former Shifting Cultivation Area (Ridge and Slope)

Local name	Scientific name
Simpor	Dillenia sp
Kalampa	-
Tembusu	Fagraea fragrans Roxb
Tekuguru	-
Lamba	-
Ribu Ribu	-
Gulok	-

Table 3-6 Vegetation in the Former Shifting Cultivation Area (Valley)

Unit: Height m
D.B.H. cm

Local name	Scientific name	Height	D.B.H.
Pendarahan	Gymnacranthera sp	25	21
Madang	-	15	13
Sireh Sireh	-	25	26
Bangkau	Xylopia sp	18	17
Gata	-	1	-
Bangkaubong	Xylopia sp	1	-
Bintangor	Calophyllum sp	0.5	-
Kemunting	-	0.5	-

Table 3-7 Tree Species in Area B

Unit: D.B.H. cm
Height m

Local name	Scientific name	D.B.H.	Height
Kapur Bukit	Dryobalanopus sp	48.5	4
Resak	Vatica sp or Dipterocarpus sp	43.1	3
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	40.4	4
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	33.5	3
Tolong	Agathis alba Lam	32.6	3
Mang	*	30.5	3
Adau	Salacia spp	30.0	2
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	29.2	2
Madang	*	29.0	3
Bintangor	Calophyllum sp	29.0	2
Resak	Vatica sp or Dipterocarpus sp	28.0	3
Sempilor	*	26.5	3
Sepetir	Sindora leiocarpa Backer ex De Wit	24.5	2
Resak	Vatica sp or Dipterocarpus sp	21.3	2
Resak	Vatica sp or Dipterocarpus sp	20.0	1
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	19.0	1
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	18.5	2
Binkulat	-	17.0	2
Bintangor	Calophyllum sp	17.3	2
Bangkulat	-	17.0	3
Bintangor	Calophyllum sp	17.0	2
Bintangor	Calophyllum sp	16.5	3
Bintangor	Calophyllum sp	16.5	2
Bintangor	Calophyllum sp	15.0	2
Kadungong	*	15.0	2
Bintangor	Calophyllum sp	15.0	2
Barangan	-	14.6	1
Mang	*	14.2	1
Leben	-	14.1	2
Bangklat	-	13.3	2
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	13.2	1
Kayukas	-	13.0	2
Bintangor	Calophyllum sp	13.0	2
Ubah	Eugenia sp	13.0	1
Ubah	Eugenia sp	12.3	2
Keruing Buah Bulat	Dipterocarpus Globosus Vesque	12.1	2
Resak	Vatica sp or Dipterocarpus sp	12.0	1
Ubah	Eugenia sp	11.0	1
Bintangor	Calophyllum sp	10.7	2
	Average	20.9	25

20.9 cm and 25.6 m respectively, with 433 trees per ha. There are many trees such as Keruing-Buah-Bulat, Resak, Bintangor (Calophyllum sp.), Sepetir (Sindora leiocarpa) and Ubah (Eugenia sp.).

(6) Agathis Forest

Although the Agathis forest is not covered by the reforestation plan, a survey was carried out for further reference in the future. Results are shown in Table 3-8. Average D.B.H. and height of the trees (more than 10 cm D.B.H.) are 28.5 cm and 24.4 m respectively, with 389 trees per ha. Besides Tulong (Agathis alba) which is the dominant species, Bintangor, Madang, Sepetir and Resak are also found in large numbers.

Table 3-8 Tree Species in Agathis Forest

Unit: D.B.H. cm
Height m

Local name	Scientific name	D.B.H.	Height
Tulong	Agathis alba Lam.	83.1	45
Tulong	Agathis alba Lam.	80.0	45
Tulong	Agathis alba Lam.	65.7	21
Tulong	Agathis alba Lam.	65.4	38
Tulong	Agathis alba Lam.	62.8	39
Tulong	Agathis alba Lam.	53.2	38
Tulong	Agathis alba Lam	53.2	38
Tulong	Agathis alba Lam.	29.0	29
Bintangor	Calophyllum sp	28.4	30
Bintangor	Calophyllum sp	26.8	23
Kempas	Koompasha malaccensis	26.0	26
Madang	Artocarpus odoratissimus Merr.	23.0	28
Sepatier	Saraca longistyla Ridl.	22.4	25
Sepatier	Saraca longistyla Ridl.	22.3	30
Nyatoh	*	22.3	21
Resak	Vatica sp or Dipterocarpus sp	20.4	21
Ubah	Eugenia sp	20.2	19
Ubah	Eugenia sp	19.6	25
Sepatier	Saraca longistyla Ridl.	19.6	25
Ubah	Eugenia sp	19.5	25
Rambutan	Nephelium cappaceum L.	19.3	22
Mata Ulat	Kokoova-lanceolata Ridl.	18.4	19
Ubah	Eugenia sp	18.3	9
Tulong	Agathis alba Lam.	17.2	22
Mata Ulat	Kokoova ovato-lanceolata Ridl.	17.0	16
Madang	Artocarpus odoratissimus Merr.	16.8	14
Sepatier	Saraca longistyla Ridl.	15.2	23
Mang	*	14.6	13
Sepatier	Saraca longistyla Ridl.	14.3	16
Rambutan	Nephelium lappaceum L.	14.2	19
Tulong	Agathis alba Lam.	14.2	14
Resak	Vatica sp or Dipterocarpus sp	14.0	17
Bintangor	Calophyllum sp	14.0	13
Ubah	Eugenia sp	13.1	13
Bintangor	Calophyllum sp	12.8	13
	Average	28.5	24.4

3-2 Results of Soil Survey

3-2-1 Description of Soil Profiles

The main objectives of this field survey are to determine the areas for trial reforestation and the nursery site and to plan the reforestation. Soil surveys have been conducted along these objectives. Firstly, as the Government of Brunei proposed several sites, preliminary surveys were conducted at these candidate sites, namely, 1) Lamunin area, 2) North of Lumut Hills (including northern part of Andulau Forest Reserve), 3) South of Lumut Hills, 4) Northern part of Labi on the Labi Road, etc. According to the results of the preliminary surveys, further detailed soil surveys were carried out to cover part of the Lumut Hills area and also part of Lamunin area. Figure 3-2 shows the position of the soil surveyed plot (area) and Figures 3-3 to 3-11 show descriptions of the soil profiles.

3-2-2 Soil Types in the Surveyed Areas

(1) Lamunin Area

The proposed area of Lamunin Hills consists of rolling hills, with winding valleys. The slope of the hill consists of the quartary belait formation and sandstone. (Soil is derived from sandy parent material and sandstone rocks.)

It is estimated that the permeability of air and water is high, however, because of generally steep topography, planting sites seem to be scarce. The flat area of the valley is very suitable for Anthocephalus spp. and other natural trees to grow, but it is likely to become a non-productive swampy area because of the disruption in running water with logging and transport operations.

Halfway to the mountains of the Lamunin Road, there are gentle undulating hills. The environmental situation of this area differs from the hills as mentioned above. In this area, Araucaria hunstenii, Pinus caribaea planted 12 years ago are growing and soil profiles of their sites are shown in No. 14 and No. 15.

These two soil profiles, clay accumulation to the lower layer (subsoil) has not occurred. Geological conditions are Seria Formation

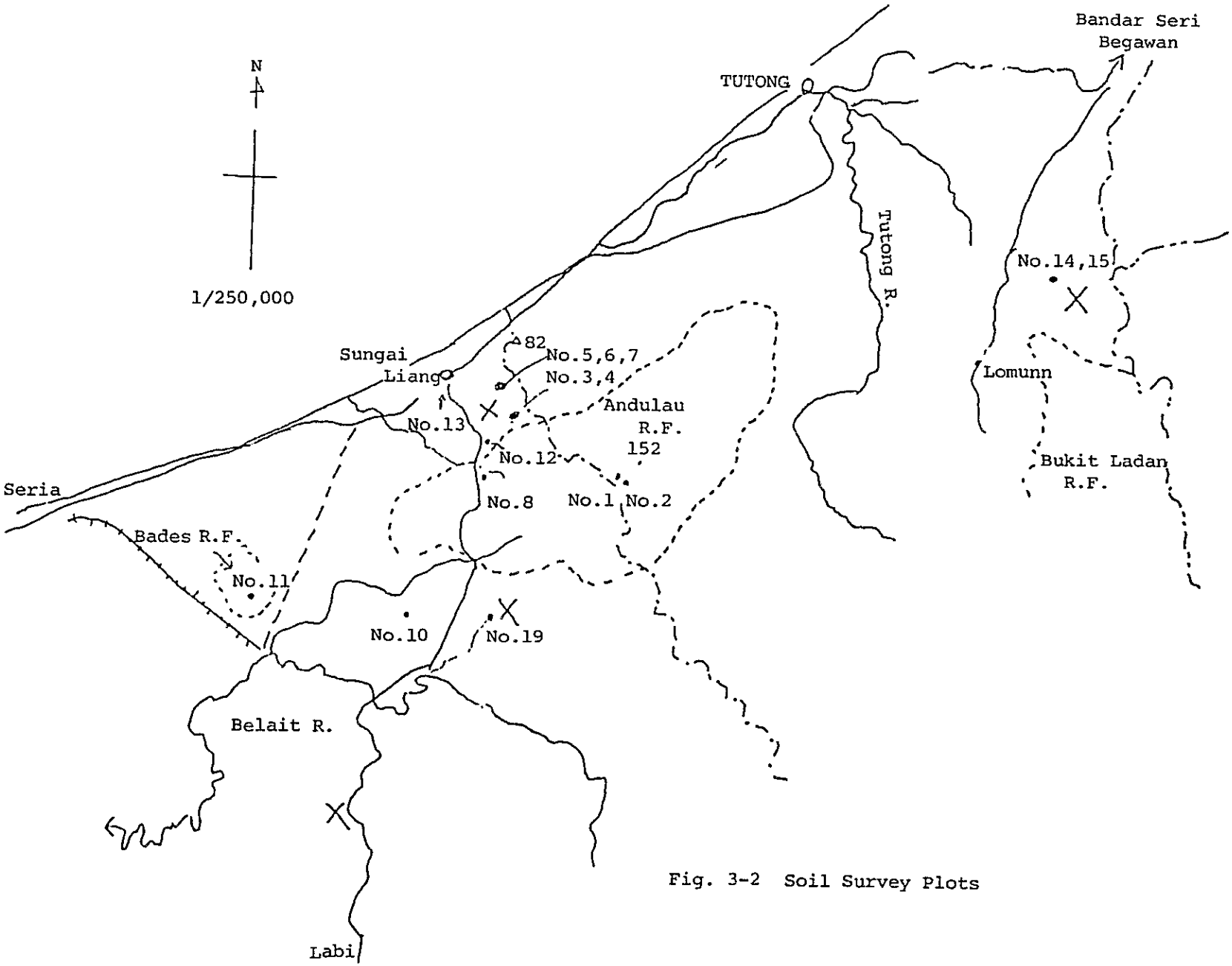
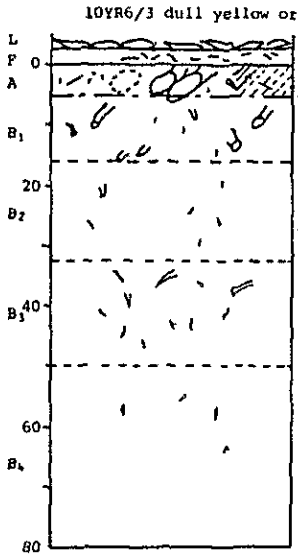


Fig. 3-2 Soil Survey Plots

No. 1 Dystric Cambisol

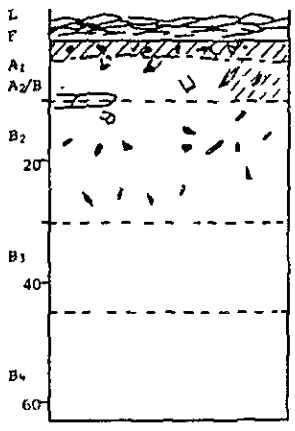


root duff
7.5YR4/2∿5/3 grayish brown fS bK dry soft friable
10 YR6/4∿6/6 dull yellow orange S bK ∿ nutty dry
2.5Y6/6 bright yellowish orange S mass " hard
2.5Y6/6 S mass somewhat moist
2 5Y6/6 S mass " few roots

Location: Center of Andulau R. Forest
Topography. Gentle concave top of undulating hill
Vegetation: Natural forest after select cuttings
Parent material: Sand terrace deposit upon Seria Formation

Remarks
Lack of gravels
Roots can be seen in deep horizon
Permeability good

No. 2 Plinthic Acrisols

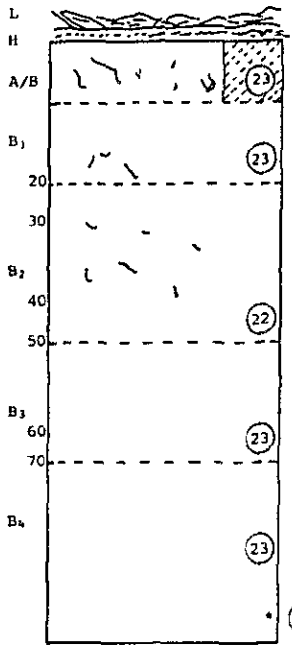


laminated layer - lower network of roots
10YR3/2 brownish brown crumb str. soft friable abundant fine root
10YR5/4 dull yellowish brown L loamy S. weak nutty firm plentiful large roots
2.5Y6/6 bright yellowish brown SL mass hard moist few roots
Charcoal
2.5YR6/8 bright yellowish brown cL mass hard no root
2 5YR6/6 molded " ScL very hard
5YR6/6 orange
5YR7/4 dull orange

location Center of Andulau Forest
Topography. Gentle valley

Fig. 3-3 Soil Profile (1)

No. 3 Orthic Acrisols



7.5YR3/2 - browns + fair sand root network
S, nutty hard

10YR5/4
dull yellowish brown

10YR6/6 S, mass very
bright yellowish brown firm

sL " firm

10YR7/8
yellow orange

scL " firm

10YR7/6
bright yellowish brown

sC " frim

10YR7/6
" "

(22) .. hardness index by Yamanaka's meter

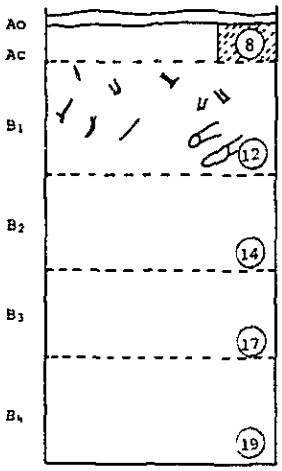
Location: Northern Ridge of Andulau

Topography: NNW, upper concaves slope L20°

Vegetation: Secondary forest

Remarks
1) Almost massive compact
2) B horizon can not find many roots
3) Some iron stone in B_4
4) Some charcoal in A/B horizon

No. 4 Plinthic Acrisols



2.5Y7/3-5/2 light yellow-dark grayish yellow	S	*loose friable (dry)* single grain	*root (-)*
2.5Y6/6 bright yellowish brown	lS	mass very firm (dry)	*root abandant*
2.5Y7/6 "	LS	mass (somewhat moist) " firm	(-)
2.5Y6/6 "	sL	" " (")	(-)
2.5Y8/3-2.5Y7/6 " pale yellow	scL	" " (")	(-)

Location *Near No.3*

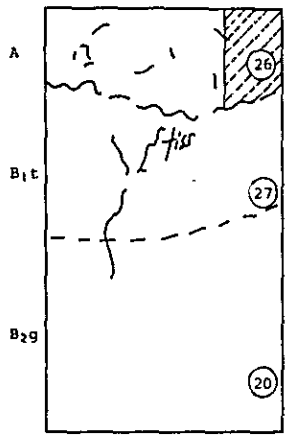
Topography: Lower port of slope

Vegetation: Secondary forest

Remarks
1) Be horizon plinthitic
2) *Roots only in B_1 horizon*
3) No gravel

Fig. 3-4 Soil Profile (2)

No. 5 Orthic Acrisols



A	7.5YR5/4 dull brown	1S nutty (dry) very hard	roots few
B1t	7.5YR5/6 bright brown	sL mass (moist) very hard	(-)
B2g	7.5YR6/8 orange	lC mass (moist) hard	(-)

Location. Northern part of Lumut Hills

Topography: Top ridge of rolling hills

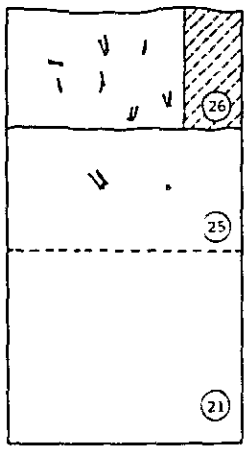
Aspect: NW

Vegetation: After fire

Remarks

1) Upper horizon are very hard
2) Few of roots
3) Lack of Litter layer

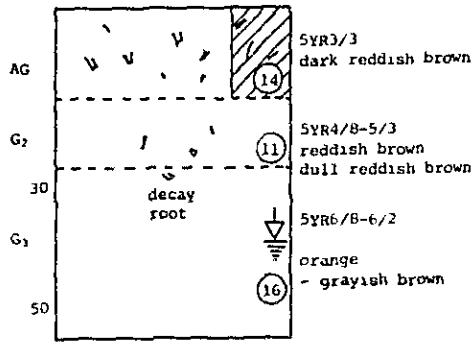
No. 6 Orthic Acrisols



	7.5YR4/4 brown	sL	nutty
	7.5YR6/6 orange	ScL	nutty c mass
	7.5YR5/8 bright brown	hC	mass

Fig. 3-5 Soil Profile (3)

No. 7 Humic Gleysols



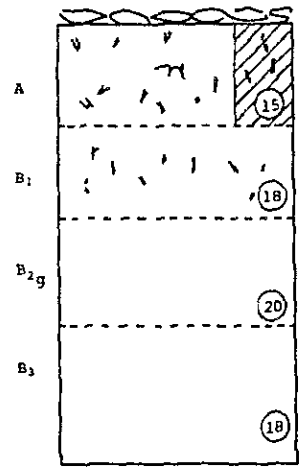
Location. Near No. 6,5

Topography: Flat plain of bottom of hill stream

Vegetation. Swamp grass

Remarks: 1) groundwater level 40 cm

No. 8 Plinthic Acrisols



L	nutty somewhat soft	
sL	mass somewhat soft	
cL	" hard	
lC	" hard	

Location: Northern part of Andulau

Topography: Flat plain (terrace) near stream

Vegetation: Natural forest

Remarks

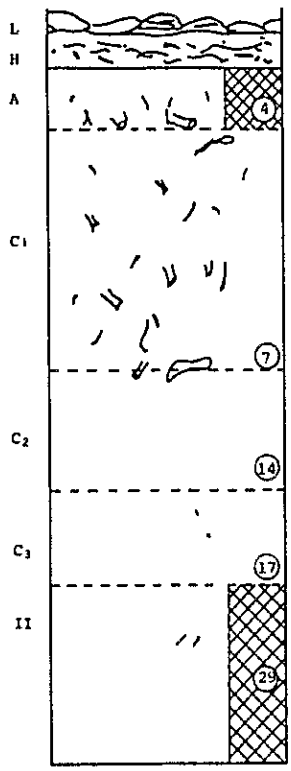
1) Root system in upper horizon

2) Lack of F.H.

3) B_2 horizon mottled

Fig. 3-6 Soil Profile (4)

No. 9 Albic Arenosols



H	root duff			
A	2.5Y2/2-5Y8/2 brownish black - light gray	S	single grain	(dry)
C1	2.5Y7/3+5Y8/2 light yellow + light gray	S	"	"
C2	5Y7/2 light gray	S	"	"
C3	5Y7/2 "	S	mass compact	(somewhat moist)
II	5Y3/1 olive black	S	mass very firm	(")

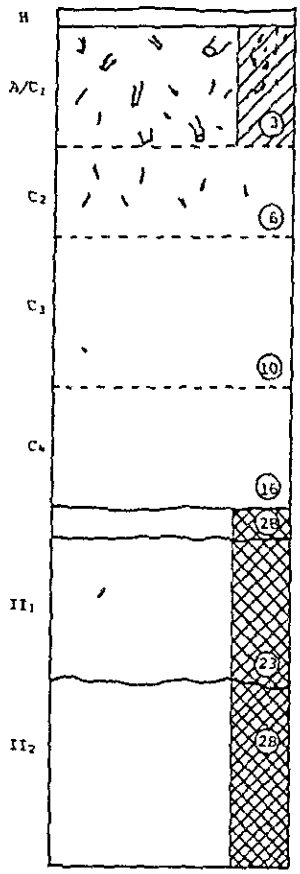
Location: Southern part Andulau

Topography. Flat plain

Vegetation· Agathis natural forest

Fig. 3-7 Soil Profile (5)

No. 10 Albic Arenosols



7 5YR5/3-7/2 dull brown light brownish gray — S — single grain

7.5YR7/2 " — S — "

2 5Y5/2 dark brownish yellow — S — "

5Y5/3 grayish olive — S — "

+ very hard cemented

5YR2/1 black — sL — mass

5YR3/2 olive black — LS — "

Location: Southern area apart from Andulau

Topography: Flat plane

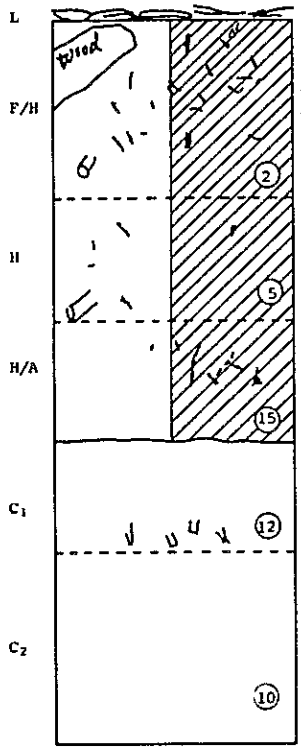
Vegetation: Agathis natural forest managed by line plating method

Remarks: 1) White sand layer

2) Root system shallow

Fig. 3-8 Soil Profile (6)

No. 11 Dystric Histosols or Humic Arenosols



5YR3/2 dark reddish brown	gr	
5YR3/1 brownish black	gr + cr	
5YR2/1 "	mass	
2.5Y8/2 light gray	S	single grain
5Y8/2 "	S	"

Location: Badas Reserve Forest near Seria

Topography: Flat alluvial plain near Belait River

Vegetation: Agathis natural forest

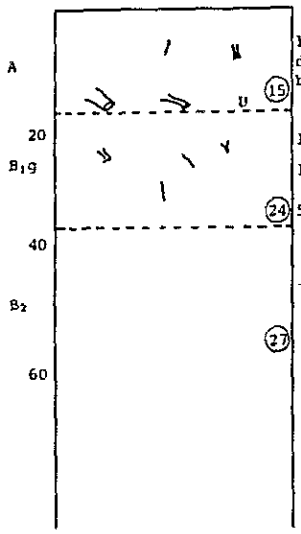
Remarks

1) Thick Ao layer

2) Root system almost in Ao layer

Fig. 3-9 Soil Profile (7)

No. 12 Orthic Acrisols



10YR5/3 dull yellowish brown — S — blocky (dry) hard

10YR8/3 light yellow orange; 10YR6/4 dull yellow orange — cS — mass (dry) very firm

5YR7/6 orange

sC — mass "

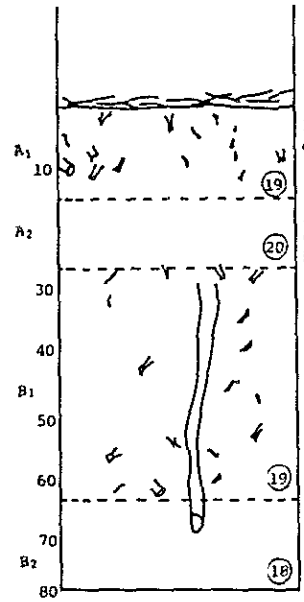
7.5YR7/8 yellow orange

Location. Northern Lumut Hill

Vegetation. Plantation of Pinus caribaea (poor growth)

Remarks
1) Shallow roof system
2) Stagno gleyish in B horizon

No. 13 Dystric Cambisols ∿ Weakly Orthic Acrisols



10YR3/3 dark brown	S	blocky ∿ nutty	friable (dry)
10YR4/2 grayish yellow brown	lS	soft blocky	" (moist)
10YR7/6 bright yellowish brown	sL	mass	hard (moist)
10YR6/6 " "	L		very hard (moist)

Location Near No. 12

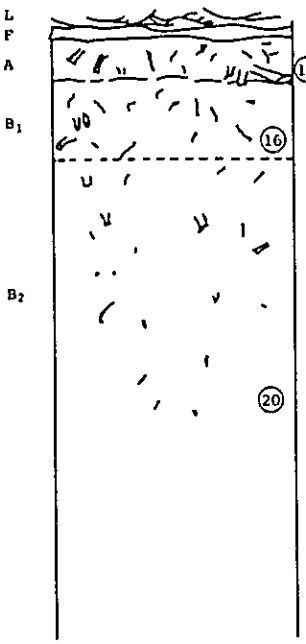
Topography. Collurial slope

Vegetation Plantation of Pinus caribaea (good growth)

Remarks
1) Argilic, weak
2) Deep root system

Fig. 3-10 Soil Profile (8)

No. 14 Dystric Cambisols



A	10YR3/2 brownish black	SiL	Crumb granale	loose friable	abundant root
B_1	10YR5/6 yellowish brown	SiL	weak nutty	friable	"
					plentiful root
B_2	10YR8/7 yellow orange	SiL	mass	hard	

Location: Lamunin

Topography: Top of undulating hill

Vegetation: Plantation of Araucaria

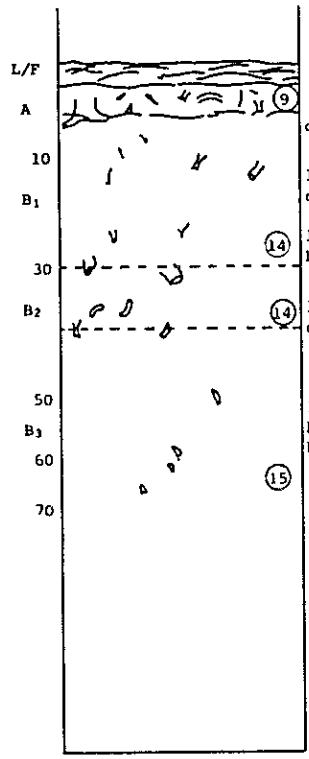
Remarks

1) Mycorrhyzal fungi in A horizon

2) Network in A horizon

3) Many roots in deep horizon

No. 15 Dystric Cambisols



A	7.5YR3/3 dark brown	SL	nutty soft friable (dry)	
B_1	10YR7/4 dull orange	S	mass soft (dry)	
	10YR6/6 bright yellowish brown			
B_2	10YR5/4 dull yellowish brown	S	" soft (dry)	
B_3	10YR6/8 bright yellowish brown	SL	" hard (dry)	

Location. Lamunin

Aspect: NNW

Vegetation: Pinus caribaea plantation 12 years old

Fig. 3-11 Soil Profile (9)

similar to the southern part of the Lumut Hills and it is assumed that sandy material was deposited on this site in past. All layers are sandy or silty and water permeability is high.

It is significant that root formation of the planted trees is vigorous and roots are found everywhere in the soil profile, and the soil is highly suitable for reforestation. It is judged that humus content is sufficient for Araucaria.

(2) Central area of Andulau Forest Reserve

Two plots were set up in the central area of Andulau Forest Reserve which is located east from Labi Road alongside a forest road which leads from the eastern part of Mount Tunggulian (82 meters high) to the southern mountains. Alongside this forest road, selective logging has been carried out. The regenerating trees are straight and growing well. The soil is sandy with some clay content and the soil type is combisols. This is an area of Seria Formation like the Lamunin area. The soil of the northern part of the Andulau Forest Reserve is sandy, being determined from roadside samples. (Geological features are Liang Formation.)

In consequence, trial reforestation will proceed to the east in the future for better environmental conditions.

(3) Western area of Lumut Hills

Plot No. 8 (site proposed from nursery) was set up in Andulau Forest Reserve and Nos. 3, 4, 5, 6, 7, 12 and 13 (7 plots) in just north of Andulau Forest Reserve for soil profiles. No. 7 soil type is Gleysols, No. 13 soil type is colluvial Cambisols and others are typical Acrisols areas. Generally, root development is poor, being distributed near the surface portion (30∿40 cm from the surface). In particular, on the ridges, root development cannot be found in deep soil. Plot Nos. 12 and 13 are to be classified for Pinus caribaea plantation, however, soil types are different. Soil of plot No. 13 is colluvial with a soil type of soft Cambisols and plot No. 12 is typical Acrisols. In the plot No. 12, B1 layer is influenced by dead water and there is no root distribution at the bottom part of the profile. For this reason, it is assumed that although tree growth in height of plot

No. 12 was faster in the early stages, root development was restrained, and further growth will be prevented. In contrast, root development in plot No. 13 is vigorous and tree growth (Pinus caribaea) is very good.

In conclusion, soil type of the proposed trial plantation area is typical Acrisols and soil conditions in plot No. 3 and No. 5, in ridges of hills, are similar to the soil condition of degenerated Pinus caribaea forest. Accordingly, during the future use of the area for trial reforestation, it is suggested that no trees be planted on the ridges, but instead the area should be used for forest roads, fire belts, shelter belts, etc. Before trees are planted on the slopes, deep plowing would be essential. Furthermore, in Gleysol area in the valley, should not be used for reforestation except as a shelter belt, since Leucaena leucocephala (Ipil Ipil) and Eucalyptus degulupta (Kamarele) prefer neutral and fertile soil, and are not suitable for this site. In plot No. 8 (the proposed area for the nursery), since the soil condition in the lower profile is hard and patchy, there may be some problems if used for reforestation. However, as a nursery site, no problems can be envisaged as a pot seedling system will be used. The upper part of mountain ridge is suitable for Pinus caribaea, Pinus merksii and Acacia mangium. The slopes are suitable for Acacia mangium and Albizia falcata. The lower part of the slopes is suitable for Maesopsis eminii, Araucaria hunstanii, Acacia mangium and Anthocephalus cadamba, etc.

(4) Southern Area of Lumut Hill (Lowlands)

Elevation in this area gradually decreases from Lumut Hill to the south. White quartz sand-Kerangas is apparently distributed throughout the area. Plot Nos. 9, 10 and 11 were set up in this area where grey unmatured sand alluvial is found. Forest type is Agathis forest. In the site where there is no humus, Casuarina species is dominant. In plot Nos. 9 and 10, on both sides of Labi road, a thin A_0 layer can be found.

The line planting system being carried out by the Government of Brunei is effective in conservation of natural environments. However,

it will be worthwhile to test wider lines.

Fertilization would be required as soil fertility is quite low at this site. However, it is suggested that fertilizer be applied every few years and that over-fertilizing be avoided.

The suitable species are Agathis, Swietenia, Araucaria and tree legumes such as Acacia mangium etc.

Figure 3-12 shows forest types, topography and soil conditions of the surveyed plots.

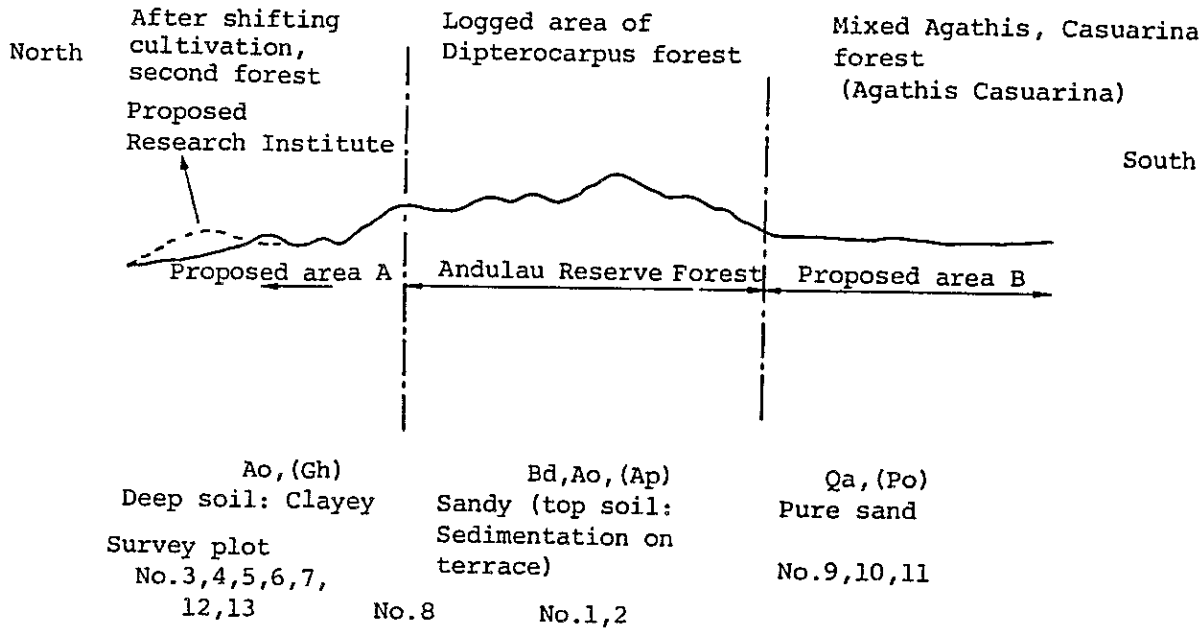


Fig. 3-12 Pattern of Soil Distribution

3-3 Tree Species for Reforestation

Based upon the results of reforestation of by the Government of Brunei and Japanese enterprises as well as the results in countries with similar climatic conditions, following 13 tree species are selected for use during the 1st phase (first 5 years) of the trial reforestation (utilization of tree species is as stated in the previous JICA report).

(Exotic fast-growing species)

- Pinus caribaea
- Acacia mangium
- Albizzia falcataria
- Maesopsis eminii
- Acacia auriculiformis
- Araucaria hunstenii
- Araucaria cunninghamii

(Indigenous species)

- Cratoxylon arborescens
- Anthocephalus cadamba
- Octomeles sumatrana
- Campnosperma auriculata
- Agathis alba

(Others)

- Swietenia macrophylla

Tree species for the 2nd phase (6th ∿ 10th year) are to be selected from among those that have had good results during the 1st phase. Presently, tentatively selected candidate species are as follows:

- Pinus caribaea
- Acacia mangium
- Maesopsis eminii
- Araucaria hunstenii

Tree species for the commercial reforestation project (11th year and after) are to be selected by the end of the 2nd phase. In addition to the above 13 species, the following species are to be planted on a small spot in order to be examined at each phase of the trial reforestation:

Dipterocarpus spp.	: (Keruing, Apitong, etc.)
Dryobalanops spp.	: (Kapur)
Pentacme contorta	: (white lauan)
Shorea spp., Rubroshorea group	: (red meranti)
Shorea albida	: (Alan)
Shorea spp., Richetioides group	: (yellow meranti)
" " , Anthoshorea group	: (white meranti)
" " , Shorea group	: (Balau, Selangan batu, etc.)
Vatica spp.	: (Resak)
Cotylelobium spp.	
Upuna spp.	
Dyera spp.	: (Jelutong)
Ceiba pentandra	: (Kapok)
Durio spp.	: Durian
	(Kedondong)
Casuarina spp.	: (Aru)
Terminalia spp.	
Diospyros spp.	: (Ebony)
Calophyllum spp.	: (Bintangor)
Dalbergia latifolia	: (rose wood)
Intsia spp.	: (Merbau)
Pterocarpus indicus	: (Narra)
Cedrela toona	: (Toon)
Toona calantas	: (Kalantas)
Eucalyptus deglupta	: (Komererc)
Gmelina arborea	: (Yamane)
Tectona grandis	: (Teak)
Vitex spp.	: (Molave)
Aucoumea klaineana	: (Okonme)
Terminalia ivorensis	: (Framire)
Terminalia superba	: (Limba, Frake)
Ceiba pentandra	: (Ceiba)
Ochroma spp.	: (Balsa)
Cedrela odorata	: (Cedro)
Cordia alliodora	: (Canalete)
Leucanea leucocephala	: (Ipil Ipil)

3-4 Facilities and Machines for Reforestation

As the areas for reforestation for each year are relatively small, reforestation office, storehouse, garage, fertilizer warehouse, bulldozer, trucks, cars for transport of both personnel and materials, 4WD vehicles, chain saws, sickles, hoes, etc. are also to be used for nursery operation. Facilities in the reforestation areas would include:

1. Reforestation and nursery office to direct reforestation and nursery operations
2. Storehouse for equipment
3. Machine warehouse for machines and various accessories
4. Garage

Refer to Chapter 4 Nursery for the layout of the facilities.

3-5 Plan for Trial Reforestation

3-5-1 Trials

The trial period is split into two phases of five years. During the 1st phase, eight trials described below would be carried out. In the 2nd phase, reforestation methods would be standardized based upon the results of the 1st phase because of the larger areas involved. Tree species for the 2nd phase are those listed under 3-3. However, according to the results of the 1st phase, methods and tree species for the 2nd phase are subject to change.

(1) Species Elimination Trial

The adaptability and growth rate of 13 species listed in part 3-3 are to be investigated employing standard reforestation methods described in part 3-6. In the 2nd year of the 1st phase, Caribean pine, Acacia mangium, Maesopsis eminii, Klinki pine and Hoop pine are to be planted on the whole area of the slope and other species on the lower part of the slope.

(2) Land Preparation and Cover Crop Trial

It is anticipated that land preparation would be very expensive because of the many residual trees in the logged-over areas and the large trees in the secondary forest. Burning is the easiest method and is also effective in controlling pests and diseases. However, soil fertility should be considered so that burning of organic material can be avoided as much as possible. Consequently, growth comparison and cost/benefit analysis for the plantations trees by each method of land preparation have to be devised. Land is to be prepared during the end of the 1st year/beginning of the 2nd year. There will be four situations:

Land Preparation	Degree
Burning	Done / Not Done
Cover Crop	Done / Not Done

Note: Seeds of Swatro, Rabrato, Stylo etc. are to be sown for cover crop purposes.

(3) Stand Density Trial

Determination of spacing is one of the most important factors for reforestation along with weeding, salvage cutting, vine killing, fertilization and thinning. Four densities, (2 m x 2 m), (3 m x 3 m), (4 m x 4 m) and (5 m x 5 m) are to be tested, and growth rate recorded for each species. In the 4th and 5th years, planting should be carried out according to Table 3-9.

(4) Natural Regeneration Trial

In Dipterocarpus and Agathis forests, removal of undesirable trees and treatment of stand floors are performed. Surveys are to be made on germination and growth of natural seedlings and on fruiting as well as on seasonal changes in the quantity of litter.

Table 3-9 Area of Spacing Tests by Specie and Year

Unit: ha

Tree species	4th year	5th year	Remarks
Pinus caribaea	5.2	3.75	(including 0.25 ha of agroforestry and provenance test)
Acasia mangume	5.2	4.2	
Albizia farcata	5.2	4.2	
Maesopsis eminii	5.2	4.2	
Acasia auriculiformis	4.8	4.8	
Araucaria hunstenii	2.4	2.4	
Araucaria canninghamii	2.4	2.4	
Cratoxylon arborescens	2.4	2.4	
Anthocephalus cadmba	2.4	2.4	
Octomeles smatrana	2.4	2.4	
Campnosperma auriculata	2.4	2.4	

Notes: (2 m × 2 m), (4 m × 4 m) test will be done in 4th year in equal hectarage.

(3 m × 3 m), (5 m × 5 m) test will be done in 5th year in equal hectarage.

(5) Line Planting

In the Dipterocarpus forests, during the 3rd year, Agathis Mahogany is to be planted on the land prepared so that width (without cutting) is 5 m, intervals of seedlings are 5 m and widths of clearing are 1, 2, 3, 4 or 5 m. Growth of the planted trees by each line and growth of Agathis trees in the existing line planted area are to be observed.

Width of clearing	Area	Number of planted trees per ha
1 m	0.24 ha	80
2	0.24	69
3	0.24	60
4	0.24	53
5	0.24	48

(6) Agro-forestry

Agro-forestry is a form of land use which combines the production of forest trees and agricultural crops and/or animals simultaneously and sequentially on the same unit of land, and accommodates farming and other cultures of the local population. Intensive agro-forestry practices require sufficient manpower and fertile soil. Though Brunei is not suitable for agro-forestry systems which have been, or being practised in Southeast Asia, because of insufficient manpower, trial agro-forestry along this concept is to be implemented with the combination of caribean pines and bananas on the area of 0.25 ha with spacing (5 m × 5 m) for both species.

(7) Fertilization Trial

In order to determine the effects of fertilizers, fixed experimental plots for fertilizing are to be established for each species. Three methods, that is, no fertilization, 50% of standard fertilization and standard fertilization are to be employed using six plots. (Each method is tested twice.) Standard fertilization is N: 20g for one tree of fast-growing species and N: 15g for a pine tree. When compound fertilizers of 15:15:15 (N:P:K) are to be used, standard quantity for one tree is 134 g/m^2 for the fast growing species and 100 g/m^2 for pines. For legumina, fertilizers with richer phosphatic contents, 13:17:12 for example, are more suitable and are to be used if available.

Fertilizers are to be applied 1∿2 months after the planting when survival of the plants can be confirmed. As fertilizers prove more effective when applied for two or three years consecutively, quantity of the fertilizer for the 2nd year is to be 20% more than the 1st year, and for the 3rd year, a further 20% increase over the 2nd year. Three or four holes are dug 20∿30 cm apart from the base of the seedlings, fertilizer is applied and the holes are covered by soil. These fertilization trials are to be made in the 3rd year. Tables 3-10 and 11 show quantity of fertilizers to be applied for this and other trials.

Table 3-10 Amount of Fertilizer (per 10 ha)

Unit: kg

Species	Year 1	Year 2	Year 3
Pine	110	132	159
Compnosperma auriculata	84	101	121
Other fast growing species	148	177	213

Table 3-11 Amount of Fertilizer (Total)

Unit: kg

Test items	Species		After planting 1st year	2nd year	3rd year	Total
Species elimination trial	Pine		308	370	444	1122
	Campnosperma auriculata		51	62	74	187
	Other fast growing species		973	1168	1402	3543
		Total	1332	1600	1920	4852
Spacing trial (including agro-forestry and provenance test)	Pine		3524	4229	5075	12828
	Fast growing species		7704	9244	11093	28041
		Total	11228	13473	16168	40869
Fertilizing trial	Pine	Standard	231	278	333	842
		1/2 standard	110	132	158	400
	Campnosperma auriculata	Standard	34	41	49	124
		1/2 standard	17	21	25	63
	Other fast growing species	Standard	637	761	913	2308
		1/2 standard	310	372	446	1128
		Total	1336	1605	1924	4865
			(Grand Total: 50586 kg)			

(8) Provenance Trials

An inter-provenance growth comparison will be carried out with the seedlings of Pinus caribaea, Acasia mangium, Maesopsis eminii, Araucaria hunstenii and Araucania cunninghamii (provenances are shown in Table 3-12), so that the most suitable clone for the proposed reforestation project can be identified. Planting for the provenance tests are to be made in the 5th year of the 1st phase on 1 ha for each species.

Table 3-12 Country of Origin and of Production of Each Tree Species

Species	Origin	Production
Pinus caribaea	Caribean region	Fiji, Malaysia
Acasia mangium	Australia	Sabah, Indonesia
Maesopsis eminii	East Africa	Liberia, Nigeria
Araucaria hunstenii	Papua New Guinea and others	Sabah, Malaysia
Araucaria canninghamii	Same as above	Australia, Brazil

3-5-2 Annual Plan of Reforestation Project

The work plan of the project covers the following stages:

1. Preparatory stage (1st year)
2. The First phase (2nd∿5th year)
3. The Second phase (6th∿10th year)
4. Commercial reforestation project (11th year and after)

During the preparatory stage of the 1st year, facilities such as nursery and roads are to be constructed, personnel and organizations decided upon, equipment and supplies procured, seeds obtained, seedlings produced and land is to be prepared in the latter part of this stage.

Eight trials as mentioned under 3-5-1 are to be carried out during the 1st phase to select suitable species and solve any possible problems. Target for four years of planting is 110 ha. Annual plan for

each test is given in Table 3-13.

Table 3-13 Annual Plan of Trials

Test items \ Year	Year 1	Y 2	Y 3	Y 4	Y 5	Y6 onward
Species elimination trial	Planting year →					
Land preparation trial	←					
Spacing trial			Planting year →			
Natural regeneration trial	←					
Line planting			Planting year →			
Agro-forestry					Planting year →	
Fertilization trial			Planting year →			
Provenance trial					Planting year →	

During the five years of the 2nd phase, reforestation is to be conducted using standard methods for the suitable species selected in the 1st phase to find various growth conditions for each forest stand and, thus, to obtain basic information for the commercial project. Target of planting is about 1,000 ha for the five years. Annual plans for the 1st and 2nd phases, and reforestation areas are shown respectively in Tables 3-14 and 3-15.

Though outside the scope of this trial reforestation project, the commercial reforestation operation would serve to identify a forest management system which could be applied later to the nationwide reforestation. Close cooperation at this stage between the Government of Brunei and Japan would be indispensable in order to provide the operation with technical, financial and organizational support and also the land suitable for tree planting. The commercial operation would start as soon as the second phase of the trial reforestation ends. Target for each year of planting during the commercial operation would be 250∿300 ha.

Table 3-14 Annual Plan of Reforestation Project

Phase	Items \ Year	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	After 10th
Preparation stage	Construction of facilities (nursery, road) Arrangement of organization Land preparation	→										
Trial phase I	Species elimination test Land preparation test Spacing test Natural regeneration Line planting Agro-forestry Fertilizing test Provenance test	110 ha ← 10 · 20 · 30 · 40 ha →										
Trial phase II	Artificial regeneration test Natural regeneration test					750 ha ← 120 · 160 · 200 · 240 · 280 → ← 30 · 40 · 50 · 60 · 70 → 250 ha						
Commercial reforestation project	Trials of forest management systems	(Annual planting area is 250∿300 ha after 10th year.)										⟷

Table 3-15 Annual Planting Area

Unit: ha

Item	Location	1st year	2nd	3rd	4th	5th	Sub-total	6th	7th	8th	9th	10th	Sub total	Total
Clear cutting and artificial regeneration	Area A		10	10	40	40	100	60	80	100	120	140	500	600
	Area B			7.6			7.6	30	40	50	60	70	250	257.6
Total			10	17.6	40	40	107.6	90	120	150	180	210	750	857.6
Line planting	Area B			2.4			2.4	30	40	50	60	70	250	252.4
Total														
Grand total			10	20	40	40	110	120	160	200	240	280	1,000	1,110
(Species)														
Pinus caribaea			1.4	2.5	5.2	5.2	14.3	25	35	45	55	65	225	239.3
Acacia mungium			1.4	2.5	5.2	5.2	14.3	25	35	45	55	65	225	239.3
Maesopsis eminii			1.2	1.8	5.2	5.2	13.4	25	35	45	55	65	225	238.4
Araucaria hunstenii			1.2	1.8	5.2	5.2	13.4	15	15	15	15	15	75	88.4
Araucaria canninghamii			1.2	1.8	4.8	4.8	12.6							12.6
Albizia farcata			0.6	1.2	2.4	2.4	6.6							6.6
Acacia auriculiformis			0.6	1.2	2.4	2.4	6.6							6.6
Cratoxylon arbolescens			0.6	1.2	2.4	2.4	6.6							6.6
Anthocephals cadamba			0.6	1.2	2.4	2.4	6.6							6.6
Octomeles smatrana			0.6	1.0	2.4	2.4	6.6							6.6
Campnosperma auriculata			0.6	1.2	2.4	2.4	6.6							6.6
Agathis alba				1.2			1.2	15	20	25	30	35	125	126.2
Swietenia macrophylla				1.2			1.2	15	20	25	30	35	125	126.2

3-6 Reforestation Standards

3-6-1 Site Preparation

Prior to planting, weeds that would limit growth of planted trees are to be cleared, residual trees felled and branches removed. Care should be taken to avoid excessive work because site preparation is labor intensive and greatly affects the costs of the operation. In Brunei, since high temperatures and humidity accelerate the decomposition of organic material, the recommendable practice is to return the organic material such as branches and leaves to the soil if possible. Different ways of site preparation, namely manual or mechanical clearing or burning, and strip land preparation method are to be employed respectively depending on the conditions of the site, e.g. shifting cultivation areas, logged-over areas and line planting areas.

3-6-2 Planting

Successful establishment of forest stands depends greatly on the survival of the seedlings. Potted seedlings are commonly used in tropical areas. At the time of planting, pots are to be broken and removed with care. Only after careful planting, good survival and growth of the seedlings can be expected from the first year. For the clear-cutting and artificial reforestation, all species are to be planted with (3 m × 3 m) spacing or 1,100/ha, with an exception of Campnosperma auriculata, which is to be planted with (4 m × 4 m) spacing or 625/ha. A row interval of 5 m, clearing widths of 1, 2, 3, 4 or 5 m and seedling intervals of 5 m are to be executed for Agathis and Mahogany in line planting areas.

3-6-3 Tending

(1) Weeding

Weeds grow quickly in the tropics and Brunei is no exception. Weeding is an important means of aiding the survival of planted trees. Intensity of weeding is one of the key factors for successful reforestation. At the same time, it must be effective because it occupies

the major portion of reforestation expenses. Therefore, application of most suitable methods for each forest stand is imperative. As weeds in Brunei grow very thickly, weeding is required four times in the first year, twice in the second year and probably once in the third year. Strip weeding and spot weeding methods to be employed depending on conditions.

(2) Vine Killing

In a few years after weeding, planted trees will tower above the weeds and can grow quickly. But at this stage, vines will climb up around the planted trees preventing further growth. Therefore, it is necessary to close the canopy of the forest as early as possible and eliminate sources of vines by removing them whenever found. Vines are to be cut during the two years after the end of weeding, and subsequently remove whenever they grow.

(3) Improvement Cutting

This is to be performed to provide sufficient space for the growth of planted trees and to create healthy forest stands by removing both unnecessary trees that hinder growth of planted trees and inferior planted trees. Improvement cutting will not be performed during the 1st phase of this trial reforestation.

(4) Thinning

This is to be done to make the stand density conform to the standard by cutting trees after the closure of the forest stand until the final cutting. Though sufficient information for tropical species is not available, thinning is to be done considering photosyntheis.

3-6-4 Protection and Management

As planted areas increase, the causes for possible forest damage also incease. Consequently, every measure is to be taken to protect the forests against possible hazards such as fires, termites, and other damages by insects and animals. Consideration is to be given

to provide proper structure to the forest stands, to maintain the environment in good condition, establishing shelter tree belts, footpaths and facilities against fire needed to maintain sound forest stands. Appropriate preventive measures should be provided through early detection of possible pests and deseases. General protective and/or control measures must cover the entire areas.

3-6-5 Standard Efficiency of Operations

The results of reforestation work varies according to topography, vegetation, labor conditions and methods of process control. The most important factors are improvement of workers' skills, and proper labor management.

This reforestation project aims to achieve the target with proper reforestation work, and to increase economic efficiency through reduction of expenditures.

The standard efficiency of operations indicated in Table 3-16, designed in consideration of social and labor conditions indicated by the field survey.

3-6-6 Organization of Reforestation Project

Nursery and reforestation operations must be carried out systematically. Organization is the basic need for production of sound seedlings, and it leads to good survival of planted trees. An excellent artificial forest is created through a proper maintenance and appropriate protection and control.

It is planned to produce sound seedlings and to reforest under the management and supervision of the following organization.

Table 3-16 Standard Reforestation Work Schedule

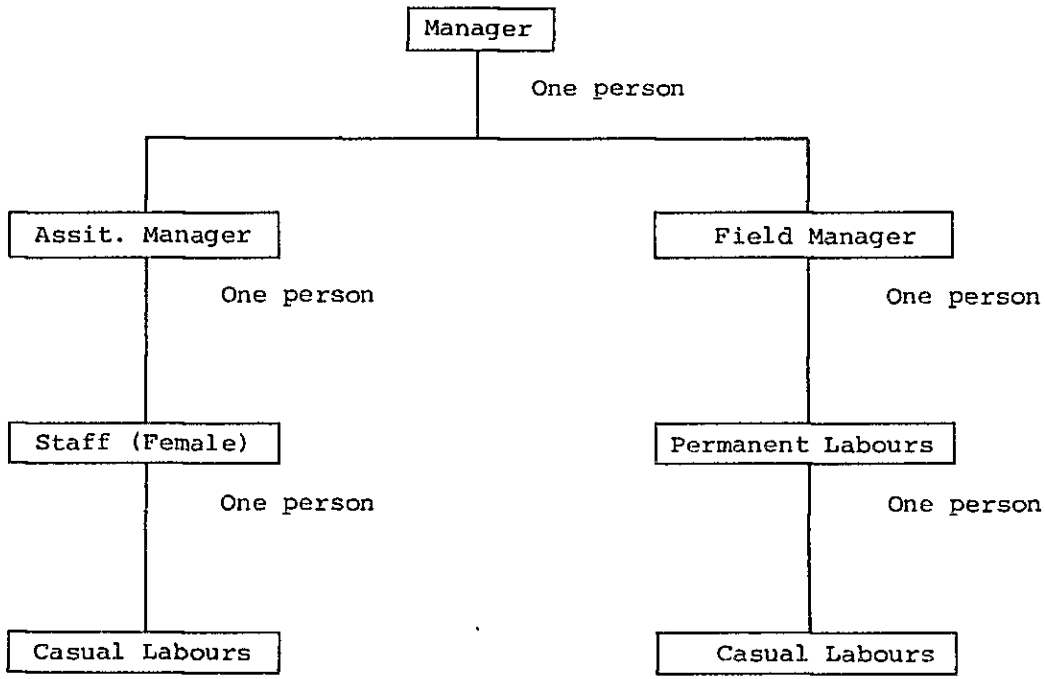
Unit: persons/ha

Type of work	Scope of work	Schedule (A) Burnt land	Schedule (B) Cleared land	Schedule (C) Line planting	Remarks
Land preparation					
Manual	Clearing and removal of shrubs and weeds	15			
Mechanical	Felling, clearing of shrubs and weeds, removal by bulldozer		30		3 chain saws, 1 bulldozer 3 chain saw operators, 1 operator
Strip	Clearing of shrubs and weeds, girdling			10	1 chain saw, 1 chain saw operator 7 men for clearing and land preparation, 3 for girdling
Planting	Control lining, stick marking, digging, planting, carrying of seedlings	12	12		Planting 1,100 per ha, stick marking 400/day, digging 250/day, planting (including the carrying of seedlings) 250/day
				6	Planting 530 per ha, same as above
Weeding (Manual)	4 times in the first year, 2 times in the second year	30	30		Total weeding, partial strip weeding 20 men for the first year, 10 men for the second year
	4 times in the first year, 2 times in the second and once in the third			19	Strip land preparation 10 men for the first year, 6 men for the second and 3 men for the third
Vine cutting	To be carried out for two years following weeding	5	5	5	3 men for the first year and 2 men for the second
Carrying of seedlings	Loading, transportation from the nursery bed to the planting site and unloading	0.2	0.2	0.1	2-ton truck at 10 thousand/day 2 men for loading and unloading
Total		62.2	77.2	40.1	
Protection and control	Patrol, fire prevention	0.3	0.3	0.3	

Notes: o Within five years for burnt land. o For cleared land, after medium sized trees have been used for chips, etc.

o For line planting, within two years of felling.

o Bulldozer operation: B$55/day (B$1 = ¥120) o Chain saw man: B$35/day (B$1 = ¥120) o Reforestation laborer: B$30/day (B$1=¥120)



Note: During the 1st Phase, permanent labours are not employed.

Fig. 3-13 Organizational Chart

3-7 Cost of Reforestation

(1) Labor Cost

Tables 3-17 and 3-18 show the scheduled reforestation operation and required labors estimated by the standard efficiency of reforestation, on the basis of the annual plan of reforestation.

The labor cost is shown in Table 3-19.

(2) Cost of Vehicles, Equipment and Materials

Reforestation operation is to be mechanized in order to increase efficiency. Vehicles are to transport workers, seedlings, materials and machines.

Suitable vehicles and machines (topography of the proposed site, vegetation, etc.) must be chosen, considering their costs, performance and work safety. Vehicles and machines needed are as follows:

(Bulldozer	Small or medium size	Lease (Lease charge: B$480/day))	
Truck	(2 ton)	1	B$22,000
Passenger & freight vehicle	(2 ton)	1	B$24,300
4WD vehicle		1	B$22,000
Chain saw		3/10 ha	B$ 2,500/10 ha
Sickles, Hoes, Others			B$ 830/10 ha

Depreciation year:
- Vehicles - five years
- Chain saw - three years
- Others - one year

Program of purchase:
- The first and sixth year - 4WD vehicle 1
- The second and seventh year - Passenger and freight vehicles 1
- The third and eighth year - Truck 1

Use of vehicles and machines are planned as follows:

Truck	20 days per month	12 months	Fuel 30 ℓ per day	(1)
Passenger and freight vehicle	" " " "	" "	" " " "	"
4WD vehicle	" " " "	" "	" " " "	"
Chain saw	" " " "	" "	" 10 ℓ " "	"

Table 3-17 Annual Scheduled Reforestation Operations

Unit { Area : ha
Seedlings: 1,000

Regeneration method	Area	Work	Year 1	2	3	4	5	Sub-total	6	7	8	9	10	Sub-total	Total
Clear-cutting and planting	Area A (A)	Land preparation	5	5	5	7		22	12	15	18	20	13	78	100
	Area A (B)	" "		10	20	28	50	108	58	75	92	110	57	392	500
	Area B (B)	" "		4	3.6		15	22.6	35	45	55	65	35	235	257.6
	Sub-total		5	19	28.6	35	65	152.6	105	135	165	195	105	705	857.6
		Planting		10	17.6	40	40	107.6	90	120	150	180	210	750	857.6
		Weeding		10	27.6	57.6	80	175.2	130	210	270	330	390	1,330	1,505.2
		Vine cutting				10	27.6	37.6	57.6	80	130	210	270	747.6	785.2
		Seedling transportation		(11.0)	(19.4)	(44.0)	(44.0)	(118.4)	(99.0)	(132.0)	(165.0)	(198.0)	(231.0)	(825.0)	(943.4)
Line planting	Area B (C)	Land preparation			2.4			2.4	30	40	50	60	70	250	252.4
		Planting			2.4			2.4	30	40	50	60	70	250	252.4
		Weeding			2.4	2.4		4.8	30	70	90	110	130	430	434.8
		Vine cutting					2.4	2.4	2.4		30	100	160	292.4	294.8
		Seedling transportation			(1.3)			(1.3)	(15.9)	(21.2)	(26.5)	(31.8)	(37.1)	(132.5)	(133.8)
Clear-cutting and planting, line planting		Protection & control		10	30	70	110	220	230	390	590	830	1,110	3,150	3,370

Table 3-18 Annual Laborers Required for Reforestation

Type of work	Item	Year 1	2	3	4	5	Sub-total	6	7	8	9	10	Sub-total	Total
(Clear-cutting and planting)														
Land preparation	Bulldozer operator		14	24	78	95	161	93	120	147	175	92	627	788
	Chain saw operator		42	71	84	195	392	279	360	441	525	276	1,881	2,273
	Laborer	75	439	689	833	1,690	3,726	2,598	3,345	4,092	4,850	2,587	17,472	21,198
	Sub-total	75	495	784	945	1,980	4,279	2,970	3,825	4,680	5,550	2,955	19,980	24,259
Planting	Laborer		120	211	480	480	1,291	1,080	1,440	1,800	2,160	2,520	9,000	10,291
Weeding	"		150	414	864	1,200	2,628	1,950	3,150	4,050	4,950	5,850	19,950	22,578
Vine cutting	"				25	69	94	144	200	325	525	675	1,869	1,963
Seedling transportation	"		2	4	8	8	22	18	24	30	36	42	150	172
Total		75	767	1,413	2,322	3,737	8,314	6,162	8,639	10,885	13,221	12,042	50,949	59,263
(Line planting)														
Land preparation	Chain saw operator			3			3	30	40	50	60	70	250	253
	Laborer			22			22	270	360	450	540	630	2,250	2,272
	Sub-total			25			25	300	400	500	600	700	2,500	2,525
Planting	Laborer			15			15	180	240	300	360	420	1,500	1,515
Weeding	"			15	15		30	190	443	570	696	823	2,722	2,752
Vine cutting	"					6	6	6		75	250	400	731	737
Seedling transportation	"			1			1	6	8	10	12	14	50	51
Total				56	15	6	77	682	1,091	1,455	1,918	2,357	7,503	7,580
Protection and control	Laborer		3	9	21	33	66	69	117	177	249	333	945	1,011
Grand total		75	770	1,478	2,358	3,776	8,457	6,913	9,847	12,517	15,388	14,732	59,397	67,854

Table 3-19 Annual Labor Cost of Reforestation

Unit: B$

Type of work	Item	Year 1	2	3	4	5	Sub-total	6	7	8	9	10	Sub-total	Total
(Clear-cutting and planting)														
Land preparation	Bulldozer operator		770	1,320	1,540	5,225	8,855	5,115	6,600	8,085	9,625	5,060	34,485	43,340
	Chain saw operator		1,470	2,485	2,940	6,825	13,720	9,765	12,600	15,435	18,375	9,660	65,835	79,555
	Laborer	2,250	13,170	20,670	24,990	50,700	111,780	77,940	100,350	122,760	145,500	77,610	524,160	635,940
	Sub-total	2,250	15,410	24,475	29,470	62,750	134,355	92,820	119,550	146,280	173,500	92,330	624,480	758,835
Planting	Laborer		3,600	6,330	14,400	14,400	38,730	32,400	43,200	54,000	64,800	75,600	270,000	308,730
Weeding	"		4,500	12,420	25,920	36,000	78,840	58,500	94,500	121,500	148,500	175,500	598,500	677,340
Vine cutting	"				750	2,070	2,820	4,320	6,000	9,750	15,750	20,250	56,070	58,890
Seedling transportation	"		60	120	240	240	660	540	720	900	1,080	1,260	4,500	5,160
Total		2,250	23,570	43,345	70,780	115,460	255,405	188,580	263,970	332,430	403,630	364,940	1,553,550	1,808,955
(Line planting)														
Land preparation	Chain saw operator			105			105	1,050	1,400	1,750	2,100	2,450	8,750	8,855
	Laborer			660			660	8,100	10,800	13,500	16,200	18,900	67,500	68,160
	Sub-total			765			765	9,150	12,200	15,250	18,300	21,350	76,250	77,015
Planting	Laborer			450			450	5,400	7,200	9,000	10,800	12,600	45,000	45,450
Weeding	"			450	450		900	5,700	13,290	17,100	20,800	24,690	81,580	82,480
Vine cutting	"					180	180	180		2,250	7,500	12,000	21,930	22,110
Seedling transportation	"			30			30	180	240	300	360	420	1,500	1,530
Total				1,695	450	180	2,325	20,610	32,930	43,900	57,760	71,060	226,260	228,585
Protection and control	Laborer		90	270	630	990	1,980	2,070	3,510	5,310	7,470	9,990	28,350	30,330
Grand total		2,250	23,660	45,310	71,860	116,630	259,710	211,260	300,410	381,640	468,860	445,990	1,808,160	2,067,870

(3) Cost for Management and Supervision

Remuneration of Manager, Assistant Manager and Staff (Female) is estimated in Table 3-20.

(4) Total Cost of Reforestation Operations

Table 3-21 shows the total of the above reforestation costs.

Table 3-20 Cost for Management and Supervision

Unit: B$

Items	Year 1	2	3	4	5	Sub-total	6	7	8	9	10	Sub-total	Total
Manager	83,500	83,500	83,500	83,500	83,500	417,500	83,500	83,500	83,500	83,500	83,500	417,500	835,000
Asst. manager	66,500	66,500	66,500	66,500	66,500	332,500	66,500	66,500	66,500	66,500	66,500	332,500	665,000
Staff (female)	10,000	10,000	10,000	10,000	10,000	50,000	10,000	10,000	10,000	10,000	10,000	50,000	100,000
Total	160,000	160,000	160,000	160,000	160,000	800,000	160,000	160,000	160,000	160,000	160,000	800,000	1,600,000
Other expenses	15,000	15,000	15,000	15,000	15,000	75,000	15,000	15,000	15,000	15,000	15,000	75,000	150,000
Grand total	175,000	175,000	175,000	175,000	175,000	875,000	175,000	175,000	175,000	175,000	175,000	875,000	1,750,000

Table 3-21 Total Cost of Reforestation

Unit: B$

Items	Details	Year 1	2	3	4	5	Sub-total	6	7	8	9	10	Sub-total	Total
Operation cost	Labor cost	2,250	23,660	45,310	71,860	116,630	259,710	211,260	300,410	381,640	468,860	445,990	1,808,160	2,067,870
	Rental charges		6,720	11,520	13,440	45,600	77,280	44,640	57,600	70,560	84,000	44,160	300,960	378,240
	Fuel and others		1,575	2,666	3,150	7,317	14,708	10,466	13,500	16,542	19,692	10,350	70,550	85,258
	Total	2,250	31,955	59,496	88,450	169,547	351,698	266,366	371,510	468,742	572,552	500,500	2,179,670	2,531,368
Maintenance cost	Vehicles	22,000	24,300	22,000			68,300	22,000	24,300	22,000			68,300	136,600
	Equipment	2,083	4,917	5,083	5,417	16,250	33,750	31,250	27,083	38,750	51,250	14,583	162,916	196,666
	Total	24,083	29,217	27,083	5,417	16,250	102,050	53,250	51,383	60,750	51,250	14,583	231,216	333,266
Overhead cost	Management cost	160,000	160,000	160,000	160,000	160,000	800,000	160,000	160,000	160,000	160,000	160,000	800,000	1,600,000
	Other expenses	15,000	15,000	15,000	15,000	15,000	75,000	15,000	15,000	15,000	15,000	15,000	75,000	150,000
	Total	175,000	175,000	175,000	175,000	175,000	875,000	175,000	175,000	175,000	175,000	175,000	875,000	1,750,000
Miscellaneous cost		450	6,395	11,900	17,690	33,910	70,345	53,275	74,217	93,750	114,525	100,100	435,867	506,212
Grand total		201,783	242,567	273,479	286,557	394,707	1,399,093	547,891	672,110	798,242	913,327	790,183	3,721,753	5,120,846

4. Plan of Nursery Construction and Operation

4-1 Production of Seedlings

The purpose of seedling production is to achieve self-sufficiency in the supply of sound seedlings for the reforestation project.

Nursery operations are carried out using pots, for efficiency, low cost, good survival and growth of planted seedlings.

Table 4-1 shows the annual production of seedlings according to the reforestation programme.

Table 4-1 Annual Plan of Seedling Production

Unit: Number · 1000 seedlings
Area · ha

Year / Kinds	1	2	3	4	5	Sub-total	6	7	8	9	10	Sub-total	Total
Number of seedlings raised	7.4	23.2	43.7	60.3	112.2	246.8	170.8	218.8	266.8	314.7	144.4	1,115.5	1,362.3
Number of seedlings out planted	-	12.0	22.7	48.2	48.2	131.1	115.0	153.2	191.6	229.8	268.2	957.8	1,088.9
(Items)													
Area of clear cutting and planting	(-)	(10)	(17.6)	(40)	(40)	(107.6)	(90)	(120)	(150)	(180)	(210)	(750)	(857.6)
Number of seedlings raised	7.4	21.4	43.7	60.3	92.2	225.0	144.2	185.6	227.0	268.1	144.4	969.3	1,194.3
Number of seedlings out planted	-	12.0	21.3	48.2	48.2	129.7	99.0	132.0	165.0	198.0	231.0	825.0	954.7
Area of line planting	(-)	(-)	(2.4)	(-)	(-)	(2.4)	(30)	(40)	(50)	(60)	(70)	(250)	(252.4)
Number of seedlings raised	-	1.8	-	-	20.0	21.8	26.6	33.2	39.8	46.6	-	146.2	168.0
Number of seedlings out planted	-	-	1.4	-	-	1.4	16.0	21.2	26.6	31.8	37.2	132.8	134.2

Table 4-1 (annex) Annual Plan of Seedling Production

Unit: 1,000 seedlings

Tree species \ Year	1	2	3	4	5	Sub total	6	7	8	9	10	Sub total	Total
Pinus caribaea		1.7	3.0	6.2	6.3	17.2	27.5	38.5	49.5	6.05	71.5	247.5	264.7
	1.1	3.0	5.8	7.8	21.2	38.9	41.2	55.0	68.8	82.5	44.7	292.2	331.1
Acacia mangium		1.7	3.0	6.3	6.2	17.2	27.5	38.5	49.5	60.5	71.5	247.5	264.7
	1.1	3.0	5.8	7.9	21.1	38.9	41.2	55.0	68.8	82.5	44.7	292.2	331.1
Maesopsis eminii		1.4	2.2	6.2	6.3	16.1	27.5	38.5	49.5	60.5	71.5	247.5	263.6
	0.9	2.3	5.3	7.8	21.2	37.5	41.2	55.0	68.8	82.5	44.7	292.2	329.7
Araucaria hunstenii		1.5	2.2	6.3	6.2	16.2	16.5	16.5	16.5	16.5	16.5	82.5	98.7
	0.9	2.4	5.3	7.9	14.2	30.7	20.6	20.6	20.6	20.6	10.3	92.7	123.4
A. cunninghamii		1.4	2.2	5.8	5.8	15.2							15.2
	0.9	2.3	5.0	7.3	3.7	19.2							19.2
Albizia falcataria		0.7	1.4	2.9	2.9	7.9							7.9
	0.4	1.4	2.7	3.6	1.8	9.9							9.9
Acacia auriculiformis		0.7	1.5	2.9	2.9	8.0							8.0
	0.4	1.4	2.8	3.6	1.8	10.0							10.0
Cratoxylon lingustrinum		0.7	1.4	2.9	2.9	7.9							7.9
	0.4	1.4	2.7	3.6	1.8	9.9							9.9
Anthocephalus cadamba		0.8	1.5	2.9	2.9	8.1							8.1
	0.5	1.4	2.8	3.6	1.8	10.1							10.1
Octomeles smatrana		0.7	1.4	2.9	2.9	7.9							7.9
	0.4	1.4	2.7	3.6	1.8	9.9							9.9
Campnosperma auriculata		0.7	1.5	2.9	2.9	8.0							8.0
	0.4	1.4	2.8	3.6	1.8	10.0							10.0
Agathis alba			0.7			0.7	8.0	10.6	13.3	15.9	18.6	66.4	67.1
		0.9			10.0	10.9	13.3	16.6	19.9	23.3		73.1	84.0
Swietenia macrophylla			0.7			0.7	8.0	10.6	13.3	15.9	18.6	66.4	67.1
		0.9			10.0	10.9	13.3	16.6	19.9	23.3		73.1	84.0
Total		12.0	22.7	48.2	48.2	131.1	115.0	153.2	191.6	229.8	268.2	957.8	1,088.9
	7.4	23.2	43.7	60.3	112.2	246.8	170.8	218.8	266.8	314.7	144.4	1,115.5	1,362.3

Notes: 1. Upper figures are number of outplanted seedlings.

2. Lower figures are number of dealed seedlings.

4-2 Nursery Construction

4-2-1 Proposed Nursery Site

(1) Selection of Proposed Nursery Site

The proposed nursery site is about 4.5 km away from Sungai Liang forest office on the left bank of the Lumut River between it and a national road. Fig. 4-1 gives a rough map of the site.

This site was selected for the following reasons:

a) Necessary area for the nursery can be secured.
b) Enough water can be supplied from the Lumut River all the year around. (The flow of stream near the site is about 50 t/min, at the end of November to the beginning of December.)
c) The proposed nursery site has not been covered with water or washed away by a flood of the Lumut River.
d) Soil for potting can be gathered near the site.
e) The site is close to the reforestation project site.
f) It is close to the forest research institute which will provide technical backstopping.

(2) Present Conditions of the Proposed Nursery Site

The proposed nursery site is located at an elevation of 80 m, and is covered by secondary growth of forest once logged for commercial timber. Most of the trees are of small diameter (less than 20 cm), but there are a few large diameter trees (more than 50 cm).

The growing stock is about 80 m^3/ha.

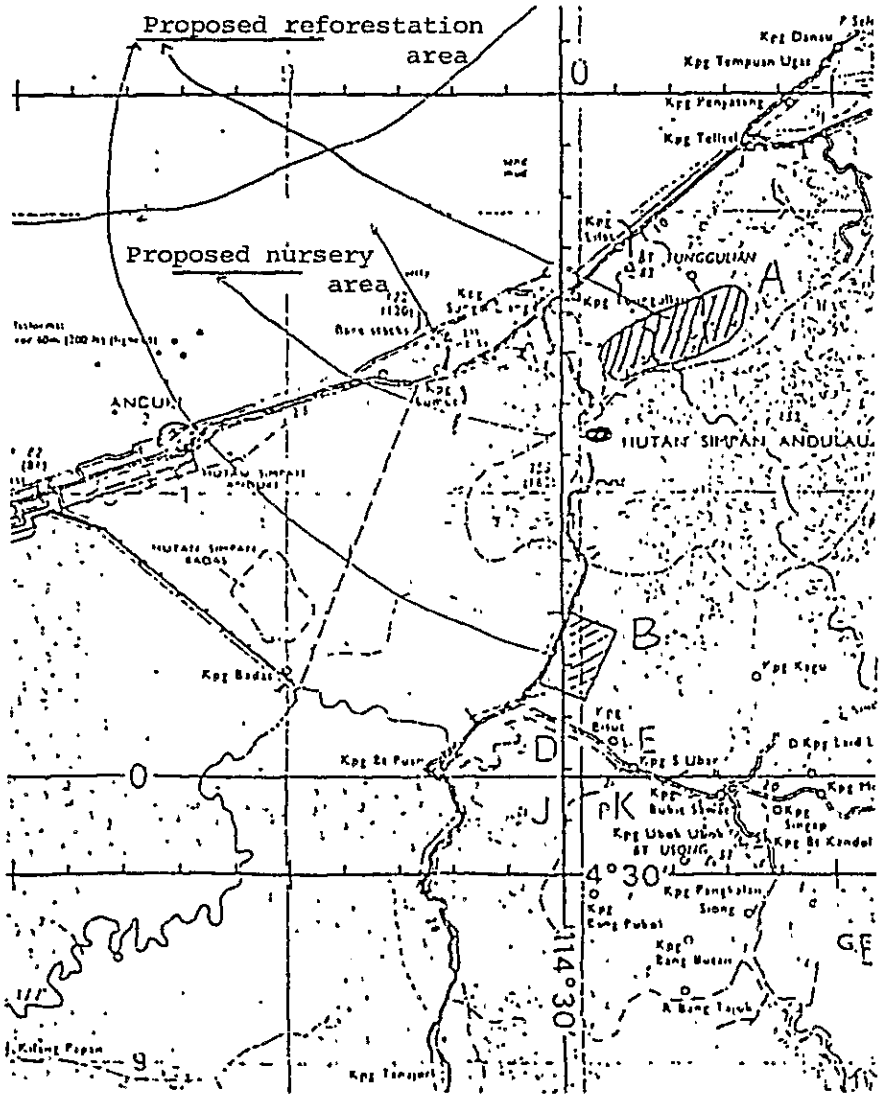
In the southern part, some trees have been damaged by road construction.

Up to 20 m of both sides of the national road were cleared but covered with weeds, ferns and bushes.

(3) Nursery Area

The size of the nursery must be decided so as to produce a sufficient number of seedlings efficiently to support the reforestation programme.

Facilities for nursery operation and administration are to be built.



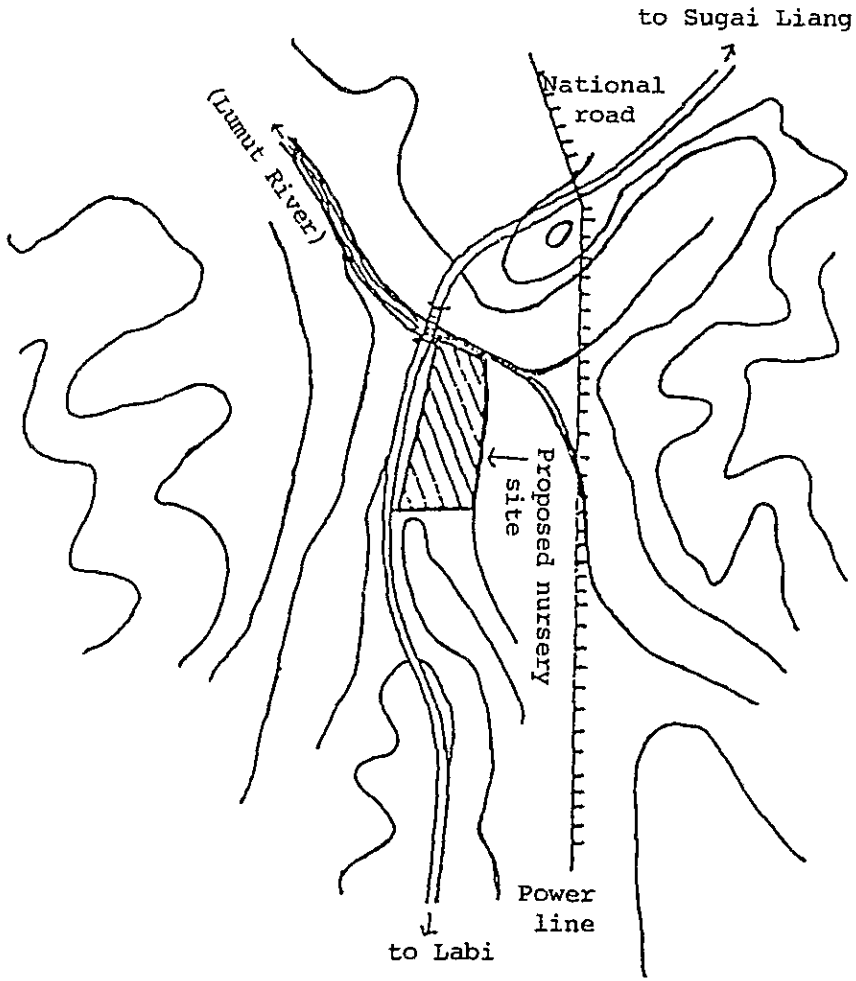


Fig. 4-1 Rough Maps of Proposed Nursery Site

Table 4-2 shows the area of the nursery.

Table 4-2 Required area of the nursery

Unit: m^2

Use	Area	Remarks
Nursing lot (Nursery bed for potted seedling)	6,200	Turnover: once a year 10% paths included
Incidental facilities	4,500	Building and others
Shelter tree belt and spare lot	9,316	
Total	20,016	

4-2-2 Nursery Design

Each facility for the nursery should be arranged, in order to produce sound seedlings efficiently, in consideration of the topography.

Fig. 4-2 indicates the lay-out of the nursery.

(1) Land Preparation

Land preparation is to be carried out for the nursery and the required facilities.

First, felling and clearing of standing trees and then removal of stumps and cultivation (for nursery beds) are to be carried out.

The cost of land preparation is shown in Table 4-3.

(2) Facilities for Nursery Practice

1) Nursing lot: Area 6200 m^2

The nursing lot is divided into blocks by paths, and simple ditches along them drain water well.

Facilities for watering and shade are provided in the nursing lot to protect the potted seedlings.

2) Nursery bed for potted seedling: Area 3800 m^2

After clearing the nursing lot, a nursery bed is made with frames of straight logs (about 4 cm in diameter).

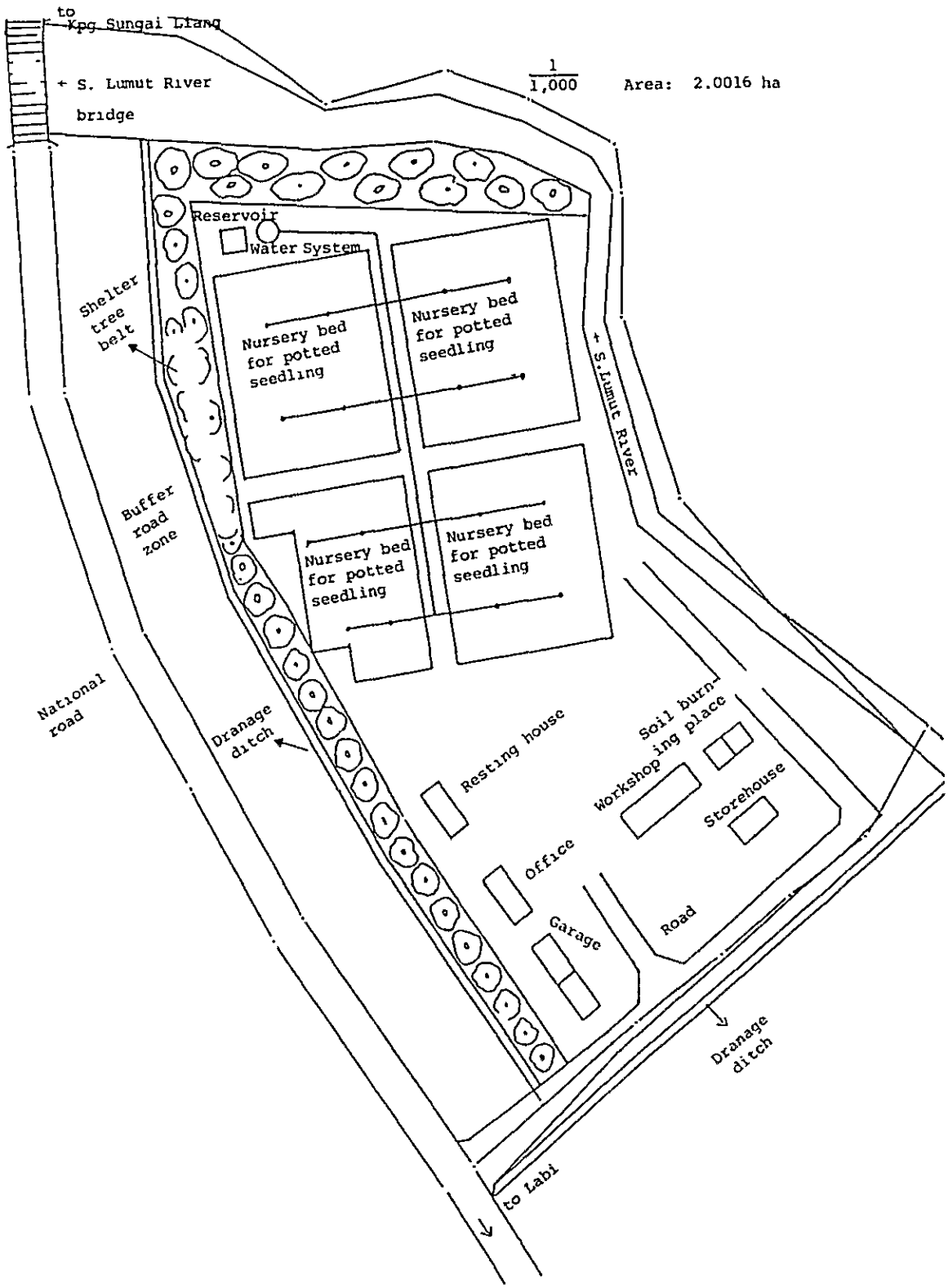


Fig. 4-2 Drawing of Nursery

Table 4-3 Cost of Land Preparations

Classification	Works	Method	Efficiency	Amount	Cost	Remarks
			persons/ha	persons/day	B$	
	Felling of standing tree	Chain saw	3	3.2	112	B$35/day
	Removal of trees		10	10.7	321	B$30/day
Clearing & land Preparation	Ground levelling	Bulldozer	1.5	1 6	88	B$55/day
	Ground levelling (mannual)		5	5 4	162	B$30/day
Total					683	
	Construction of access road (banking)	Bulldozer Width 5m Distance 100m	m/day 25	person/day 4.0	220	B$55/day
Road Construction	Construction of path (inside of nursery)	320m	200	1.6	88	
	Mannual work	420m	50	8.4	252	BS$30/day
Total					570	
Lease	Bulldozer lease	Ground preparation 1.6 days path 5.6 days		7.2 days	3,456	B$480/day (including fuel)
Total					3,456	
Others	Odd jobs, fuel, etc.				167	
Total					167	
Grand total					4,866	

Note: Area: 10,700 m^2

Plastic sheets are to be laid on the ground in order to settle the earth, prevent weeds, and interrupt expansion of roots from pots to the earth.

Wire nets with 10 cm meshes are to be installed, to straighten seedlings. 10 cm meshes are selected because pots of 8 cm in diameter are to be used.

Table 4-4 indicates the construction cost of the nursery bed.

3) Facilities for shade: Area 3800 m^2

Facilities for shade, using logs of about 4 cm in diameter, are to be provided on the nursery bed to promote early growth of seedlings.

Light intensity is controlled with cloth.

The cost is shown in Table 4-5.

4) Watering facilities: Area 4850 m^2

Plastic pots are used in raising seedlings. Watering is necessary because water does not permeate from the earth in the nursery bed.

A sprinkler system is to be installed.

The portable sprinkler with a nozzle should get water from Lumut River via a reservoir from which water is pumped by a pressure pump to the sprinkler. A jet pump should be used between the river and the reservoir.

a) Water requirements

It is anticipated to supply the equivalent of 5 mm of rain fall per day by watering facilities during the dry season.

Calculation of maximum amount of water.

Watering area: 1 block $1.6\ m \times 7\ m \times 5$ lines $= 56\ m^2$

$56\ m^2 \times 86 = 4816\ m^2 \fallingdotseq 4850\ m^2$

Amount of water: $4850\ m^2 \times 0.005\ m = 24.25 m^3 \fallingdotseq 24.5$ ton

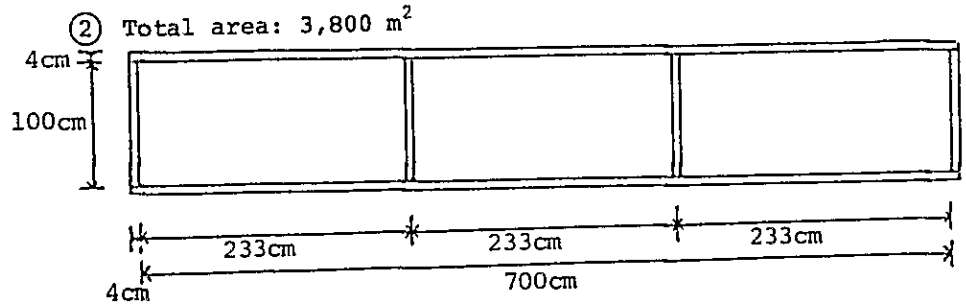
Area of reservoir: The pond that can store water required for one day.

$5\ m \times 5\ m \times 1\ m = 25\ m^3$

Table 4-4 Construction Cost of Nursery Bed

Classification	Method	Performance	Amount	Cost	Remarks
Timber arrangement	Logs(Diameter:4 cm) locally collecting	person 0.1 /10m^2	persons 38	B$ 1,140	B$30/day
Wire for net		5kg/10m^2	1,900kg	4,370	B$2.3/kg
Flame wood working and netting		person 0.1 /10m^2	persons 38	1,140	B$30/day
Vinyl sheets	thickness 0.5mm Width 100cm		380	7,600	B$20/10m^2
Earth break & frame setting		0.1person /day	persons 38	1,140	B$30/day
Others		1.5persons /1,000m^2	persons 6	150	B$25/day
Total				15,540	

Note: ① Annual installation plan: 1 year 1,000 m^2 B$4,090
: 5 years 1,700 m^2 B$6,952
: 9 years 1,100 m^2 B$4,497



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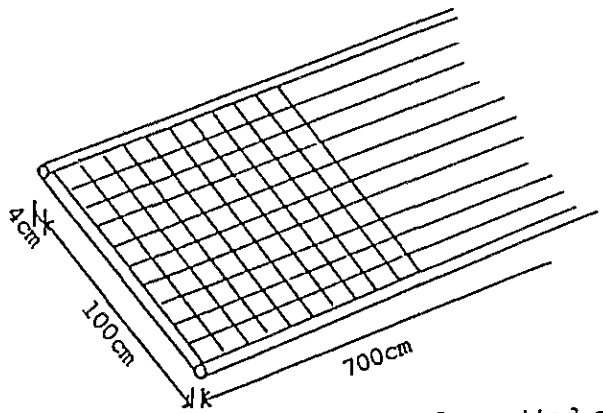

Fig. 4-3 Illustration of Nursery Bed (place for potted seedlings)

Table 4-5 Construction Cost of Shade Facilities

Classification	Method	Performance	Amount	Cost B$	Remarks
Poles and Flames	Logs (Diameter:4 cm) Locally collecting	0.1 person/ 10 m^2	Persons 38	1,140	B$30/day
Lawn cloth	Width 135 cm. 10 m	240 days/m	Persons 380	760	B$2.3/kg
Wire		0.5 kg/10 m^2	190 kg	437	B$30/day
Nail		0.1 kg/10 m^2	38 kg	61	B$20/10 m^2
Construction work		0.1 person/ 10 m^2	Persons 38	1,140	B$30/day
Others		1.5 persons/ 1,000 m^2	Persons 6	150	B$25/day
Total				3,688	

Note: ① Annual installation plan: 1 year 1,000 m^2 B$971
: 5 years 1,700 m^2 B$1,651
: 9 years 1,100m^2 B$1,067

② Are: 3,800 m

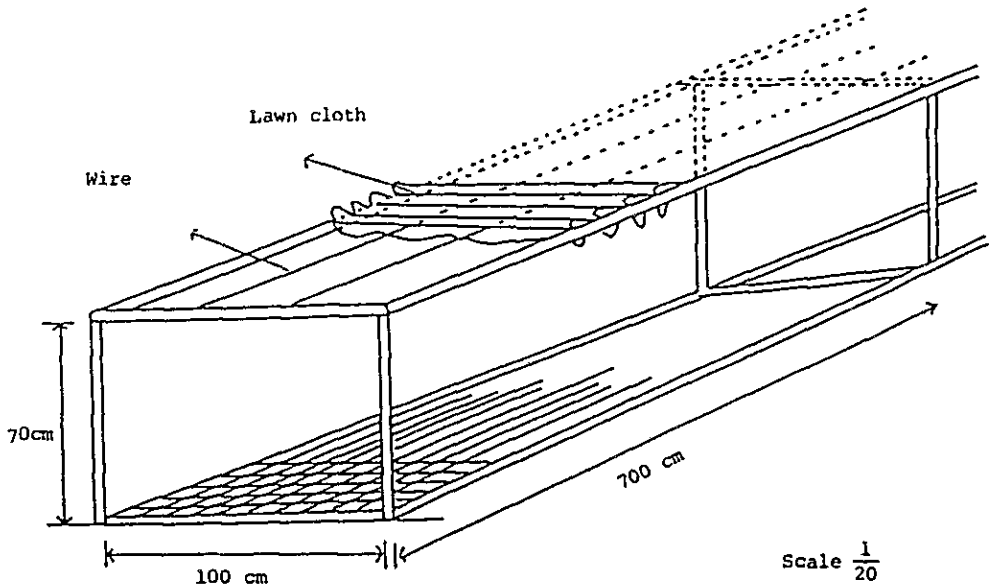

Fig. 4-4 Illustration of Shade Facilities

b) Specifications of a jet pump

* Height required : 10 m (from the river water level to the highest point of the reservoir)
* Distance of water conveyance : 20 m (to the reservoir)
* Water storage capacity of the reservoir: 24.5 ton
* Jet pumping capacity : 24.5 ton in two hours or

  24.5 ton ÷ 2h = 12.25/h = 0.2 m^3/min
* Intensity of jet pumping up: Distance 20 m

  Friction loss (with 2-1/2 in pipe)

  : SpG 5.7 m/100 m

  $20\ m \times \frac{5.7\ m}{100\ m} \times 120\% = 1.368\ m \fallingdotseq 1.4\ m$

  10 m + 1.4 m = 11.4 m ≒ 12 m
* Specification : 0.3 m^3/min × 12 m

c) Specifications of a pressure pump

* Specifications of a sprinkler

  Sprinkling diameter 16.8 m

  Sprinkling capacity 6.4ℓ/min
* Total capacity 6.4ℓ/min × 6 pieces × 4 units ≒ 154ℓ/min ≒ 0.15 m^3/min
* Length and friction loss of main pipe

  Pipe: 2-1/2 inch Length: 100 m

  Friction loss 2.6 m/100 m × 100 m = 2.6 m
* Length and friction loss of branch pipe

  Pipe: 1-1/2 inch Length: 100 m

  Friction loss 6 m/100 m × 100 m = 6 m
* Flow out pressure of pump

  Water pressure required 2 kg/cm^2

  20 m (2 kg/cm^2) + 2.6 m + 6 m = 28.6 ≒ 29 m
* Specification of pressure pump

  0.15 m^3/min × 29 m

Table 4-6 shows the cost of the watering facilities.

Table 4-6 Construction Cost of Watering Facilities

Classification	Specification	Amount	Cost B$	Remarks
Jet pump	0.3 m^3/min × 24 m	1	1,250	
Pressure pump	0.21m^3/min × 37 m	1	1,650	
Water reservoir	5 m × 5 m × 1 m	1	1,667	
Pump house	Wooden house 4 m^2	4 m^2	1,540	B$385/$m^2$
Main pipe	Vinyl chloride pipe 2-1/2	100 m	125	B$1.25/m
Pipe setting		100 m	830	B$8.3/m
Electricity work	Poles 25, B$1,000	1,600 m	16,000	B$1,000/100 m
Total (Foundation work)			23,062	
Branch pipe	Vinyl chloride pipe 1-1/2	100 m	970	B$0.97/m
Sprinkler	20φ27°	16	733	
Hose	Polyethylene pipe 1/2	50 m	207	B$4.15/m
Pipe setting		100 m	830	B$8.3/m
Other construction	20% of total construction costs		5,150	
Total			7,890	
Grand total			30,952	

Note:

1. Annual construction plan:
   - 1 year Foundamental work and watering area 1,200 m^2 B$25,000
   - 5 years Enlargement of watering area 2,200 m^2 B$3,567
   - 9 years Enlargement of watering area 1,450 m^2 B$2,385

2. Area: 4,850 m^2

(3) Buildings

1) Nursery office: Area 60 m^2

The nursery office is a wooden one-story building with a raised floor on a simple foundation. Office equipment supplies and furniture should be provided. This should also function as a reforestation office.

2) Storehouse: Area 50 m^2

The storehouse is a simple wooden one-story building with enough space to keep materials for the nursery and the reforestation operations.

3) Garage: Area 100 m^2

The garage is a simple wooden one-story building for all the vehicles, i.e. a truck, a passenger and freight car, and a 4WD.

4) Resting room: Area 50 m^2

The resting room is a wooden one-story house with a raised floor on a simple foundation. The lower half is surrounded with a wooden wall for good ventilation provided with simple but necessary facilities for workers to rest.

5) Workshop: Area 100 m^2

The workshop is a very simple wooden one-story building and is used to store material soil for potting seedlings, and for such operations as filling pots with soil, transplanting and sowing.

Germination of small seeds, sowing of germination boxies, and take care of young seedlings before transplanting to pots are also performed have.

6) Soil burning house: Area 25 m^2

The house for burning soil material is a very simple wooden one-story building. A furnace is also simple, of iron plate and using wood fuel.

7) Storage of burned soil: Area 25 m^2

The storage of burned soil is a wooden one-story house with earth floor, since burned soil material is stored here.

The house has a simple wooden wall to keep the rain out.

(4) Vehicles

The following vehicles are provided for efficient nursery work, for adequate management and to supply sound seedlings.

Truck	2 ton	1
Passenger & freight car	2 ton	1
4WD	2 ton	1

Depreciation period : five years

Table 4-7 indicates the cost of the facilities mentioned under (3) and (4). Fig. 4-5 is an illustration of the buildings (ground floor).

4-2-3 Schedule for Nursery Construction

Since the nursery must provide seedlings for reforestation, the nursery construction must be started well ahead of other operations.

Planting is scheduled to start the year following the nursery construction is started.

The schedule for nursery construction is shown in Table 4-8.

4-2-4 Cost of Nursery Construction

Nursery construction should proceed according to Table 4-8.

Table 4-9 indicates the cost estimates.

Table 4-7 Cost of Construction Building and Vehicles

Unit: B$

Facility	Amount	Unit Cost	Cost	Remarks
(Buildings)		B$	B$	
Office	60 m^2	963.75	57,825	Simple foundation, wooden one storey
Storehouse	50 m^2	405.42	20,271	Simple foundation, wooden one storey
Garage	100 m^2	320.00	32,000	Simple wooden one storey
Resting house	50 m^2	473.83	23,642	Simple foundation, wooden one storey
Workshop	100 m^2	244.17	24,417	Simple wooden one storey
Soil burning place	25 m^2	218.33	5,458	Simple wooden one storey
Storage of burned soil	25 m^2	218.33	5,458	Simple woode one storey
Total	7		169,072	
(Vehicles)				
Truck	2 units	22,000	44,000	2 ton
Passenger & freight car	2 units	24,300	48,600	2 ton B$2,916
4WD	2 units	22,000	44,000	
Total			136,600	
Grand total			305,672	

Note: 1. Annual procurement plan:
1 year 4WD 1 unit, passenger/freight car
2 years truck 1 unit
6 years 4wd 1 unit, passenger/freight car
7 years truck 1 unit

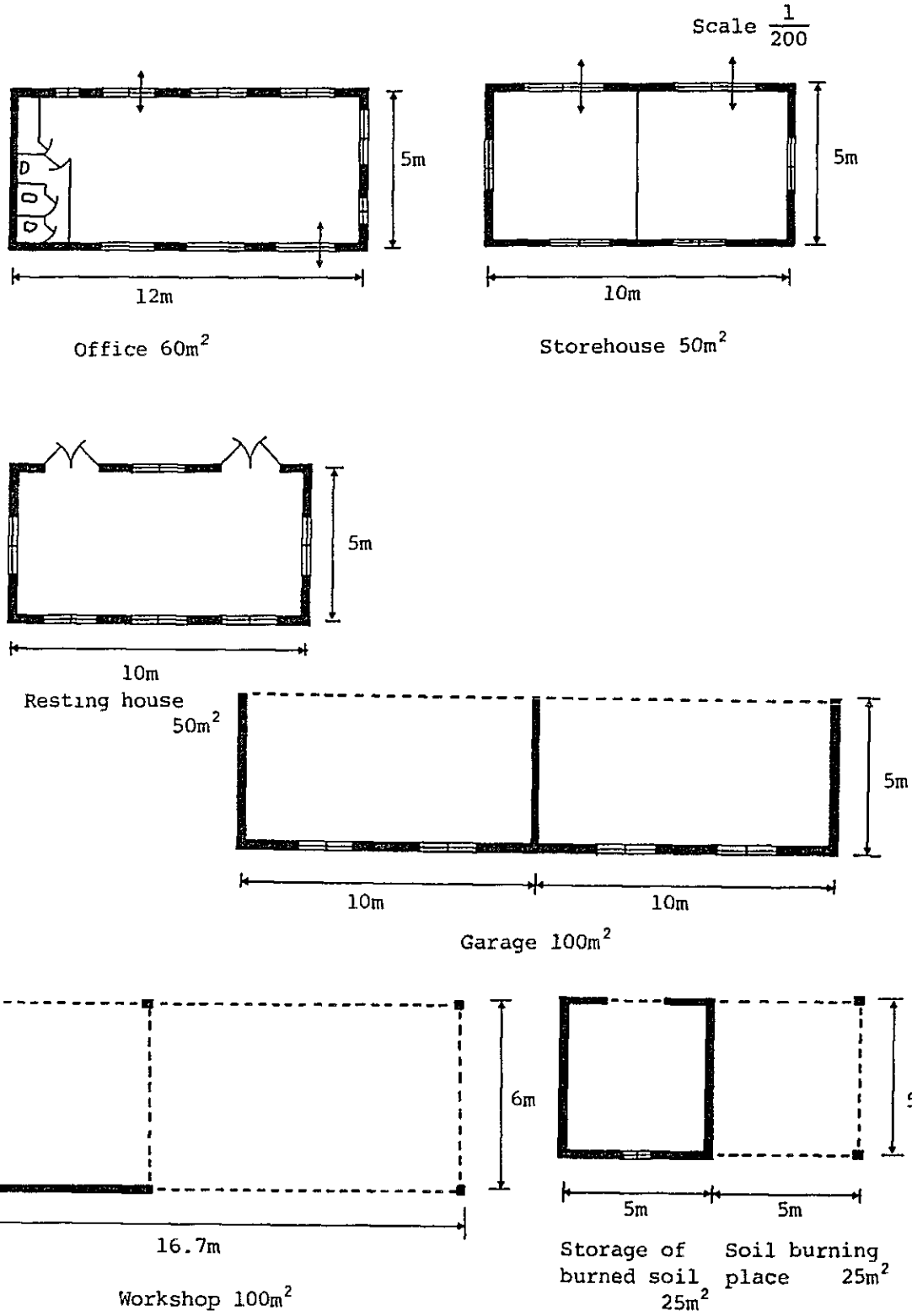

Fig. 4-5 Illustration of buildings (ground floor)

Table 4-8 Schedule of Nursery Constructions

Items \ Month	1	2	3	4	5	6	7	8	9	10	11	12
Application of land lease	→											
Permission of land lease		→	→									
Clearing of standing trees				→								
Stump removal and ground breaking				→								
Construction of access road				→								
Ground survey				→								
Earth preparation of nursing lot				→	→							
Construction of facilities for nursery practice					→	- - →	- - →	- - →				
Construction of watering facilities					→	→	- - →	- - →				
Construction of workshop					→	→						
Construction of office					→	→	→					
Construction of garage & Storehouse					→	→	→	→				
Construction of resting house					→	→	→	→				
Starting of nursery operation							→	→	→	→	→	→

Table 4-9 Construction Cost of Nursery

Unit: B$

Facilities	Items	Amount	Unit cost	Cost
Earth preparation	Levelling	10,700 m^2	1,000 m^2 63.83	683
	Passage	420 m	1 m 1.33	560
	Lease, others			3,624
Total				4,866
Facilities for nursery operation	Seedling bed	3,800 m^2	1,000 m^2 4,089.47	15,540
	Shade	3,800	1,000 m^2 978.42	3,718
	Watering facilities	(4,850) 3,800	1,010 m^2 8,145.26	30,952
Total				50,210
Building	Office	60 m^2	963.75	57,825
	Storehouse	50 m^2	405.42	20,271
	Garage	100 m^2	320.00	32,000
	Resting house	50 m^2	472.84	23,642
	Workshop	100 m^2	244.17	24,417
	Soil burning place	25 m^2	218.32	5,458
	Storage of burned soil	25 m^2	218.32	5,458
Total				169,071
Vehicles	Truck	2 units	22,000	44,000
	Passengers & freight car	2 units	24,300	48,600
	4WD	2 units	22,000	44,000
Total				136,600
Grand total				360,747

4-3 Plan for Nursery Operations

4-3-1 System of Nursery Operations

The forest tree species to be used in the reforestation project are as follows:

Pinus caribaea
Albizia falcata
Acacia auriculiformis
Acacia mangium
Maesopsis eminii
Araucaria hunstni
Araucaria cunninghamii
Cratoxylom lingustrinum (Geronggan)
Anthocephalus cadamba (Kalampayan)
Campnosperma auriculata
Octomeles smatrana
Agathis alba
Swietenia macrophylla

Seedlings of these species are grown in pots for the time being. Other raising methods may be tried in future.

Large seeds are sown directly in pots, but small ones are germinated in sowing boxes and then transplanted to pots.

Fig. 4-6 illustrates this process.

4-3-2 Process of Nursery Operations

(1) Procurement of Seeds

Fresh and vigorous seeds collected with a good timing must be chosen.

Advance arrangements for procurement of these seeds are necessary as there is no agent or dealer in Brunei.

Seeds of the indigenous species are collected by the project or by a subcontractor recommended by the Forest Department of Brunei.

Seeds of exotic species must be procured with the assistance of the Forest Department, or through the government agencies or dealers in the countries of origin.

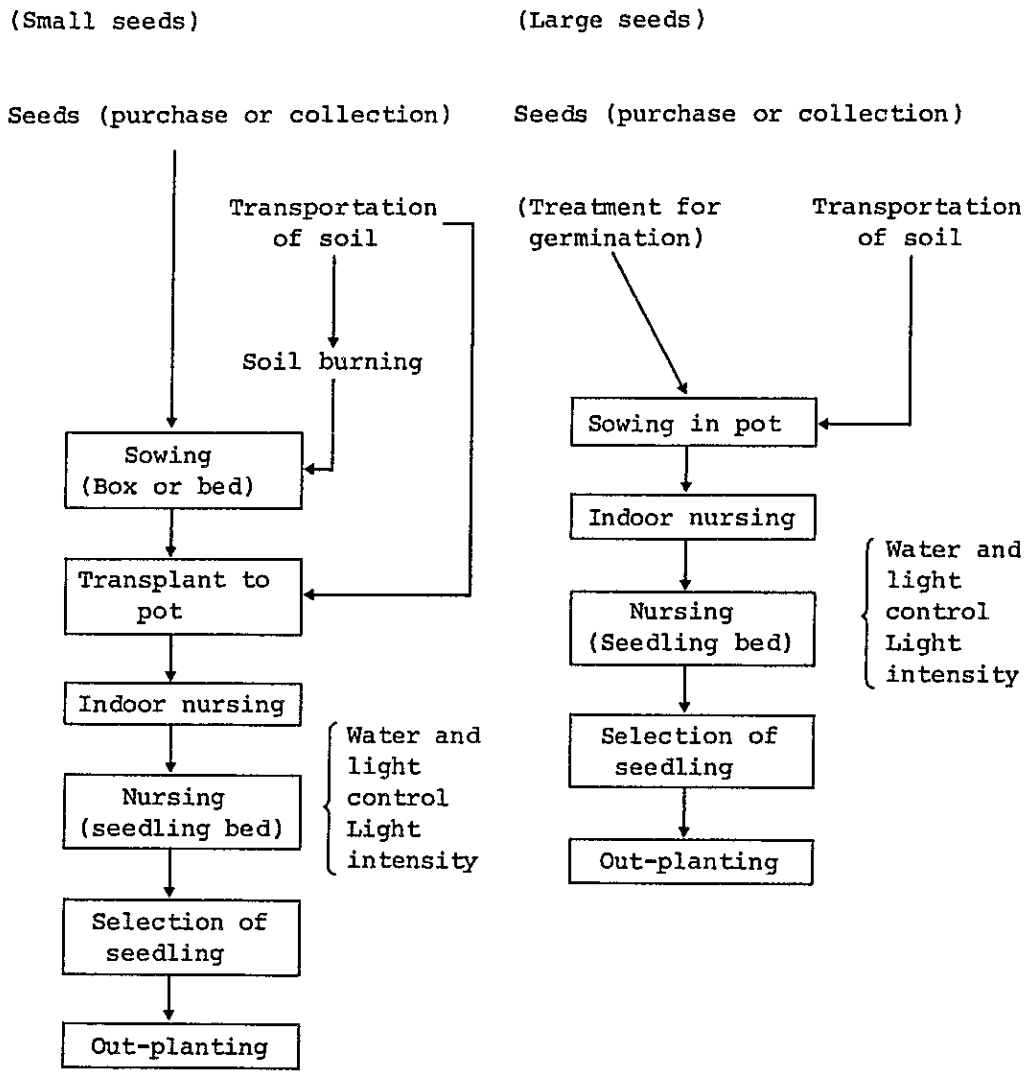

Fig. 4-6 Process of Nursery Operation

(2) Collection, Transportation and Storage of Material Soil

Material soil for potting can be collected easily in the forest around the nursery site and in the fertile sediment of the Lumut River.

It is collected and transported as and when needed.

Transported soil is stored indoors after natural drying and sieving.

The soil for sowing is stored in the yard after burning.

(3) Treatment for Germination

Seeds with hard coats are sown after treatment for germination. The following methods of treatment are employed.

a) Breaking with knife or scissors.
b) Soaking in boiled water (80°C∿100°C) for 3∿8 minutes.
c) Soaking in a solution of sulfuric acid for 5∿10 minutes.
d) Treating in a tumbler coated with carborundum.

(4) Sowing

Small seeds are sown in boxes and covered with the burnt soil.

The burnt surface soil of the boxes should be about 1 cm. After sowing, the boxes are kept indoors until transplanting into pots. Large seeds are sown in pots directly, one or two per pot.

(5) Soil Potting and Transplanting

Such soils as fine sand, micro-fine sand, loam, clay and peat are naturally dried and sieved. They are mixed and put in pots, patting a couple of times so as to slightly compact the soil.

After sufficiently watering, the germinated and sprouting seedlings in sowing boxes are transplanted to pots, after making a hole with a stick or pencil.

(6) Indoor Nursing of Potted Seedlings

Transplanted seedlings and directly sown seedlings into pots are kept in a corner of the workshop for 10∿15 days.

Watering is needed 3∿5 mm once per day, depending on the dryness of the condition of the soil.

(7) Outdoor Mursing of Potted Seedlings

After indoor nursing, potted seedlings are moved to the nursery bed. Light intensity control is provided using shade for about two weeks or for 1∿2 months in the case of slow growing seedlings.

During this time, watering is needed about 5∿10 mm per day.

Afterwards, then removed seedlings grow under full light, but with watering of about 5∿10 mm per day.

(8) Outplanting

After these processes, seedlings will reach 30 cm in height and will be outplanted.

It is important to select healthy seedlings with no insect damage.

(9) Standard Efficiency of Nursery Operations

Healthy and low-cost seedlings can be produced only if management of nursery operations is successful.

This depends on workers' skill as well as proper managerial capacity.

Thus, the standard efficiency of nursery operations as shown in Table 4-10 is indicated on the basis of the social and labour conditions found by the field survey.

4-3-3 Cost of Nursery Operations

(1) Labour Cost

Table 4-11 shows the number of workers required for the nursery work. This estimate is made according to the standard efficiency of nursery operations as planned in the annual seedling production.

(2) Cost of Materials

The cost of seeds, plastic pots, fertilizer and other materials was estimated. However, the cost of nursery facilities is not included in the cost of materials.

Table 4-12 shows both costs of labour and materials.

Table 4-10 Standard Efficiency of Nursery Operation

Unit: 1,000 seedling

Work	Details	Efficiency		Remarks
		Small seed (Sawing in box, replant to pot)	Large seed (Direct sowing in box)	
Soil collecting	Soil collection, transportation	Persons 0.14	Persons 0.14	Soil 0.7 m^3, Mechanical force 0.2person/m^3 B$30/day 1B$ = ¥120
Soil burning	Collection of fuel (wood), soil burning, storing	1.80		Soil burning 0.1 m^3 18.0 persons/m^3 B$30/day 1B$ = ¥120
Sowing and maintenance	Preparation of sowing bed an box, sowing, watering, etc.	0.17		B$25/day ,1B$ = ¥120
Soil potting	Fill up soil in pot	1.33	1.33	750/day B$25/day 1B$ = ¥120
Replanting to pot	Replant seedlings from sowing box to pots	2.50		400/day B$25/day 1B$ = ¥120
Direct sowing and maintenance	Direct sowing in pot and watering, maintenance		1.25	800/day B$30/day 1B$ = ¥120
Replacing of pots	Replace seedlings from indoor to seedling bed	1.00	1.00	1,000/day B$30/day 1B$ = ¥120
Watering, weeding, etc.	Watering for seedlings weeding in nursing lot	0.20	0.20	5,000/day B$30/day 1B$ = ¥120
Total		7.14	3.92	

(3) Cost of Management and Supervision

Seedling production must be carried out systematically under the proper organization which is the basis of producing sound seedlings. The technicians in charge of the nursery operations supervise the operation of the nursery under the direction of the manager.

The salary of the field manager and the permanent workers was estimated as shown in Table 4-13.

Table 4-14 indicates the total cost of the nursery.

Table 4-11 Required Number of workers for Nursery Operations

Unit: Person/day

Work \ Year	1	2	3	4	5	Subtotal	6	7	8	9	10	Subtotal	Total
Soil collecting	1.0	3.2	6.1	8.4	15.7	34.4	23.9	30.6	37.4	44.1	20.2	156.2	190.6
Soil burning	2.3	7.6	14.8	19.4	9.7	53.8	23 9	30.0	35.8	41.9	41.9	173.5	227.3
Sowing and maintenance	0.2	0.7	1.4	1.8	0.9	5.0	2.3	2.8	3.4	4.0	4.0	16.5	21.5
Soil potting	9.8	30 9	58.1	80 2	149.2	328 2	227 2	291.0	354.8	418.6	192.1	1,483.7	1,811.9
Replanting to pot	3.3	10.5	20.5	27.0	13.5	74.8	33.3	41.5	49.8	58.3	58.3	241.2	316.0
Direct sowing and maintenance	7.6	23 8	44.4	61.9	133.5	271.2	197.0	252.8	308.6	364.3	151.4	1,274.1	1,545.3
Replacing of pots	7.4	23.2	43.7	60 3	112 2	246.8	170 8	218.8	266.8	314.7	144.4	1,115.5	1,362.3
Watering, weeding, etc.	1.5	4.6	8.7	12.1	22 4	49.3	34.2	43.8	53 4	63.0	28 9	223.3	272.6
Total	33.1	104.5	197.7	271.1	457.1	1,063.5	712.6	911.3	1,110.0	1,308.9	641.2	4,684 0	5,747.5

Table 4-12 Cost of Labour and Materials

Unit: B$

Work \ Year	1	2	3	4	5	Subtotal	6	7	8	9	10	Subtotal	Total
[Labour cost]													
Soil collecting	30	96	183	252	471	1,032	717	918	1,122	1,323	606	4,686	5,718
Soil burning	69	228	444	582	291	1,614	717	900	1,074	1,257	1,257	5,205	6,819
Sowing and maintenance	5	18	35	45	22	125	58	70	85	100	100	413	538
Soil potting	245	773	1,452	2,005	3,730	8,205	5,680	7,275	8,870	10,465	4,803	37,093	45,298
Replanting to pot	83	262	512	675	338	1,870	833	1,037	1,245	1,458	1,457	6,030	7,900
Direct sowing and maintenance	228	714	1,332	1,857	4,005	8,136	5,910	7,584	9,258	10,929	4,542	38,223	46,359
Replacing of pots	222	696	1,311	1,809	3,366	7,404	5,124	6,564	8,004	9,441	4,332	33,465	40,869
Watering, weeding, etc.	45	138	261	363	672	1,479	1,026	1,314	1,602	1,890	867	6,699	8,178
Total	927	2,925	5,530	7,588	12,895	29,865	20,065	25,662	31,260	36,863	17,964	131,814	161,679
[Cost of materials]													
Vinyl pots	258	808	1,533	2,108	3,934	8,641	5,975	7,658	9,342	11,017	5,050	39,042	47,683
Fertilizer	25	83	150	208	391	857	600	766	933	1,100	508	3,907	4,764
Material and seeds	35	100	185	250	465	1,035	705	910	1,105	1,310	600	4,630	5,665
Total	318	991	1,868	2,566	4,790	10,533	7,280	9,334	11,380	13,427	6,158	47,579	58,112

Table 4-13 Cost for Management and Supervision

Unit: B$

Classification \ Year	1	2	3	4	5	Subtotal	6	7	8	9	10	Subtotal	Total
Field Manager	14,000	14,000	14,000	14,000	14,000	70,000	14,000	14,000	14,000	14,000	14,000	70,000	140,000
Permanent workers							8,000	8,000	8,000	8,000	8,000	40,000	40,000
Total	14,000	14,000	14,000	14,000	14,000	70,000	22,000	22,000	22,000	22,000	22,000	110,000	180,000
Miscellaneous	1,400	1,400	1,400	1,400	1,400	7,000	2,200	2,200	2,200	2,200	2,200	11,000	18,000
Total													
Grand total	15,400	15,400	15,400	15,400	15,400	77,000	24,200	24,200	24,200	24,200	24,200	121,000	198,000

Table 4-14 Total Cost of Nursery Operation

Unit: B$

Items	Sub-items	1 year	2 year	3 year	4 year	5 year	Subtotal	6 year	7 year	8 year	9 year	10 year	Subtotal	Total
Production cost	Labour cost	927	2,925	5,530	7,588	12,895	29,865	20,065	25,662	31,260	36,863	17,964	131,814	161,679
	Cost of materials	318	991	1,868	2,566	4,790	10,533	7,280	9,334	11,380	13,427	6,158	47,579	58,112
	Total	1,245	3,916	7,398	10,154	17,685	40,398	27,345	34,996	42,640	50,290	24,122	179,393	219,791
Overhead cost	Management cost	14,000	14,000	14,000	14,000	14,000	70,000	22,000	22,000	22,000	22,000	22,000	110,000	180,000
	Miscellaneous	1,400	1,400	1,400	1,400	1,400	7,000	2,200	2,200	2,200	2,200	2,200	11,000	18,000
	Total	15,400	15,400	15,400	15,400	15,400	77,000	24,200	24,200	24,200	24,200	24,200	121,000	198,000
Miscellaneous	Sundry expenses	250	785	1,480	2,035	3,535	8,085	5,465	6,995	8,515	10,050	4,842	35,867	43,952
	Total													
Grand total		16,895	20,101	24,278	27,589	36,620	125,483	57,010	66,191	75,355	84,540	53,164	336,260	461,743

4-4 Nursery Trials

4-4-1 Types of Trials

(1) Species and Provenance Trials

Growth and survival rate vary according to the provenance of species and seeds. This is also true in the nursery. Therefore, in both nursery and planted lots, species and provenance trials are to be conducted. Thus, species and provenance of seeds suitable for the region can be identified.

These are as follows:

Species	Provenance
Pinus caribaea	Honduras, Fiji, Malaysia
Acacia mangium	Australia, Sabah, Indonesia
Araucaria cunnighamii	Papua New Guinea, Australia, Brasil
Maeosopsis eminii	Cameroon, Liberia, Nigeria
Albizia falcata	Productions of seedling after the checking of provenance
Acacia auriculiformis	
Cratoxylon lingustrinum	
Anthocephalus cadamba	
Octomeles smatrana	
Campnosperma auriculata	
Agathis alba	
Swietenia macrophylla	

(2) Watering and Shade Intensity Trials

Watering and shade intensity trials are conducted for the purpose of growing vigorous seedlings.

The resulting data will help to decide watering and shade intensity.

Classification	Watering	Shade intensity	Remarks
Much watering	Twice a day	Weak shade, 20%	Watering:5mm each time
Little watering	Twice a day	Strong shade, 30%	Watering:3mm each time
Occasional watering	On occasion	Strong shade, 30%	

(3) Fertilization Trial

The following trial is conducted in order to investigate the effect of fertilizers:

a) Species:

Pinus caribaea

Acacia mangium

Araucaria hunstenii

Araucaria cannighamii

Maeosopsis eminii

Albizia falcata and other 7 species

b) Trial conditions:

No fertilizer

N.P.K.mixed fertilizer

N.P.K.mixed pellet fertilizer

N sole fertilizer

N sole pellet fertilizer

(Undetermined)

c) Note:

No fertilizing: seasoned, dried and siened soil.

N.P.K.soil and fertilizer mixed and N soil and fertilizer mixed.

N.P.K.mixed pellet fertilizer and N sole pellet fertilizer: use pellet type.

Time: In case of the mixed fertilizer, at the time of soil potting.

: In case of pellets, after germination and transplanting to pots.

(4) Trials for Potting Material

Fertile soil that lets in water and air well and allows easy extraction of seedlings from pots at the time of planting should be used for planting.

The following trials are conducted in order to investigate the kinds of soil for potting, mixing ratio, the growing effect of seedlings and so on.

a) Species:

Pinus caribaea

Acacia mangium

Araucaria hunstenii

Araucaria cannighamii

Maeosopsis eminii

Albizia falcata and 7 other species

b) Classification of soil:

(i) Sand soil + peat moss + clay

(ii) Sandy loam + clay

(iii) Natural forest soil

c) Note:

Mixing rate of (i) class is 3:3:1.

Mixing rate of (ii) class is 3:1.

(iii) class is fertile sandy loam,

Sand soil: Kerangas

Peat moss: Peat moss piled up on swamp or kerangas

Clay: Deep soil in forest

Sandy loam
Natural forest soil } : Top soil in forest or sedimented soil.

(5) Others

The following trials or tests of the above species will be desirable:

a) Seed storage test

b) Number of seeds per weight

c) Germination test

d) Propagation test of mycorrhiza

e) Production rate of outplanted seedling

f) Cutting propagation test

4-4-2 Design of Tests/Trials

The annual programme of the above tests and/or trials have been designed as shown in Table 4-15.

4-4-3 Methods of Tests/Trials

The following procedures are to be followed during the tests and/or trials:

a) Seedlings are measured by provenance of seeds and species.
b) Each item of the test/trials is recorded.
c) The seedlings are measured and placed inside the nursery bed to avoid the influence of the paths and headges.
d) The seedlings are measured before being outplanted.
e) The length and weight of seedlings are measured.
f) Three plots for each item are measured. (one plot should have 30∿50 seedlings)
g) The process of nursery operation is recorded.

All these data are recorded, compiled, analysed and used for the establishment of a system of nursery operations and improvement of techniques.

Table 4-15 Annual Programme of Nursery Test

Unit: 1,000 seedlings

Year	Species	Items of test	Sub-items	Remarks	Number of seedling raised	Recovery rate	Number of outplanted seedling	Remarks
1	P. caribaea	Species, provenance	Provenance of seed	Nursing by each provenance	1.1	80 %	0.9	
	Ac. mangium	"	"	"	1.1	"	0.9	P : Pinus
	M. eminii	"	"	"	0.9	"	0.7	Ac : Acacia
	Ar. hunstenii	"	"	"	0.9	"	0.7	Ar : Araucaia
	Ar. cunninghamii	"	"	"	0.9	"	0.7	M : Maeosopsis
	A. falcata Other 5 species	"	"	"	2.5	"	2.0	
	Total				7.4		5.9	
2	P. caribaea	Species, provenance	Provenance of seed	Nursing by each provenance	3.0	80	2.4	A · Albizia 7 species
	Ac. mangium	"	"	"	3.0	"	2.4	Acacia auriculiformis
	M. eminii	"	"	"	2.3	"	1.8	Cratoxylon lingustrinum
	Ar. hunstenii	"	"	"	2 4	"	1.9	Anthocephalus cadamba
	Ar. cunninghamii	"	"	"	2.3	"	1.8	Octomeles smatrana
	A. falcata Other 7 species	"	"	"	10 2	"	8.1	Campnosperma auriculata Agathis alba
	Total				23.2		18.4	Swietenia macrophylla
3	P. caribaea	Watering and shading intensity	Watering much	Watering once 5 mm Shading intensity 20%	2 0	80 %	1 6	Watering twice a day Shading week
			Watering little	Watering once 3 mm Shading intensity 30%	2 0	"	1.6	Watering twice a day Shading strong
			Watering on occasion	Watering on occasion Shading intensity 30%	1.8	"	1 4	Watering on occasion Shading strong

(Continued)

Unit: 1,000 seedlings

Year	Species	Items of test	Sub-items	Remarks	Number of seedling raised	Recovery rate	Number of outplanted seedling	Remarks
3	Ac. mangium	Watering and shading intensity	Watering on occasion	Watering on occasion Shading intensity 30%	5.8	% 8.0	4.6	Watering on occasion Shading strong
	M. eminii	Same as above	Same as above	Same as above	5.3	"	4.2	Same as above
	Ar. hunstenii	"	"	"	5.3	"	4.2	"
	Ar. cunninghamii	"	"	"	5.0	"	4.0	"
	A. falcata Other 5 species	"	"	"	16.5	"	13.2	"
	Total				43.7		34.8	
4	P. caribaea	Fertilizing	No fertilizing		1.8	80	1.4	
			N.P.K. mixed	3 g per one pot	1.5	"	1.2	
			N.P.K. mixed pellet	"	1.5	"	1.2	
			N. sole	"	1.5	"	1.2	
			N. sole pellet	"	1.5	"	1.2	
	Ac. mangium	"	Same as above	Same as above	7.9	"	6.3	
	M. eminii	"	"	"	7.8	"	6.2	
	Ar. hunstenii	"	"	"	7.9	"	6.3	
	Ar. canninghamii	"	"	"	7.3	"	5.8	
	A. falcata Other 5 species	"	"	"	21.6	"	17.2	
	Total				60.3		48.0	
5	P. caribaea	Material soil	Sand + peat + clay		7.0	80	5.6	
			Sandy loam + clay		7.0	"	5.6	
			Natural forest soil		7.2	"	5.7	
	Ac. mangium	"	Same as above		21.1	"	16.9	
	M. eminii	"	"		21.2	"	16.9	
	Ar. hunstenii	"	"		14.2	"	11.4	
	Ar. canninghamii	"	"		3.7	"	3.0	

(Continued)

Unit 1,000 seedlings

Year	Species	Items of test	Sub-items	Remarks	Number of seedling raised	Recovery rate	Number of outplanted seedling	Remarks
5	A. falcata Other 7 species	Material soil	Sand + peat + day Sandy loam + clay Natural forest soil		30.8	80 %	24.6	
	Total	〃			112.2		89.7	
	1st phase total				246.8		196.8	
6	P. caribaea	Retest if necessary			41.2		33 0	Ag: Agathis S: Swietenia
	Ac. mangium				41.2		33.0	
	M. eminii				41.2	80	32.9	
	Ar. hunstnii				20.6	〃	16 4	
	Ag. alba				26 6	〃	21.3	
	S. macrophylla							
	Total				170.8		136.6	
7	4 species as in 6th year	Retest if necessary			185 6	80	148 5	5 species P caribaea Ac mangium Ar. hunstnii Ar. cunnighamii M eminii 2 species Ag. alba S. macrophylla
	2 species as in 6th year	〃			33.2	80	26.5	
	Total				218.8		175.0	
8	4 species as in 6th year	Retest if necessary			227.0	80	181 6	
	2 pecies as in 6th year	〃			39 8	80	31.8	
	Total				266 8		213 4	
9	4 species as in 6th year	Retest if necessary			268.1	80	214.4	
	25 species as in 6th year	〃			46.6	80	37.2	
					314 7		251.6	

(Continued)

Unit: 1,000 seedlings

Year	Species	Items of test	Sub-items	Remarks	Number of seedling raised	Recovery rate	Number of outplanted seedling	Remarks
10	4 species as in 6th year	Retest if necessary			144.4	80 %	115.5	
	2 species as in 6th year	"			-	-		
	Total				144.4		115.5	
	2nd phase total				1,115.5		892.1*	*:
Grand total					1,362.3		1,088.9	

4-5 Seed Management · Seed Source

4-5-1 Seed Management

(1) Provenance of Seed and Quality of Mother Trees

In reforestation, it is important to grow trees of good genetic characteristics.

Provenance of seeds and mother tree are closely related to the genetic type of trees, and it is important to know the difference natural conditions between proposed reforestation area and provenance. For example, in the tropics, caribbean pine can be introduced in latitudes south of that of the provenance (Central America) with good results. But fox tail and sterility occur at latitudes too far south probably because conditions are too different.

In this connection, a study was made of a young caribbean pine of a stand 12 years old in Sungai Liang. The phenomenon of fox tail was common in the young stand. Although their provenance was unknown, this did not seem to be caused by different conditions, but most probably by different provenances. Past experiences would add to a foresters' conviction that success of reforestation is closely related to the provenance of seeds and quality of mother trees.

Therefore, it is unreliable to use seeds whose provenance and mother trees are unknown, even if they are fresh. Provenance and quality of mother trees must be identified at all times.

(2) Storage of Seeds

A success of seed collection depends highly on whether a harvest is rich or poor.

Generally speaking, many seeds with a high germination rate can be easily collected in a rich harvest year. The reverse is true in a poor harvest year. Harvest of seeds and cycle are different according to species. Seeds must be smoothly supplied to carry out the reforestation project without interruption. It is therefore necessary to store seeds collected in a rich harvest year to guard against a poor harvest year.

Temperature and humidity of storage should be carefully controlled.

Table 4-16 shows the storage conditions of seeds.

Table 4-16 Conditions of Seed Storage

Species	Process
Pinus caribaea	Cold, dry, sealed
Acacia mangium	Dry, sealed (can cold storage)
Albizia falcata	Dry, sealed (can cold storage)
Maesopsis eminii	Dry, dark, cool, ventilated
Acacia auriculiformis	Dry, sealed (can cold storage)
Araucaria hunstenii	Dry, sealed
Araucaria cunninghamii	Dry, sealed
Cratoxylon lingustrinum	Dry, sealed
Anthocephalus cadamba	Dry, sealed
Octomeles sumatrana	Dry, sealed
Campnosperm auriculata	Dry, sealed
Agathis alba	Dry, sealed
Swietenia macrophylla	Dry, sealed

4-5-2 Seed Source

During reforestation, the following case might arise. Even though sound seedlings were planted carefully and both their survival and maintenance were good, their growth slowed several years after planting. In such a case, if provenance and mother tree had been identified, it should have been discovered that they were unsuitable in the first place.

Such cases happen when provenance and mother tree were not confirmed at the time of procurement of seeds and/or seedlings.

(1) Importance of Provenance (Clone) and Mother Tree

If a certain species repeatedly regenerates and grows in a region or conditions (climate, soil, etc.) for many years, only adaptable types survive as a result of natural selection.

This means that the seeds of the species have a certain inherited quality according their provenance and clone.

An example in Japan could probably be quoted.

In Iwate Prefecture (the northern part of Japan), seeds of Pinus densiflora collected from 16 mother tree forests all over Japan, were planted in order to compare their growth. Looking at the growth of these trees after 31 years, except one or two cases, it became obvious that the farther the provenance from the trial stand the less the growth. The northern trees are 300 m^3 ∿ 350 m^3/ha in growing stock, but the southern ones are inferior (the worst, 150 m^3/ha). In addition, the farther away the provenance, the higher the rate of gall disease and dead trees.

In the case of exotic species in Brunei, for instance, there are three kinds of caribbean pine. The first is Pinus caribaea var. hondurensis (natural distribution in Honduras, Guatemala and Nicaragua. Grows naturally in low land up to 1000 m above sea level). The second is P. caribaea var bahamesis (grows naturally at an elevation of 0 ∿ 1200 m, from Bahamas and Caicos Is.). The third is P. caribaea var. caribaea (grows naturally at an elevation of 0∿280 m in Cuba and the Pine Islands). Among them, pine of Honduras has been planted widely, although it has the disadvantages already mentioned.

Eucalyptus deglupta is naturally distributed in the Philippines, Indonesia (Irian Jaya) and Papua New Guinea, and is being used widely in various parts of the tropics for reforestation. There is an excellent man-made forest of E. deglupta at Bulolo in the main island of Papua New Guinea. The seeds of the trees in this forest were collected from sound mother trees that were grown in the man-made forest in Keravat of New Britain island.

When an man-made forests are established with exotic species in a region located far from the place of origin, it is important to study the conditions and results of reforestation in the provenance.

(2) Preparation of seed source

When reforestation with exotic species has been successful, seeds must be collected from the established forest. It is unwise to continue importing, because, as mentioned before, unsuitable clones would have been eliminated and suitable ones surviving. Thus, the forest is established with clones having genes that are suitable for the location of the tree plantation.

It should be taken as a principle that seeds of the indigenous species should be collected from mother trees in the healthy natural forests and those of the exotic species from mother trees in vigorous forests.

For the time being, it is most important to reserve sound natural forests of indigenous species and to keep records of the provenance of the exotic species used in reforestation.

5. Road Plans

5-1 The Plan

The road system in this project consists of principal forest roads (including access road), branch forest roads, feeder roads and footpaths. It is important to design and construct these so that they can accomplish their functions to a full extent.

These roads are constructed not only for the convenience of the current planting operation, but also for the future convenience of forest management and production.

Principal forest roads are planned taking into account of the existing public roads to form a key framework in the proposed area. Most of branch forest roads diverging from the principal ones end without further connection, but they should be planned so as to lead to as many feeder roads as possible from their ends. Route and structure of feeder roads should be planned that they will be able to function as branch forest roads in future, especially at the time of thinning and final felling. They are designed also to allow passage of four-wheel-drive vehicles for forest management purposes.

Footpaths are important for intensive forest management, therefore they are planned so that even small ridges can be fraversed on foot. Ideally, four-wheel-drive vehicles may use main footpaths.

Cost and benefit in road construction should be carefully considered Grades, total distance and structure of the roads may have to be scaled down if the construction cost exceeds the expected benefits, because these roads are constructed only for the trial project.

In this project, a road plan has not been prepared for every proposed area, but only in the area of about 100 ha in Sungai Liang as a model. Further plans can be prepared, of course, as the reforestation activities are expanded.

5-2 Forest Road Network

Planning of the forest road network, particularly the selection of routes, has an effect not only on the construction and maintenance costs, but also on the future function of the whole road network. Therefore at the planning stage, the following points must be considered, after the actual conditions in the area have been correctly understood by aerial photographs and field surveys.

(1) The annual construction programme is prepared by each catchment area and a logging system employed there, and based on the future plan of road network envisaged in consideration of the present conditions of the existing road network.

(2) The road types and grades (principal forest roads, branch forest roads, feeder roads and footpaths) should be chosen considering systematically the life and efficiency of the roads.

(3) Three requisites for selecting routes are safety against erosion and for passing, efficiency and economy in construction and maintenance, although they differ according to the topography, geological conditions, weather conditions, etc. of each area. In order to fulfil these three requisites, the route should be chosen generally to pass on hill-sides to ridges or on ridges. At the time of construction of the roads, it is important to consider drainage, treatment of drained water, conservation of ecology, and soil conservation.

(4) The route of principal roads and branch forest roads should be circular as a general rule. But in case of branch forest roads, some of them have no further connection because of topographic conditions and to economize the cost, and usually end near the border of a catchment area.

(5) Continuous steep gradients should be avoided, but if unavoidable a cross ditch is used to slow down the water running in a side ditch and drain off surface water.

(6) The route is planned surrounding the plantation area as much as possible in order to function as a fire break.

5-3 Forest Road Structure

5-3-1 Standard of Forest Road

Table 5-1 shows the standards of the structure of forest roads except for those indicated in road cross sections (Ref. Fig. 5-1).

Table 5-1 Standard of Road Structure

Item \ Types	Principal	Branch	Feeder
Planned speed m/h	20	10	
Minimum radius of curvature m	30	20	10
Distance of view m	40	20	20
Controlled gradient %	7	10	12
Maximum gradient %	9	12	15
Thickness of road surface cm	30	20	10
Culvert	Corrugated pipe	Corrugated pipe	Corrugated pipe

5-3-2 Road Cross Sections

Road cross sections (Fig. 5-1) indicate width of forest roads, shape of side ditch and gradient of roadside.

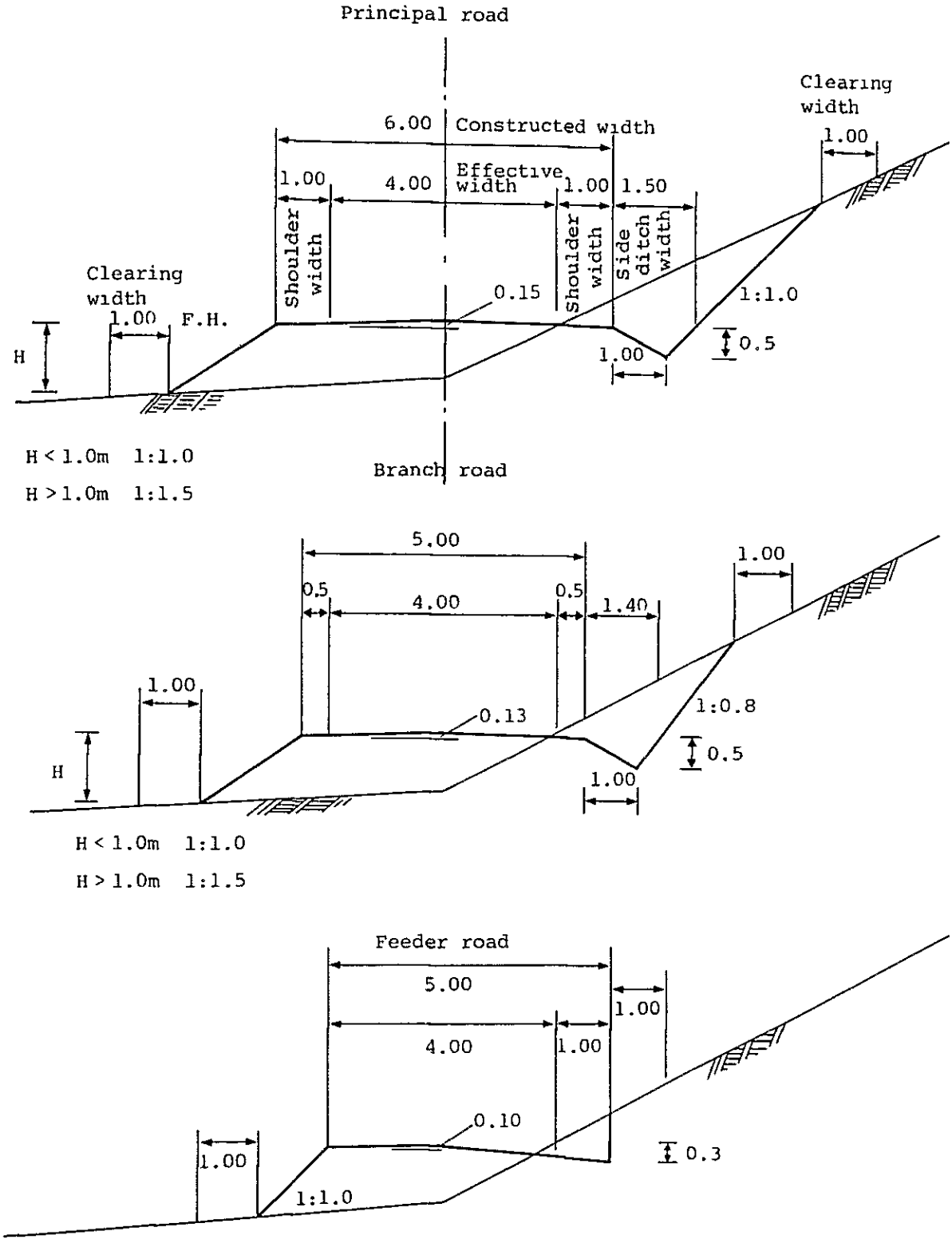

Fig. 5-1 Road Cross Sections

(1) The width of the road should be wider when turning with a small radius of curvature.

(2) Surface slope should be constructed according to the standard (along a contour line if possible) from the beginning, because expenses for reconstruction are prohibitive.

(3) Cutting slope should be shortened as much as possible at the place of cutting. Siding area and turning point will be taken into consideration at the place where waste soil is produced.

(4) Banking slope should be as gentle as possible and trodden hard and is protected from erosion by greening of surface.

(5) Drainage work must be performed if there is a possibility that water remains and the subgrade is saturated with water.

5-4 Road Construction Programme and Cost

The road plan in the 1st phase has been drawn on a map with a scale of 1:5,000, using aerial photographs, after measurements from existing roads around the proposed area and part of the proposed forest road.

The construction cost is calculated as follows:

* An average unit cost calculation method is adopted because the construction is mostly done by a hired bulldozer.
* The cost of bridges and other facilities is included in unit cost (per meter).
* Ballast on road surface is not used in this project, because it is not produced in Brunei and it would have to be imported and too expensive.
* The applied unit cost is expressed from an exchange of local unit cost (Brunei dollar) to Japanese yen. (Exchange rate: B$1 = ¥120)

Bulldozer lease charge (D6)		¥57,600/day
Wages for a driver of bulldozer		¥ 6,600/day
Wages for a labour		¥ 3,600/day
Dump truck (6 tons)		¥20,400/day
Gravel		¥ 4,680/m^3
Corrugated pipe	φ400 mm = 1.6	¥ 8,738/m
" "	φ600 mm = 1.6	¥12,000/m
" "	φ1,000 mm = 2.0	¥19,107/m
" "	φ2,000 mm = 2.7	¥66,058/m

The detailed calculations of the construction cost are shown in Tables 5-3, ① ∿ ⑦.

Table 5-2 is an annual forest road construction plan and costs incurred.

Table 5-2 Annual Plan of Road Construction and Cost

Unit: Distance (m)
Cost ¥1,000

Year	1		2		3		4		Sub-total		5	
Class	Distance	Cost	Distance	Cost	Distance	Cost	Distance	Cost	Distance	Cost	Distance	Cost
Principal road	1,500	3,528	0	0	0	0	300	706	1,800	4,234	966	2,272
Branch road	700	1,096	1,000	1,566	2,000	3,132	500	783	4,200	6,577	2,250	3,524
Feeder road	500	587	900	1,056	1,900	2,229	1,900	2,229	5,200	6,101	2,784	3,266
Total	2,700	5,211	1,900	2,622	3,900	5,361	2,700	3,718	11,200	16,912	6,000	9,062

Year	6		7		8		9		Sub-total		Total	
Class	Distance	Cost	Distance	Cost	Distance	Cost	Distance	Cost	Distance	Cost	Distance	Cost
Principal road	1,288	3,029	1,610	3,787	1,932	4,544	2,254	5,301	8,050	18,933	9,850	23,167
Branch road	3,000	4,698	3,750	5,873	4,500	7,047	5,250	8,222	18,750	29,364	22,950	35,941
Feeder road	3,712	4,354	4,640	5,443	5,568	6,531	6,496	7,620	23,200	27,214	28,400	33,315
Total	8,000	12,081	10,000	15,103	12,000	18,122	14,000	21,143	50,000	75,511	61,200	92,423

Table 5-3

① Unit Cost of Road Construction

Item	Amount	Unit	Unit cost	Cost	Remarks
Principal road	1	m		¥2,352	¥1,572 + ¥780 See Tables ② and ③.
Branch road	1	m		¥1,566	¥786 + ¥780 See Tables ② and ③.
Feeder road	1	m		¥1,173	¥393 + ¥780 See Tables ② and ③.

② Unit Cost of Bulldozer Operation

Item	Amount	Unit	Unit cost	Cost	Remarks
Bulldozer lease charge	1	day	¥57,600	¥57,600	D6 class including fuel
Bulldozer operator fee	1	person/ day	¥6,600	¥6,600	
Labour	4	"	¥3,600	¥14,400	Manual work
Total				¥78,600	
Principal road /m				¥1,572	78,600 ÷ 50 m/day
Branch road /m				¥786	78,600 ÷ 100 m/day
Feeder road /m				¥393	78,600 ÷ 200 m/day

③ Unit Cost of Corrugated Pipe Work

Item	Amount	Unit	Unit Cost	Cost	Remarks
ϕ400				¥262,808	See Table ④
ϕ600				¥203,520	See Table ⑤
ϕ1,000				¥101,295	See Table ⑥
ϕ2,000				¥211,890	See Table ⑦
Total				¥779,513	
per/m				¥780	¥779,513 ÷ 1,000 m

④ Unit Cost (1 km) of Corrugated Pipe Work (ϕ400 mm)

Item	Amount	Unit	Unit cost	Cost	Remarks
Pipe cost	1	m	¥8,738	¥8,738	
Earth work	0.18	person/day	¥3,600	¥648	Labour
Total				¥9,386	
Per one lot	7	m	¥9,386	¥65,702	One lot = 7 m
Per 1 km	4	lot	¥65,702	¥262,808	each 250 m one lot

⑤ Unit Cost (1 km) of Corrugated Pipe Work (ϕ600 mm)

Item	Amount	Unit	Unit cost	Cost	Remarks
Pipe cost	1	m	¥12,000	¥12,000	
Earth work	0.2	person/day	¥3,600	¥720	Labour
Total				¥12,720	
Per one lot	8	m	¥12,720	¥101,760	one lot = 8 m
Per 1 km	2	lot	¥101,760	¥203,520	each 500 m one lot

⑥ Unit Cost (1 km) of Corrugated Pipe Work (ϕ1,000 mm)

Item	Amount	Unit	Unit cost	Cost	Remarks
Pipe cost	1	m	¥19,107	¥19,107	
Earth work	0.32	person/day	¥3,600	¥1,152	Labour
Total				¥20,259	
Per one lot	10	m	¥20,259	¥202,590	one lot = 10 m
Per 1 km	0.5	lot	¥202,590	¥101,295	each 2 km one lot

⑦ Unit Cost (1 km) of Corrugated Pipe Work (ϕ2,000 mm)

Item	Amount	Unit	Unit cost	Cost	Remarks
Pipe cost	1	m	¥66,058	¥66,058	
Earth work	1.27	person/day	¥3,600	¥4,572	Labour
Total				¥70,630	
Per one lot	12	m	¥70,630	¥847,560	one lot = 12 m
Per 1 km	0.25	lot	¥847,560	¥211,890	each 4 km one lot

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