4 Silviculture for Multi-Storied Forest

4-1 Planting Work

4-1-1 Five-Year Planting Plan

The current planting plan and actual progress are shown in Table 53. Planting was begun in 1992 under the five-year plan.

Although 1992's initial planting plan were 100 hectares in the Chikus sites (50 each in sites A and B), actual planting stopped at 46 hectares in site A (including the 8 ha. arboretum) and 42 hectares in site B, for a total of 88 hectares. The major reasons were the inability to acquire the required number of seedlings of dipterocarps and other high-quality timber species, and delays in the preparation of nursery, etc.

For the 1993 plan, unplanted area in 1992 were added to the 1993 planting areas. Current estimates are for 80 hectares for site A (including the 8 ha. arboretum), 80 ha. for site B and 7 ha. for the Bukit Kinta site, for a total of 167 ha., which slightly exceeds the original total of 164 ha. (100 ha. for Chikus site A (including the 8 ha. arboretum), 58 ha. for site B, and 6 ha. for the Bukit Kinta site). Although operations for 1993 were scheduled for completion by December 1993, abnormally high precipitation (the highest in several years) in the October-to-December rainy season - which interfered with field burning and muddied roads, thus delaying the trucks - and the collapse of a bridge along the access road led to a 3-month delay, and all scheduled planting is now rescheduled for completion by the end of March 1994. See Fig. 13 for the amount of planting at each location for each year.

Table 53. Five-year planting plan and actual results

Unit: ha

Site/Year	1992		1993		1994		1995	1996	Total		Completion
	Plan	Result	Plan	Result	Plan	Result	Plan	Plan	Plan	Result	rate (%)
Chikus Block-A	50	46	100	(80)	104	-	-	0	300	(126)	42
1) Multi-storied forest planting	50	38	92	(72)	100	-	-	0	280	(110)	39
2) Arboretum planting	0	8	8	(8)	4	-	-	0	20	(16)	80
Chikus Block-B											
1) Multi-storied forest planting	50	42	58	(80)	60	-	-	0	200	(122)	61
Bukit Kinta											
1) Multi-storied forest planting	0	0	6	(7)	14	-	-	-	50	(7)	14
Total	100	88	164	(167)	178	-	-	-	550	(255)	46
Cumulative total	100	88	264	(255)	442	-	-	-	550	(255)	46

Note: 1. Planned workloads for 1995 and beyond are based on the results of the previous year and so are not included in this table.
2. Parentheses shows estimated figures.

4-1-2 Planting Species/Experimental Plots

1) Planting species in 1992 and 1993

A total of 20 species were planted between December 1991 and the end of February 1994: 9 dipterocarps and 11 non-dipterocarps. This total increased to 36 (16 dipterocarps. 19 non-dipterocarps and 1 non-woody) if all species planned for 1993 are included (Table 54).

At the multi-storied forest experimental site at Chikus Block-A (an open land produced by clear cutting), multi-storied forests comprised of fast-growing *Acacia mangium* and high-quality timber species planted together in five different patterns (1, 2,4, 8 or 16 alternating rows of *Acacia mangium* and high-quality timber species) are to be established by taking advantage of the difference in growth rates. Four high-quality timber species (all dipterocarps) were planted in 1992 and eight in 1993 (3 dipterocarps and 5 non-dipterocarps).

At the multi-storied forest experimental site at Chikus Block-B, high-quality timber species will be planted in the line gaps in existing *Acacia mangium* man-made forest. The gaps were cut in five different patterns (1:1 [one row cut, one row left], 2:2, 4:4, 8:8 and 16:16). Three high-quality timber species (all dipterocarps) were planted in 1992 and ten species (seven dipterocarps, two non-dipterocarps and 1 non-woody) in 1993.

At the Bukit Kinta multi-storied forest site, multi-storied forests will be established through the enrichment planting of high-quality timber species in gaps in logged-over natural forests. In 1993, the year this project began, *Shorea parvifolia* that grow in this region naturally was planted.

Planned for Chikus Block-A is an arboretum of approximately 50 different species, which will be used to collect physiological and ecological data that will be used in the selection of species for planting. Sixteen species were planted in 1992 (8 dipterocarps and 8 non-dipterocarps) and 16 in 1993 (6 dipterocarps and 10 non-dipterocarps).

Table 54. Planted species in 1992 and 1993 plans

A) Experiments for Establishing Multi-Storied Forest

(a) Chikus Block-A (Mix-planting of fast-growing species and high quality timber species on clear-cut open land)

Planting in 1992 (4 species)		
* *Shorea leprosula*	(Meranti tembaga)	Planted in Apr. 1993
* *Shorea parvifolia*	(Meranti sarang punai)	Planted in May 1993
* *Hopea odorata*	(Merawan siput jantan)	Planted in May 1993
* *Neobalanocarpus heimii*	(Chengal)	Planted in Apr. 1993
Planting in 1993 (8 species)		
* *Shorea acuminata*	(Meranti rambai daun)	Scheduled for planting in Mar. 1994
* *Shorea bracteolata*	(Meranti pa'ang)	Scheduled for planting in Mar. 1994
* *Dryobalanops aromatica*	(Kapur)	Scheduled for planting in Mar. 1994
Scaphium macropodum	(Kembang semangkok jantong)	Scheduled for planting in Mar. 1994
Calophyllum spp.	(Bintangor)	Scheduled for planting in Mar. 1994
Pentaspadon motleyi	(Pelong lichin)	Scheduled for planting in Mar. 1994
Endospermum malaccense	(Sesendok)	Scheduled for planting in Mar. 1994
Pouteria malaccensis	(Nyatoh nangka kuning)	Scheduled for planting in Mar. 1994

(b) Chikus Block-B (Line planting in existing *Acacia Mangium* man-made forest)

Planting in 1992 (3 species)		
* *Shorea leprosula*	(Meranti tembaga)	Planted in Oct. 1992
* *Shorea parvifolia*	(Meranti sarang punai)	Planted in Oct. 1992
* *Neobalanocarpus heimii*	(Chengal)	Planted in Nov. 1992
Planting in 1993 (10 species)		
* *Shorea acuminata*	(Meranti rambai daun)	Scheduled for planting in Mar. 1994
* *Shorea laevis*	(Balau kumus)	Scheduled for planting in Mar. 1994
* *Parashorea densiflora*	(Gerutu pasir)	Scheduled for planting in Mar. 1994
* *Dryobalanops aromatica*	(Kapur)	Scheduled for planting in Mar. 1994
* *Shorea macroptera*	(Meranti melantai)	Scheduled for planting in Mar. 1994
* *Hopea odorata*	(Merawan siput jantan)	Scheduled for planting in Mar. 1994
* *Shorea singkawang*	(Meranti sengkawang merah)	Scheduled for planting in Mar. 1994
Palaquium gutta	(Nyatoh taban merah)	Scheduled for planting in Mar. 1994
Pentaspadon motleyi	(Pelong lichin)	Scheduled for planting in Mar. 1994
Calamus manan	(Rotan manau)	Scheduled for planting in Mar. 1994

(c) Bukit Kinta (Gap planting in logged-over areas of natural forests)

Planting in 1993 (1 specie)		
* *Shorea parvifolia*	(Meranti sarang punai)	Scheduled for planting in Mar. 1994

B) Experimental Plots for Establishing Arboretum

(a) Chikus Block-A

Planting in 1992 (16 species)		
* *Shorea laevis*	(Balau kumus)	Planted in Feb. 1993
* *Shorea leprosula*	(Meranti tembaga)	Planted in Feb. 1993
* *Shorea acuminata*	(Meranti rambai daun)	Planted in May 1993
* *Shorea ovalis*	(Meranti rambai daun)	Planted in May 1993
* *Dryobalanops aromatica*	(Kapur)	Planted in May 1993
* *Hopea odorata*	(Merawan siput jantan)	Planted in May 1993
* *Neobalanocarpus heimii*	(Chengal)	Planted in May 1993
* *Shorea parvifolia*	(Meranti sarang punai)	Planted in Aug. 1993
Scaphium macropodum	(Kembang semangkok janton	Planted in Jan. 1993
Swietenia macrophylla	(Mahogany)	Planted in May 1993
Pentaspadon motleyi	(Pelong lichin)	Planted in May 1993
Hevea brasiliensis	(Rubber tree)	Planted in May 1993
Durio spp.	(Durian)	Planted in May 1993
Tectona grandis	(Teak)	Planted in Jun. 1993
Intsia palembanica	(Merbau)	Planted in Jun. 1993
Parkia spp.	(Petai)	Planted in Jun. 1993

Planting in 1993 (16 species)		
* *Shorea dolichocarpa*	(Damar hitam katup)	Planted in May 1993
Alstonia spp.	(Pulai)	Planted in Oct. 1993
Cinnamomum spp.	(Medang teja)	Planted in Oct. 1993
Toona sureni	(Surian wangi)	Planted in Oct. 1993
Endospermum malaccense	(Sesendok)	Planted in Oct. 1993
* *Shorea roxburghii*	(Meranti temak nipis)	Scheduled for planting in Mar. 1994
* *Shorea macroptera*	(Meranti melantai)	Scheduled for planting in Mar. 1994
* *Shorea singkawang*	(Meranti sengkawang merah)	Scheduled for planting in Mar. 1994
* *Shorea hopeifolia*	(Damar hitam siput jantan)	Scheduled for planting in Mar. 1994
* *Dipterocarpus cornutus*	(Keruing gombang)	Scheduled for planting in Mar. 1994
Calophyllum spp.	(Bintangor)	Scheduled for planting in Mar. 1994
Heritiera spp.	(Mengkulang)	Scheduled for planting in Mar. 1994
Dacryodes spp.	(Kedondong)	Scheduled for planting in Mar. 1994
Koompassia malaccensis	(Kempas)	Scheduled for planting in Mar. 1994
Agathis borneensis	(Damar minyak)	Scheduled for planting in Mar. 1994
Palaquium gutta	(Nyatoh taban merah)	Scheduled for planting in Mar. 1994

Note: Dipterocarps are indicated with an asterisk (*).

2) Setting-Up of Experimental Plots

Experimental plots were set-up in order to collect data (for establishment of the multi-storied forest) on all the species listed below (Table 55). A total of 197 plots (containing 59 species) have been set-up so far.

Table 55. Experimental plots

Planting in 1992	**Number of species**	**Number of plots**
Chikus Block-A		
1) Multi-storied forest site	4	20
2) Arboretum site	16	16
Chikus Block-B		
1) Multi-storied forest site	3	30
Planting in 1993	**Number of species**	**Number of plots**
Chikus Block-A		
1) Multi-storied forest site	8	40
2) Arboretum site	16	16
3) Ploughing/fertilization test site	1	3
Chikus Block-B		
1) Multi-storied forest site	10	65
Bukit Kinta		
1) Multi-storied forest site	1	7
Total	59	197

Note: The actual number of species is 36; the total of 59 is the aggregate.

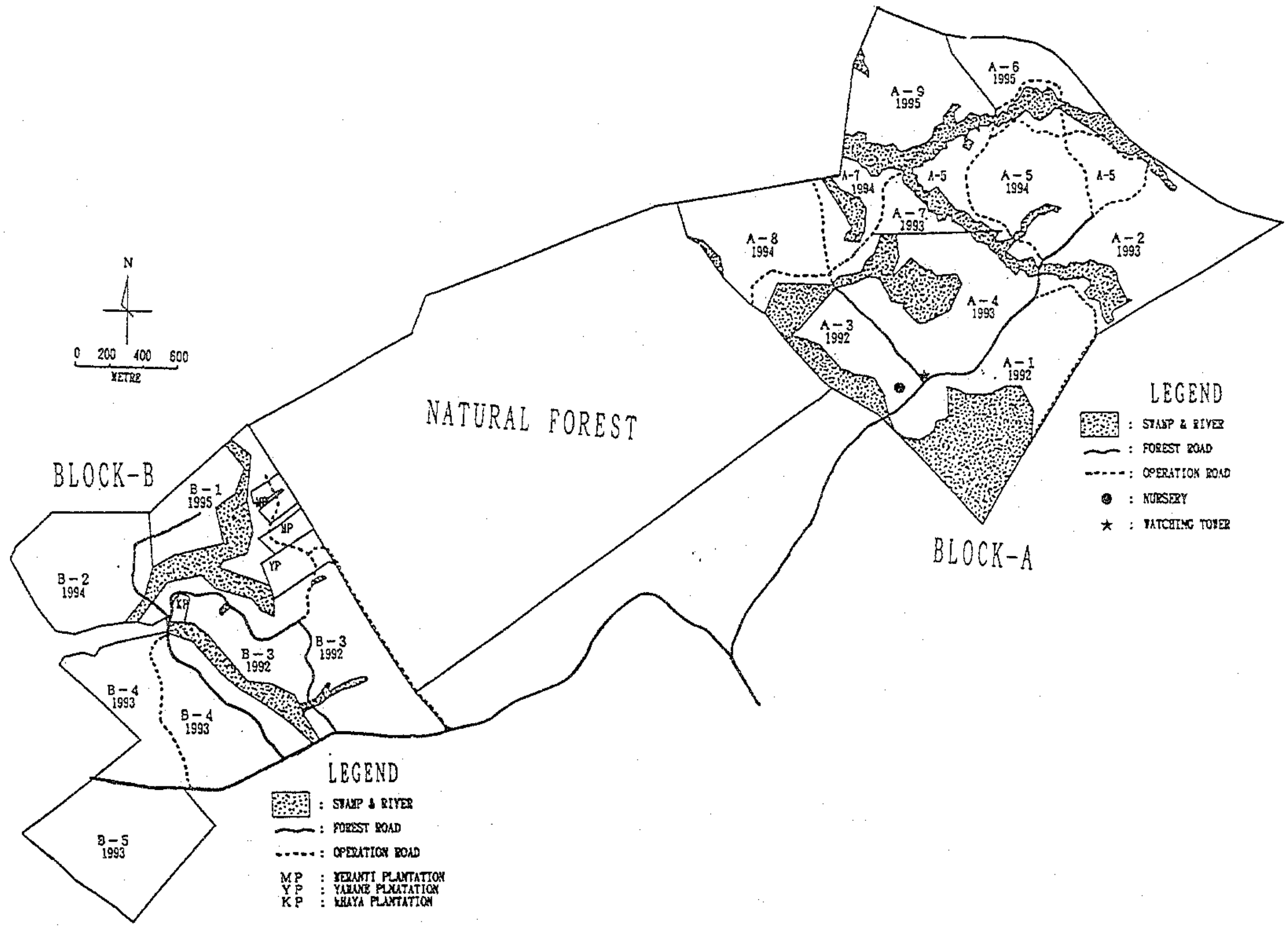


Fig. 13. Chikus forest reserve planting order

4-1-3 Current Planting Methods in This Project

1) Multi-Storied Forest Plantation in Existing Man-Made Forests (Chikus Site Block-B)

(1) Felling and Extraction of Timber in Man-Made Forests

Trees were felled with chainsaws and pruned on the spot, with branches cut at the point where the diameter is approximately 5 cm. This process is normally done by one worker. This felling creates gaps 1, 2, 4, 8 or 16 rows wide, with the resultant gap width being 7.4, 11.1, 18.5, 33.3 or 62.9 metres, respectively. Although a bulldozer could be used for opening wide gaps, a farm tractor (Ford 5000 series) should be used to avoid compacting the soil. All felled trees were collected in tree length timber. The work team normally consists of one loader and one unloader for each farm tractor. Timber, because of its limited quantity, placed along the shoulders of forest roads and operation.

(2) Site Preparation

Site Preparation consists of the clearing of branches from felled trees, the removal and trimming of regenerating plants, and weeding. The implement used is a long (roughly 54 cm.) hatchet called "parang" in Malay. Branches were cut and accumulated towards the side of remaining trees. Because of the considerable regenerative capabilities of *Acacia mangium*, Escort 60DF was applied on all remaining stumps to stop from sprouting. The width of weeding is 2 m. along the planting line (i.e., 1 metre on each side of the position of planting).

(3) Staking

Staking involved placing bamboo stakes into the ground to mark the planting position (i.e., the hole where seedlings were to be planted). When planting in felled *Acacia mangium* forest, seedlings were planted between stumps, which made the planting position somewhat clear, but staking was still carried out to make this position clear during subsequent weeding around seedlings.

(4) Species Selection

While species with established planting standards are desirable for afforestation projects, these standards are unclear for many of the high-quality timber species in Peninsular Malaysia. In addition, factors such as irregular flowering and fruiting patterns among many species (making regular seeds acquisition impossible) and the lack of an organized system for seedlings production prevent adequate seedlings acquisition for large scale afforestation projects. This forces us to rely on a passive system of seedlings selection in which high-quality timber species were selected on the basis of the ability to secure a certain quantity of seedlings during that fiscal year. High-quality timber species are selected from "Pocket Check List of Timber Trees" (Malayan Forest Records No. 17). About 20 species will be selected for planting in the experimental plots for establishing multi-storied forest in existing man-made forests. The species suitable for the planting of multi-storied forests in existing man-made forests will be listed in the final report.

(5) Seedlings Transportation

Seedlings were transported from the nursery to the site before 11:00 a.m. or after 5:00 p.m. This is to avoid the harsh daytime sun, which could harm the seedlings. A covered truck was used for long-distance transport (i.e., more than 30 minutes).

(6) Planting Spacing

Seedlings were planted in 3.7 m. x 3.0 m. in accordance with the spacing of *Acacia mangium* man-made forest. Although this resulted in a density of 900 trees per hectare, the actual density of high quality timber species in project sites came to 450 trees per hectare as 50% of upper layer were designated for felling.

(7) Planting Methods

Although planting was conceivably possible all year-round because of Peninsular Malaysia's tropical climate; it is best to select a planting season based on local meteorological data. For the Chikus sites, the period from early October to early December is ideal for planting because it is during rainy season, although in terms of workload and available labour, the period from late September through late December could be considered suitable.

Generally, the time of day designated for planting was from sunrise to 11:00 a.m. and or 4:00 p.m. to sunset. During line planting in existing man-made forest, however (i.e., in areas where gaps 1, 2 or 4 rows wide had been cut) this restriction need to be applied.

The planting hole is 20 cm. in diameter and 20 cm. depth, or slightly larger than pot size. Instead of hoes, an implement called a "pengali" in Malay (a round blade with a 1.4-metre handle) was used to dig these holes. Before planting, the plastic pots were removed carefully to prevent the soil inside from crumbling. Removed pots were placed on bamboo stakes when placed in the ground to indicate the planting position. These pots on bamboo stakes indicate that seedlings have actually been planted, and served as marker for subsequent weeding.

(8) Survival Rate Surveys

A survival rate survey is carried out one month after planting. If it is determined that 20% or more of the seedlings had died, supplemental planting is carried out within the next two months.

(9) Weeding (Including Cutting of Liana)

In cases of the line planting of multi-storied forests like that in Chikus Block-B, the growth of the planted seedlings and the types and heights of forest floor vegetation depended on gap width. The following four species of herbage were frequently encountered in weeding around seedlings.

Ekor kuching (grass family): This is the predominant species of weed in wide-gap (i.e., 8 [cutting width: 33.3 m.] and 16 [cutting width: 62.9 m.] rows) areas and other locations that receive ample sunlight. It is hardly never found in shaded areas, such as the narrow gaps in 1- and 2-row cutting (7.4 and 11.1 metres respectively).

Climbers (3 species): Belokok, found extensively in Block-B, can completely cover and kill planted seedlings if weeding is delayed. This climber can bend the shoot of seedlings and greatly retard the growth of *Shorea leprosula*, *Shorea parvifolia* and other species with extremely soft shoots. This climber tends to grow extensively on moist soil and wide gaps, but is also found in narrow gaps as well. The climber Selaput tunggul is not as extensive as Belokok but has thicker stems (2 - 3 mm.) and can bend seedlings' shoots and retard seedlings growth. Duri, though less widely distributed, has even tougher and thicker stems (4 - 5 mm.) and can bend over, and thus damage, the entire seedling.

Table 56. Main plants targeted for weeding at Chikus Block-B (1992 afforestation sites)

Ekor kuching	- *Perotis latifolia*	(grass)
Belokok	- *Dioscorea spp.*	(climber)
Selaput tunggul	- *Ipomoea triloba*	(climber)
Duri	- *Randia fasciculata*	(climber)

Under a contract, extensive weeding suited to the volume of vegetation was difficult because of the large scale of area. The frequency of weeding for each method of line planting (as stipulated in the weeding contract for sites line planted in October and November 1992 and as deemed necessary upon on-site observation) are shown in Table 57. Although weeding was only carried out during the first year in cases of 1-, 2- and 4-row line planting, one or two more weedings (primarily of climbers) is expected to be necessary.

Table 57. Frequency of weedings for each type of line planting (per year)

Type of line planting (cutting width)	Frequency of weeding	Remarks
1-row line planting (7.4 m)	2 - 3 times	1st weeding: primarily grasses
2-row line planting (11.1 m)	2 - 3 times	2nd weeding: primarily climbers
3-row line planting (33.3 m)	3 times	Grasses and climbers weeding
4-row line planting (33.3 m)	3 - 4 times	Grasses and climbers weeding
5-row line planting (62.9 m)	4 - 5 times	Primarily grasses

(10) Protection

While no major damage due to disease or insects has occurred since 1992's planning, many dipterocarps suffer some damage by leaf-eating insects. Because of the Chikus sites' flat terrain, numerous marshes and adjacency to former tin-mining sites (where plants and other weeds are bountiful), water buffaloes and cattle were put to pasture here, and many entered the project sites to graze on the plants that grew after weeding. While damage from this grazing was not extensive, some seedlings were trampled, and although we have asked the owners to graze their water buffaloes and cattle elsewhere, it had proven impossible to determine who were the actual owners of the animals responsible for the damage.

2) Multi-Storied Forest in Open Land (Chikus Block-A)

(1) Felling of Low-Quality Secondary Forest

In October 1992 when the site preparation started in Chikus Block-A, the low-quality secondary forest (2-3 metres high) that had regenerated after two and a half years of the clearing of the natural forest there (from June 1988 to March 1989) were cleared using heavy machinery (a backhoe), on which we were forced to rely because of the prohibitive amount of time that manual clearing would have taken. Although soil compacting was expected, it was not certain what effect this will have on the growth of trees subsequently planted.

(2) Site Preparation

Felled trees were left for several weeks to dry, after which they were heaped and burned. Heaping involved using a bulldozer (D6 class) to stack them at appropriate intervals. After burning, the remaining timber was again heaped and burned (burning is normally carried-out twice). When heaping trees with the bulldozer, care must be taken to move topsoil as little as possible.

(3) Staking

Staking involved placing bamboo stakes roughly 1-metre-long into the ground to mark the spots where seedlings will be planted.

(4) Species Selection

While species with established planting standards are desirable for afforestation projects, these standards are unclear for many of the high-quality timber species in Peninsular Malaysia. In addition, factors such as irregular flowering and fruiting patterns among many species (making regular seeds acquisition impossible) and the lack of an organized system for seedlings production prevented adequate seedlings acquisition for large scale afforestation projects. This forced us to rely on a passive system of seedlings selection in which high-quality timber species are selected on the basis of the ability to secure a certain quantity of seedlings during that fiscal year. High-quality timber species were selected from "Pocket Check List of Timber Trees" (Malayan Forest Records No. 17). The most important prerequisite in selection is the ability to withstand harsh sunlight. About 20 species will be selected for planting in the experimental plots for establishing multi-storied forest in open land. The species suitable for the planting of multi-storied forests in open land will be listed in the final report.

(5) Seedlings Transportation

Seedlings are transported from the nursery to the site before 11:00 a.m. or after 5:00 p.m. This is to avoid the harsh daytime sun, which can harm the seedlings. A covered truck was used for long-distance transport (i.e., more than 30 minutes).

(6) Planting Spacing

Seedlings were planted in 3.7 m. x 3.0 m. in accordance with the spacing of *Acacia mangium* man-made forest. This results in a density of 900 trees per hectare. As alternating rows of fast-growing species and high-quality timber species were planted together, the density was 450 trees per hectare for both the former and the latter.

(7) Planting Method

Although planting was conceivably possible year-round because of Peninsular Malaysia's tropical climate, it is best to select a planting season based on local meteorological data. For the Chikus sites, the period from early October to early December is ideal because it is during rainy season, although in terms of workload and available labour, the period from late September through late December could be considered suitable.

Generally, the time of day designated for planting is from sunrise to 11:00 a.m. or from 4:00 p.m. to sunset. Although the time of day is not a major factor for the planting of potted seedlings, it is still best to avoid planting under harsh sunlight.

The planting hole is 20 cm. in diameter and 20 cm. depth, or slightly larger than pot size. Instead of hoes, an implement called a "pengali" in Malay (a round blade with a 1.4-metre handle) was used to dig these holes. Before planting, the plastic pots were removed carefully to prevent the soil inside from crumbling. Removed pots were placed on bamboo stakes which were placed in the ground to indicate the planting position. These pots on bamboo stakes indicate that seedlings have actually been planted, and served as marker for subsequent weeding. After planting, the ground around the seedlings was covered with mulch (i.e., dead grass, etc.) to prevent drying and rise in soil temperature.

(8) Survival Rates Surveys

A survival rates survey is carried out one month after planting. If it is determined that 20% or more of the seedlings have died, supplemental planting is performed within next two months.

(9) Weeding (Including Cutting of Liana)

Generally, homogenous species of weeds are found in open land (as in Chikus Block-A). The predominant weed requiring removal is "Ekor kuching" (a member of the grass family), which grows to heights of 3 to 4 metres. Climbers are seldom found.

Sites planted in April and May 1993 with *Shorea leprosula*, *Shorea parvifolia*, *Neobalanocarpus heimii* and *Hopea odorata* require at least five weedings per year (as stipulated in the weeding contract and as deemed necessary upon on-site observation). Poor survival rates of the three species *Shorea leprosula, Shorea parvifolia* and *Neobalanocarpus heimii* require supplemental planting and prevent continuous weeding, while the 80% survival rate of *Hopea odorata* conversely requires that weeding be continued. However, it is not known many years it will take for the trees to exceed the maximum height of these weeds.

(10) Protection

Nearly all dipterocarps planted since April 1993 have suffered damage from leaf-eating insects (which have yet to be identified). And despite the almost total absence of insect damage at Chikus Block-B, there was damage from cattle: Because of this site's flat terrain, numerous marshes and adjacency to former tin-mining sites (where plants and other weeds are bountiful), water buffaloes and cattle were put to pasture here, and many enter the project site to graze on the plants that grew after weeding. While damage from this grazing was not extensive, some seedlings were trampled, and eaten (especially *Parkia* spp. and *Hevea* spp.). Although we have asked the owners to graze their water buffaloes and cattle elsewhere, it had proven impossible to determine who are the actual owners of the animals responsible for the damage.

3) Multi-Storied Forest in Logged-Over Natural Forest (Bukit Kinta Site)

As site preparation and planting began in early February 1994, sufficient data are still unavailable, and so the progress of this operation will be detailed in future reports.

4-1-4 The Current Status Of Silvicultural Operation In Peninsular Malaysia *[1]

1) Natural Forests

(1) Girdling And Cutting of Liana (GCL)

Silvicultural treatment, is required when timber trees have regenerated sufficiently after logging as their canopies are competing for space or are covered with liana. This involves the girdling of some of the relics/defective trees and the cutting of all liana. This removal of those relics, defective trees (i.e., trees injured during cutting) and liana that interfered with the regeneration of timber trees liberates the latter from competing with these relics and defective trees, and can speed the growth of timber trees up to the next cutting. During girdling a safe distance must be maintained between streams, rivers and main roads.*[2]

Under the Fifth Malaysia Plan (FMP) period (1986 to 1996), GCL were carried out in 260,468 hectares (as of late September 1990) out of the 369,252 hectares planned cumulative planting area of 963,745 hectares. In the Sixth Malaysia Plan (1991 to 1995) a total of 584,250 hectares will be treated.

(2) Enrichment Planting

Enrichment planting, is carried out in the logged-over forest which is poorly stocked with natural regeneration of preferred species following the results of the post-felling inventory. Taking into account the preferred species generally found in the area, seedlings were planted along cleared lines under the canopy of the residual stands at the spacing of 3 m. x 6 m. Enrichment planting is carried out during the rainy season with lines planted in the east-west direction supplemental planting, weeding, and the girdling of relics/defective trees that shade seedlings is normally carried-out for 2 years thereafter.

The target for the FMP period is 4,250 ha or annual target of 850 ha. Of this, enrichment planting had already been carried out in 1,520 ha by the end of September 1990, bringing the overall total area planted to 17,885 ha. The primary species planted include *Shorea leprosul* (Meranti tembaga), *Shorea parvifolia* (Meranti sarang punai), *Shorea platyclados* (Meranti bukit), *Anisoptera* (Mersawa), *Dryobalanops aromatica* (Kapur), *Scaphium* spp. (Kembang semangkuk), and *Dyera costulata* (Jelutong). The Sixth Malaysia Plan (1991-1995) includes a planned planting area of 5,700 hectares.

(3) Rattan Planting

After timber, rattan is the most important non-wood produce from the natural forests. In Peninsular Malaysia 104 species in 8 genera have been identified (quite a few of which are used commercially), while rattan harvests have increased in volume due to the rapidly growing demand for rattan furniture. The planting of rattan in natural forests to ensure the stable supplies of rattan, whereby seedlings were planted at spacing of 10 m. x 10 m. and cared for regularly. The target under the FMP period is 3,330 ha. Of this target, a total of 2,505 ha. had been planted by the end of September 1990, bringing the overall total area planted to 3,283 ha.

Apart from planting in forest areas, efforts were also being taken to encourage owners of rubber smallholdings to plant rattan. Towards this end, the Forestry Department assists in providing technical advice and supplying suitable seedlings. Since the inception of this programme, a total of 381 ha. had been planted. A total of 9,000 ha. will be planted by the Forestry Department under the Sixth Malaysia Plan (1991-1995).

(4) Planting In Mangrove Forests

Mangrove forests, which comprised part of the Permanent Forest Estate, are found mainly along the western coast of Peninsular Malaysia. Mangrove trees are cut each year and replanting is carried out in spots where natural regeneration is poor. These seedlings, mainly *Rhizophora* spp., are planted at intervals of 1.2 m. x 1.2 m. in places away from the water's edge, and at intervals of 1.8 m. x 1.8 m. near rivers and other natural waterways. The method of planting is simple: Fresh seeds were collected and placed in the mud with the root end pointing downward. An average of 800 hectares are planted each year.

2) Forest Plantations

While emphasis is now placed on natural regeneration in natural forests, the importance of forest plantations continues to grow. Commercial establishment of forest plantations was undertaken as early as 1957 with planting of *Tectona grandis* (teak) in the northern states of Perlis and Kedah where 839 ha. had been established. Teak was chosen for these states primarily because of its suitability to the climate and the high quality of its timber. From the late 1960s to early 1970s fast-growing tropical pines (mainly *Pinus caribaca, Pinus merkusii,* and *Araucaria* spp.) were planted in the states of Johor, Negri Sembilan, Pahang and Selangor in Peninsular Malaysia (total area of 5,538 ha.) as a source of long-fibre pulp for local pulp and paper plants. However, the planting of pines was discontinued because of the unfavourable economic outlook.

In order to prevent shortages of timber and timber products resulting from population increases expected in Peninsular Malaysia in the mid-1990's, the government implemented the Compensatory Forest Plantation Project in 1982 in response to growth forecast in the domestic market for general timber. This project calls for the planting of 188,000 hectares of man-made forests of fast-growing trees - e.g., *Acacia mangium, Gmelina arborea* (Yamane), and *Paraserianthes falcataria* (Batai) - with 15-year rotation. The choice of these species was based on the following criteria:

(a) Fast-growing and able to attain sawlog size in about 15 years.
(b) Able to produce timber suitable at least for general utility purposes.
(c) Amenable to planting under plantation conditions in Peninsular Malaysia.
(d) Able to produce seeds in abundance under local conditions or large quantities of seeds can be imported from overseas.

This project was implemented with an initial loan of RM 20 million (roughly 800 million yen at the current rate) from the federal government to the State Governments of Johor, Pahang, Selangor, Negri Sembilan. In 1985 a sectoral loan of US$ 24.5 million was provided by the Asian Development Bank (ADB) to partially cover the costs of planting 40,000 hectares, with the remainder provided by the government. By September 1990 a total of 36,874 hectares had been planted at a cost of RM 51,540,000-, of which RM 26,830,000 was from the ADB and RM 24,710,000 from the Federal Government.

The principal species planted in this project is *Acacia mangium*, which shows favourable results with an expected Mean Annual Increment (MAI) of 17.5 m.^{3}/ha./year. The Financial IRR (Internal Rate of Return) based on a rough calculation of planting and maintenance costs and income from thinning and final harvest, is 19.4%, making this a worthwhile investment.

Following on the heels of a successful phase I in the ADB project, an additional 42,000 hectares of forest plantation was planned for the period of 1989 to 1993. ADB has approved the second sectoral loan of US$ 29.5 million for the establishment of these areas and the management of established plantations, while the Federal Government authorized an allocation of US$ 24.1 million. With the states of Kelantan, Perak and Terengganu also included in this phase, roughly 100,000 hectares are expected to be planted by the end of the Sixth Malaysia Plan (1995).

4-1-5 Guidelines For The Planting Of High-Quality Timber Trees In Peninsular Malaysia*[3]

1) Sites Suitable For Planting

Several types of planting sites are available in Peninsular Malaysia. They include the following:

(1) Natural Forests

In certain cases natural forests have in the past been converted into plantation of fast growing timber species. In Peninsular Malaysia, the preferred choice is still to manage natural forests rather than convert them into plantations.

If natural forests are converted to plantations, do the following:

- extract all standing timber first;
- clear fell the rest of the vegetation;
- wait until secondary vegetation attains a height of 1.5 to 3.0 m. before planting.*[4]

(2) Degraded Forests

These forests are mostly devoid of standing timber and young regeneration and are certainly the preferred ones for starting plantations.

Here, employ the clear felling method above (1) for site preparation. Alternatively, completely poison-girdle all trees 10 cm. dbh and larger 4 years in advance. The intent is to create ground cover of a young belukar stand when planting is scheduled.

(3) Belukar (Secondary Forest)

Belukar sites are ideal for planting most of the climax phase timber species of the everwet tropics. No site preparation is necessary in closed-canopy belukar except for cutting planting lines. If any larger relics of the original forest are present, poison-girdle them. Likewise, cut large woody climbers at the ground level and dampen the stump with poison. If the belukar is older, and the vegetation is above 3 m. in height, planting lines may be overshaded. Such areas may require clear felling as part of the initial ground preparation.

(4) Plantations Of Fast-Growing Species

Discussions are underway to convert even some of the existing fast growing exotic species plantations (e.g., *Acacia mangium* plantations) into quality timber species plantation. This move may prove worthwhile where development into sound sawlog is in question. In such cases, the existing exotics may serve as nurse trees, with the quality timber species underplanted. However, research in this field is still underway, and the present guidelines do not address underplanting in such plantations.

(5) Degraded Lands

High degraded lands, (such as former mining land) and sites infested with resam and lalang require amelioration through afforestation and other efforts. In this general category one can also include heavily compacted and eroded sites. They are not suitable for starting quality timber plantations. The present guidelines do not apply to such sites. Following amelioration such sites may be suitable for planting, though.

(6) Enrichment Planting

Wyatt-Smith (1963) provides planting guidelines for enrichment planting in poorly stocked logged forests.*5

2) Planting-Site Preparation

(1) Spacing

Before starting field operations, determine an appropriate stocking level. From existing plantation stands in FRIM, it appears the best stands are those carrying about 120 - 140 final crop trees/ha. Several species can achieve a minimum diameter of 50 cm. dbh in 40 - 50 years in such stands. To attain straight boles, start the stand with high stem numbers, to aid self-pruning and to train the crop trees. At the pole stage, release potential final crop trees from all competitors. Further thin the stand with regeneration felling until the stocking is 100 - 140 trees/ha.

A second consideration for initial planting density is the vegetation on site. A completely open site with young belukar ((1.5 m. height) would benefit from a more dense planting, compared to an older, taller belukar (1.5 - 3.0 m. height).

- On more open sites, consider planting at a spacing of 5 m. x 3 m. (667 trees/ha.).
- In shadier areas, and appropriate spacing would be 7 m. x 3 m., (476 trees/ha.). The lower density is acceptable because the older belukar will provide side shade for self pruning and training.

(2) Operation

When the belukar is at the appropriate height, prepare the area in the following manner:

- Cut a central path/base line to facilitate seedlings transport, supervision and travel into and out of the area;
- Cut the planting lines in a north-south direction preferably, 5 m. (or 7 m.) apart and 1 m. wide;
- Dig the planting holes at 3 m. intervals. The holes for planting should be large enough that the planter could put his fingers between the cylinders of soil and the sides of the hole, and deep enough for the container. A post-hole digger with a semi-circular sharpened blade is a good tool for digging. Dig the holes in just the day before planting, to prevent drying up.

(3) Fertilizer Application

In heavily disturbed sites, where previous land use removed the vegetation with heavy machinery, nutrient deficiencies may surface. Before developing a fertilizer regime, ascertain whether such deficiencies exist. Currently, there are no hard and fast nutrient requirements known for the recommended species, but general recommendations are as follows:-

- Do not apply nitrogen to newly planted trees. Nitrogen is poorly held by the soil; it also stimulates weed growth.

- Use fertilizers high in phosphorus and potassium and low in nitrogen.

- Combine weed control with fertilizer.

(4) Planting

For planting to succeed, take care that the roots are in contact with soil; the plants are not damaged in the planting process; they are firmly in the soil; and the root collar is slightly below ground level. To these ends, observe the following suggestions:

- The best time to plant is at the onset of the rainy season. Determine locally, appropriate planting dates using the local district's meteorological data. The recommended planting time is in the morning before 11:00, but it is possible to plant later with seedlings in containers;

- Young seedlings between 3 to 8 months old give the best results. The precise age of preferred planting stock is given under each species (see later).

- Grade seedlings for uniformity of size. Discard all weak, badly shaped, or diseased stock. Plant size should be at least 50 cm. and not more than 75 cm. tall.

- Use of hardened seedlings. Plant them on the same day you lift them.

- Do not allow seedlings to dry out prior to planting. Keep them shaded and moist as much as possible between lifting and planting.

- Avoid obstacles like large boulders, big roots, stumps etc. when planting. Plant each seedling in a convenient spot, as exact spacing and alignment are not important.

- Place the cylinder of soil with the seedling in the hole. Fill the hole up, and pile additional soil from the digging around the plant. Firm up the soil with two pressures of the foot, one on each side of the plant. Do not touch the stem! The root collar should be slightly below ground (2 cm.) level when planting is completed.

3) Care Of Plantations In Initial Stages (Crop Reaches About 6 m. Height)

Plantations will fail if simply formed and forgotten. The first two years of establishment are critical for success. For economic as well as biological reasons, work to establish the stand as swiftly as possible. For this you must permit the plants to grow rapidly. The main danger is excessive shade, either from between line growth or from exuberant weed growth in the lines. Regular monitoring and tending are required, as follows:

(1) Weeding

- It is better to slash back or pull up the climbers around the plant than to disentangle them from the plant.

- If *Mikania* creeper is present, you may need to make monthly rounds for up to a year to keep the weed off the plant.

- In open sites herbaceous weeds and grass may appear. Clean weed them for a radius of 0.5 m. around the plant. Pull up the weeds after loosening with a hand fork if necessary. Do not conduct this weeding with a hoe or cangkul as such practice will inevitably result in damage to the seedlings. Instead, an effective herbicide would do as well.

(2) Shade

All the recommended species belong to the emergent or canopy storey and are light demanding, but some may need shade immediately after planting.

- If there is no natural shade on the site, use species or stock that can tolerate full light should be used.

- If planting sun-sensitive plants on a predominantly shaded site use palm fronds or saplings stuck firmly to the ground to provide shade in open patches during the transplanting. Do not use shades that could fall over and kill the seedlings.

- If planting on a shaded site, reduce the shade as soon as the plants have recovered from transplanting shock. Conduct the first opening of the closed canopy a month after planting, when undertaking the first counting. Give each plant a patch of overhead light. Poison-girdle overhead trees, and cut saplings and climbers in a similar position.

- At three months after planting, widen the opening. Re-treat any trees that have: not succumbed. Do not allow the openings to close up.

- Drop the cut vegetation around the seedlings as a mulch.

- After 2 - 3 years, the planting should be in a dominant competitive position. Keep them free of climbers or close competition belukar trees.

(3) Surveys

Until the plantation is considered established, the Plantation Manager/District Forest Officer must inspect the stand regularly.

- Enumerate the stand according to height class (<1 m., >1 m., <1.5 m.> , 1.5 m., <3 m., and >3 m.) at 1, 3, 6 and 12 months.

- Following that, annually enumerate the stand for 5 years, using 1 cm. diameter (at breast height) classes for trees >3 m. tall, including an estimate of the average height of the dominant trees.

- Evaluate the success of planting at one year of age. Any losses after that result from causes other than planting mortality. The first year is the "formation" year. From then until the plantation is established is the "establishment" period. Once the trees are able to look after themselves, the plantations are "established".

(4) Supplementary planting

- At the end of the first month, the desired survival rate is 80%, with mortality evenly distributed. If survival after 1 year is still above 75% and evenly distributed, no supplementary planting is necessary. If this standard is not met, you must decide whether to fill the blanks or start anew.

- If weather permits, fill the blanks immediately after the first survey (1 month). You may wait until the third month or repeat the process at that time.

- If a seedling is moribund, plant another seedling nearby at the third month (if planting stock in limited, fill blanks first).

- If you cannot fill the blanks by the sixth month, then try to obtain larger seedlings for filling at one year.

(5) Cleaning Operations (From 6 m. Height To About 15 m. Top Height Of The Main Crop)

During this stage, when main crop is between 6 to 15 m. top height, maintain strong side shelter. Keep the stands close to enhance self-pruning and stem straightness. Confine tending operations to cleanings and removal of poorly formed trees so that crop trees are not hindered. Carry out the operations below in 1 or 2 steps.

- Cutting climbers (including rattans).

- Remove wolf trees hampering the crown development of dominant and co-dominant crop trees.

Note: *1 FORESTRY DEPARTMENT HEADQUARTERS
1991 Current status of forestry sector in Peninsular Malaysia

*2 The reason for avoiding girdling near streams and rivers is to prevent river contamination from the defoliant used in girdling in Malaysia. Girdling is not performed near main roads because, just as in Japan, girdled trees could fall and cause accidents or block roads.

*3 FOREST RESEARCH INSTITUTE MALAYSIA (FRIM)
Guidelines for planting quality timber trees in Peninsular Malaysia

*4 The reason for planting after secondary vegetation grows to heights of 1.5 to 3 metres is that this secondary vegetation provides seedlings with shading.

*5 Forestry Department operates the Enrichment Planting based on "HANDBOOK ON ENRICHMENT PLANTING", Silviculture Unit, Forestry Department, Peninsular Malaysia 1978.

4-2 Planting Experiments

The Context and Significance of This Experiments/Research

With increased recognition of the importance of striving for the sustainable development of tropical rainforests, from the viewpoint of global environmental conservation, forest management systems designed to achieve this objective should be established now.

Multi-storied forest management system is one of the systems used to sustain tropical rainforests. In this system different species of trees are planted together to create mixed forests with a complex, multi-storied structure. Such forests transcend the limitations of single-species single storied forests and, having advanced conservation functions and resistance to disease and insects, make possible diverse timber production at the same time. However, the actual implementation of multi-storied forest plantation in tropical regions is hampered by the limited techniques and knowledge.

Consequently, the objective of this experiment is to test the techniques and methods for establishing multi-storied forests in locations of varying conditions, such as open land (e.g., clear-cut natural forests), *Acacia mangium* man-made forests, and logged-over natural forests.

4-2-1 The Experiment for Establishing Multi-Storied Forest in Open Land (Clear-Cut Natural Forest)

1) Introduction

This report is limited to item a. below, "Selecting species suited to multi-storied forests," and the survival rates and growth of four species of dipterocarps six months after planting.

2) Objectives

The objective of this experiment was to mix plant different species with different growth rates in open land (a clear-cut site) in a tropical region in order to gather basic data for using this difference in growth rates to establish multi-storied forest management system, and to arrive at technical standards on the planting of such forests. The experimental items were as follows.

a. Selecting species suited to multi-storied forests.
b. Silviculture techniques for various types of multi-storied forests.
c. Cost analysis on various types of multi-storied forests.

3) Site Location

The site is located in the Chikus forest reserve which is under jurisdiction of the South Perak district forest office of Perak State Forestry Department in Malaysia. Although formerly a large number of lowland dipterocarps forests were distributed, this area was clear-cut between June 1988 and March 1989 (to replace this low-productivity natural forest with high-productivity *Acacia mangium* man-made forest), after which it laid idle until September 1992. During this approximately two-and-a-half-year period, secondary forest predominated by *Macaranga* and other pioneer tree species (height: 2 - 3 m.).

4) Site Conditions

Under Köppen meteorological classifications, this area is categorized in a tropical rainforest climate (Af). The Tapah weather station, the closest to the experimental site (approximately 10 km. to the north), reports an annual average precipitation of 3,313 mm., an annual average temperature of 27.6 °C, an annual average low temperature of 21.7 °C, an annual average high temperature of 33.3 °C, and an annual average of 168 days of rainfall. The area, with an elevation of 30 m., has a flat topography and numerous marshes. The adjacent forest reserve consists of lowland dipterocarps such as *Shorea leprosula*, *Neobalanocarpus heimii*, etc. Geologically, the area is made up of sedimentary and metamorphic rock from the Silurian through Ordovician periods, and the soil is classified as acrisols under FAO/UNESCO classifications.

5) Methods

(1) Experimental Plots

In a clear-cut open land, experimental plots were set-up for each species of the five planting patterns (1, 2, 4, 8 or 16 alternating rows of each species). Within each experimental plot a permanent plot for data collection was set-up so as to have a 20-metre-wide buffer zone around it. These permanent plots were set-up so as to contain at least one hundred trees to be measured. See Table 58 for the planting pattern and size of each experimental plot, and Fig. 14 for the lay-out of each plot.

Table 58. The planting pattern and size of each experimental plot

Planting pattern	Size of experimental plot
1 alternating rows (A type)	27 rows/35 trees in each row; 100 x 105 m.
2 alternating rows (B type)	30 rows/33 trees in each row; 111 x 99 m.
4 alternating rows (C type)	28 rows/38 trees in each row; 104 x 114 m.
8 alternating rows (D type)	32 rows/33 trees in each row; 118 x 99 m.
16 alternating rows (E type)	48 rows/33 trees in each row; 178 x 99 m.

(2) Site Preparation

From September 1992 to January 1993, the trees in this secondary forest were felled, heaped and burned, and the site was prepared. The site was not cultivated. Although the initial plan called for the completion of site preparation by November 1992, the poor performance of the contractor resulted in a two-month delay.

(3) Planting Species

Four species were selected for planting: *Shorea leprosula*, *Shorea parvifolia*, *Neobalanocarpus heimii* and *Hopea odorata*. All these seedlings, purchased from the Forestry Department and private nurseries, had been collected in the wildings and nursed in the nurseries for 6 to 8 months.

(4) Planting Direction and Planting Spacing

Seedlings were planted in the east-west direction. Lines were spaced 3.7 m. apart and individual seedlings 3 m. apart, in accordance with the spacing of *Acacia mangium* man-made forest.

(5) Date of Planting

Planting was carried-out from January to May 1993. In spite of an original schedule of November to December 1992, poor performance of contractor resulted in significant delays in planting.

(6) Dates of Measurements

Survival rate and height growth were examined six months after planting (between July and November 1993). Survival rate and height growth were not examined one month after planting because of delays in experimental plot preparation.

6) Results

(1) Survival Rates

Table 59 shows the survival rates six months after the four species of dipterocarps were planted on a large (roughly 46 ha.) clear-cut open land. Other than *Hopea odorata*, which had a survival rate of 80.1%, the overall survival rate for each species was considerably low: *Shorea leprosula*, 16.0%; *Shorea parvifolia*, 25.1%; *Neobalanocarpus heimii*; 44.3%. Because of the sparse leaves and lack of vitality of seedlings of these three species, more are expected to die in the future, suggesting an extremely poor possibility of afforestation. Even the survival rate of *Hopea odorata* seedlings, currently a high 80%, is expected to drop in the future because of the seedlings' current lack of vitality. Nevertheless, it is not possible to reach conclusions about the possibility of afforestation of *Hopea odorata*, and further observation is necessary. The reason that survival rates were lower than in the 16-alternating row plot at Block-B (planting pattern E) despite nearly equal sunlight conditions is believed to be the large size of this clear-cut open land, which resulted in conditions (e.g., temperature, sunlight, soil, humidity and soil temperature) that even more detrimental to growth. Other factors conceivably related to these extremely low survival rates are listed below.

a. Insufficient hardening prior to planting, resulting in "sunburn" (4 species)
b. Trampling by cows (4 species)
c. Damage by leaf-eating insects (*Shorea leprosula* and *Shorea parvifolia*)

While it is the confluence of these various factors that is believed to have resulted in such low survival rates, the major factors were high temperatures and insufficient hardening. What only *Hopea odorata* had high survival rates despite no pre-planting hardening (as with the other three species) indicates that this species is much more resistant to high temperatures and harsh sunlight.

Table 59. Survival rates after six months of planting

Species	Planting pattern and survival rate (unit: %)					
	A (1)	B (2)	C (4)	D (8)	E (16)	Plot average
Shorea leprosula	19.7 (93/4)	12.1 (93/4)	25.4 (93/4)	6.7 (93/4)	16.8 (93/2)	16.0
Shorea parvifolia	32.2 (93/3)	20.4 (93/3)	14.8 (93/3)	47.7 (93/3)	32.2 (93/2)	25.1
Neobalanocarpus heimii	40.0 (93/4)	33.0 (93/4)	43.2 (93/4)	51.6 (93/4)	*48.3 (93/1)	44.3
Hopea odorata	77.4 (93/5)	75.4 (93/5)	69.6 (93/5)	85.9 (93/5)	85.2 (93/5)	80.1

Note: 1. ( ) indicate the year/month of planting.
2. Data obtained 7 months after planting is indicated with an asterisk (*).

(2) Height Growth

Table 60 shows the height growths after six months of planting and the height increments during these six months. Because of the extremely poor survival rates of the 3 species other than *Hopea odorata*, seedlings height after six months had actually dropped due to wilting. *Hopea odorata*, despite high survival rates, showed almost no growth, suggesting that the seedlings were barely alive.

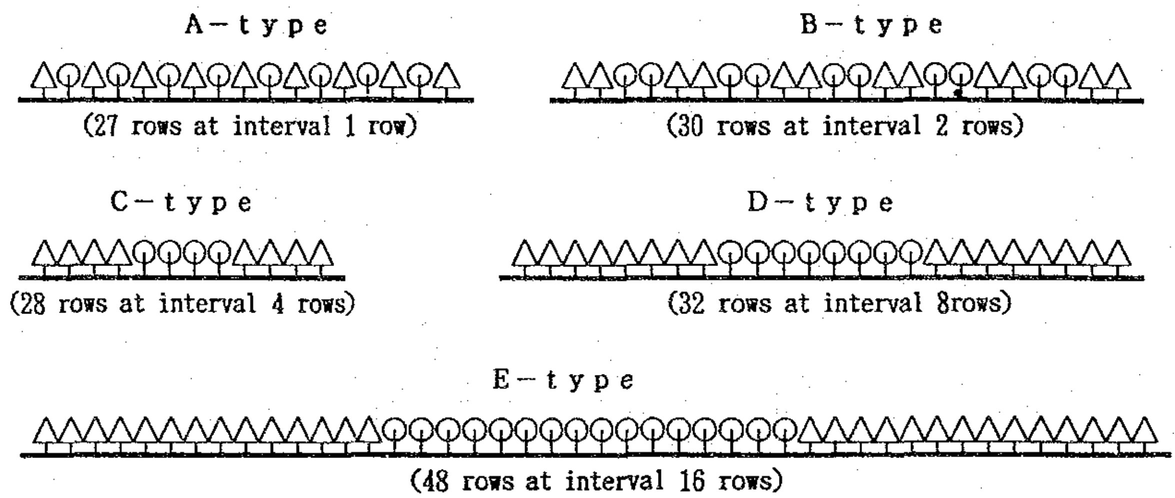
Table 60. Height growth after six months of planting

Species	Height growth (unit: cm)				
	A (1)	B (2)	C (4)	D (8)	E (16)
Shorea leprosula	53 (-6)	42 (-6)	48 (-2)	35 (-3)	36 (-2)
Shorea parvifolia	40 (-3)	43 (-4)	45 (+3)	51 (-5)	38 (-2)
Neobalanocarpus heimii	44 (-7)	28 (-6)	40 (-5)	32 (-5)	*35 (+2)
Hopea odorata	48 (-3)	49 (-2)	44 (+3)	42 (-2)	52 (-2)

Note: 1. ( ) indicate the increment of growth.
2. Data obtained 7 months after planting is indicated with an asterisk (*).
3. Seedlings height at planting was calculated by measuring 50 seedlings in each plot.

7) Consideration

The general environmental factors conceivably affecting tree growth were climatic conditions (e.g., temperature, amount of sunlight, humidity) and soil conditions (such as physical and chemical properties, moisture content, mycorrhiza and soil temperature). While it must still be determined which environmental factors had the greatest inhibitory effect on seedlings growth, a system for hardening seedlings in the nursery (which greatly effects survival rates immediately after planting) must be established to start with. We believe that the selection of high quality timber species suited to open land planting must also include nursing techniques, cost analysis and planting methods in order to determine the most practical multi-storied forest planting technique, on a comprehensive basis, for each species.



Remarks 1. △ indicates Fast Growing Species (e.g., *Acacia mangium*)

2. φ indicates High Quality Timber Species (e.g., *Dipterocarpaceae*)

3. Planting spacing : 3.0 m. X 3.7 m.

Fig. 14. Planting patterns at Chikus Block-A

Photo I. Growth of *Shorea leprosula* (six months after planting)

Photo II. Growth of *Shorea parvifolia* (six months after planting)

Photo III. Growth of *Neobalanocarpus heimii* (six months after planting)

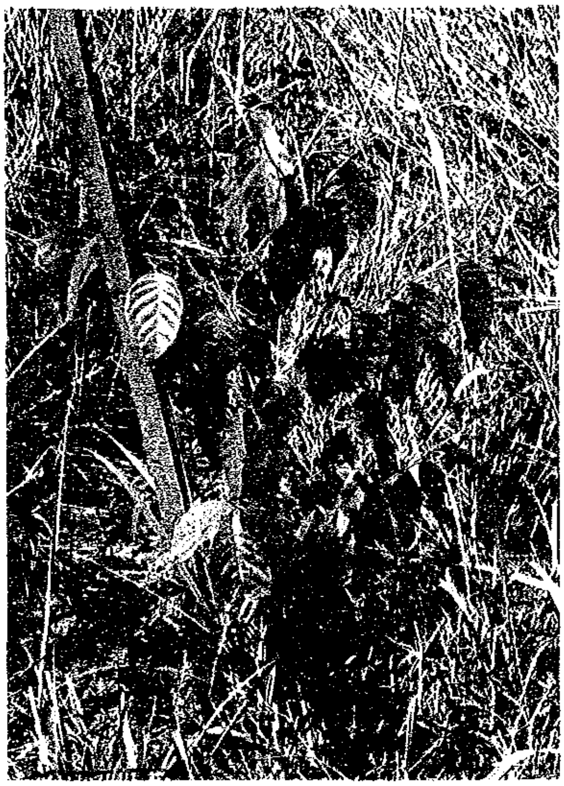


Photo IV. Growth of *Hopea odorata* (six months after planting)

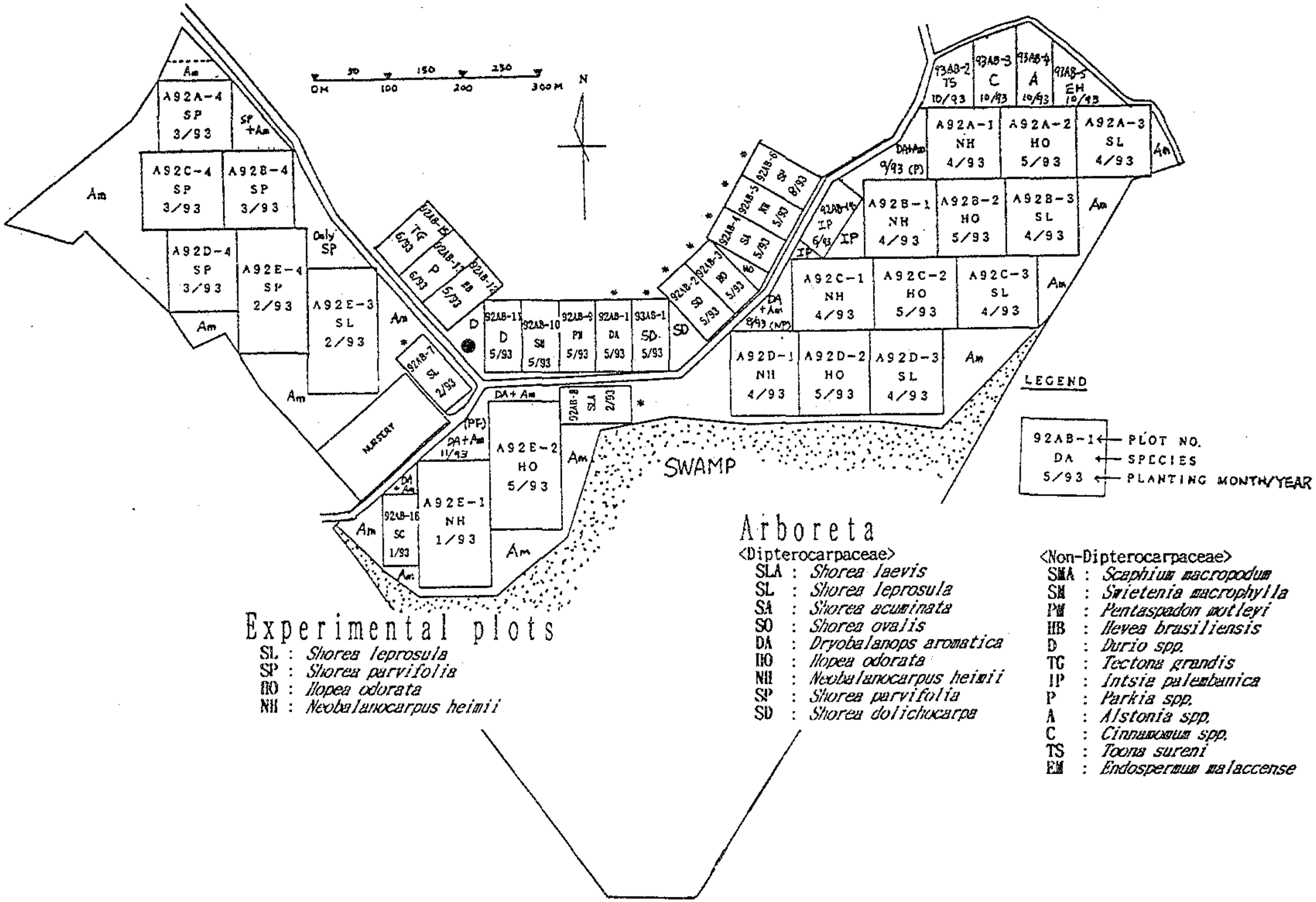


Fig. 15. Planting order in Block-A (as on 1 May, 1994)

4.2.2 The Experiment for Establishing Multi-Storied Forest in Existing Man-Made Forests

1) Introduction

This report is limited to item a. below, "Selecting Species Suitable for Multi-storied Forest Planting," and the survival rates and growth of three species of dipterocarps 12 months after planting.

2) Objectives

The objective of this experiment is to collect basic data for converting single-species man-made forests into multi-storied forests in tropical regions, and use this data to establish standards for multi-storied forest management system.

The experimental items of this experiment are as follows.

a. Selecting species suitable for multi-storied forest planting.
b. Silvicultural techniques for various types of multi-storied forests.
c. Cost analysis of various types of multi-storied forests.

3) Silvicultural Site Location

The site is located in the Chikus forest reserve, which is under jurisdiction of the South Perak District Forest Office of Perak State Forestry Department in Malaysia. This area, which originally consisted of lowland dipterocarps, was clear-cut between June 1988 and March 1989 to convert to *Acacia mangium* man-made forest, which was planted in November 1989 after two burnings in April of that year. As of November 1993 these *Acacia mangium* forests were four years old. Before designation of this site, two weedings and one climber cutting were carried out between December 1989 and April 1990, followed by one pruning of all trees in July 1991 (in which branches below each tree's halfway point were cut). The *Acacia mangium* cut from July to September 1992 had an average height of 13 m. and an average diameter at breast height of 14 cm.

4) Site Conditions

Under Köppen meteorological classifications, area is categorized in a tropical rainforest climate (Af). The Tapah weather station, the closest to the experimental site (approximately 10 km. to the north), reports an annual average precipitation of 3,313 mm., an annual average temperature of 27.6 °C, an annual average low temperature of 21.7 °C, an annual average high temperature of 33.3 °C, and an annual average of 168 days of rainfall. The area, with an elevation of 30 m., has a flat topography and numerous marshes. The adjacent forest reserve consists of lowland dipterocarps such as *Shorea leprosula* and *Neobalanocarpus heimii*, etc. Geologically, the area is made up of unconsolidated sedimentary rock from the Quaternary period, and the soil is classified as acrisols under FAO/UNESCO classifications.

5) Methods

(1) Experimental Plots

Experimental plots were set-up in line cutting *Acacia mangium* man-made forest (2 years and 10 months old) according to five different patterns: 1:1 (1 row cut, 1 row left; type A), 2:2 (B), 4:4 (C), 8:8 (D), and 16:16 (E); see Fig. 16. *Acacia mangium* were felled in two different directions: north-south, the direction in which they were planted; and east-west, perpendicular to the direction in which they were planted. Consequently, 10 plots were set-up for each species. Furthermore, within each plot a permanent plot which is for data collection surrounded by a 20-metre buffer zone was set-up so as to contain at least 100 trees for measurement. Table 61 shows the sizes and line widths of each experimental plot See Fig. 17 for a layout of each plot.

Table 61. The sizes and line width of each experimental plot

Felling pattern	Size of experimental plot	Line width
1 row cut; 1 row left (type A)	(27 rows/35 trees in each row; 100 x 105 m)	7.4 (6.0) m
2 row cut; 2 row left (type B)	(30 rows/33 trees in each row; 111 x 99 m)	11.1 (9.0) m
4 row cut; 4 row left (type C)	(28 rows/38 trees in each row; 104 x 114 m)	18.5 (15.0) m
8 row cut; 8 row left (type D)	(32 rows/33 trees in each row; 118 x 99 m)	33.3 (27.0) m
16 row cut; 16 row left (type E	(48 rows/33 trees in each row; 178 x 99 m)	62.9 (51.0) m

Note: Line widths not in parentheses are north-south felling direction; those in parentheses are east-west felling direction.

(2) Site Preparation

Felling and extracting of *Acacia mangium* were carried out from July to September 1992, with farming tractors (wheel-type) used for extracting, after which, from September to October 1992, site preparation was carried out in all lines. The soil was not cultivated.

(3) Planting Species

Three species were planted: *Shorea leprosula*, *Shorea parvifolia*, and *Neobalanocarpus heimii*. All seedlings were wildings and were nursed at nurseries for 6 to 8 months. These seedlings, purchased from Forestry Department and private nurseries, had average heights at planting of 44 cm. (*Shorea leprosula*), 40 cm. (*Shorea parvifolia*), and 28 cm. (*Neobalanocarpus heimii*).

(4) Planting Direction and Planting Spacing

Seedlings planted in the north-south direction were planted 3 metres apart in rows 3.7 metres apart (in accordance with upper layer *Acacia mangium* forest); those planted in the east-west direction were planted 3.7 metres apart in rows 3 metres apart. Seedlings were positioned between the stumps of felled *Acacia mangium*.

(5) Date of Planting

Planting was carried out from October to November 1992.

(6) Dates of Measurements

Measurements of growth were carried out in June to July (1st.) and October to November (2nd.). Relative illuminance, checked in October 1992 at the time of planting (1st.) and in July (2nd.) and October (3rd.) 1993, was calculated by integrating measurements taken on slightly overcast days by walking through exposed spots and the illuminance data collection plots for a 10-minute period between 12:30 and 14:30 (one hour before and after the sun crosses the meridian). Measurements were made at a height of roughly 1.3 metres using a Minolta T-1H digital illumination meter. Measurements for integrated illuminance were taken in the *Shorea leprosula* plots (in the north-south directions).

6) Results

(1) Line Width and Relative Illuminance

Table 62, the relationship between line width and relative illuminance, reveals the considerable effect on relative illuminance of line width and the state of pre-existing trees (i.e., tree height and canopy development). In non-felling plots, relative illuminance dropped as tree height increased - from 20.1% (at the time of planting in October 1992) to 18.3% eight months after planting (July 1993) and 6.8% twelve months after planting (October 1993). Although upper *Acacia mangium* canopy already nearly enclosed in October 1992, height growth resulted in greater volumes of leaves, further reducing relative illuminance. In type A, relative illuminance changed from 38.6% to 34.4% and 14.2%, and line width at the time of planting was 60% of tree height; in type B, from 65.4% to 62.2% and 22.9%, with a line width of 90% of tree height; in type C, from 71.8% to 66.8% and 42.8%, with a line width of 140% of tree height; in type D, from 93.2% to 88.7% and 68.1%, with a line width of 260% of tree height; and in type E, from 97.5% to 94.2% and 94.1%, with a line width of 480% of tree height.

In type A where line width was 6 - 7 metres, the canopy of *Acacia mangium* trees reached enclosure in roughly one year; in type B <east-west> (line width: roughly 9 m.), in roughly one and a half years; in type B <north-south> (line width: roughly 11 m.), enclosure is expected to occur within 2 to 3 years.

Table 62. The relationship between relative illuminance and line width

	Relative illuminance and pre-existing tree (Acacia mangium) height			
Plot (line width)	**Oct. 1992 (%)**	**Jul. 1993 (%)**	**Oct. 1993 (%)**	**Line width/ tree height Oct. 1992**
Non-felling plot	20.1	18.3	6.8	
1 row cut; 1 row left (A: 7.4 m)	38.6	34.4	14.2	0.6
2 row cut; 2 row left (B: 11.1 m)	65.4	62.2	22.9	0.9
4 row cut; 4 row left (C: 18.5 m)	71.8	66.8	42.2	1.4
8 row cut; 8 row left (D: 33.3 m)	93.2	88.7	68.1	2.6
16 row cut; 16 row left (E: 62.9 m)	97.5	94.2	94.1	4.8
Average tree height (m)	(13)	(17)	(18)	
Average diameter at breast height (c	(14)	(17)	(18)	

Note: 1. The figures for average tree height and average diameter at breast height for *Acacia mangium* represent averages for the six above plots.

(2) Line Width (Relative Illuminance) and Survival Rates

Although relative illuminance in the forest decreases as pre-existing trees grow, for all three species planted, survival rates and growth one year after planting were better in plots with narrow lines (where relative illuminance was between 30 and 70 percent) than in plots with wide lines (where relative light intensity was 90% or more). As suggested by Table 62, which shows the relationship between line width and pre-existing tree height in plots where relative illuminance immediately after line planting was 30 to 70 percent, a line width equivalent to 50% to 100% of tree height would seem optimum In plots E and D, where seedlings of all three species had fewer leaves and lacked vitality, survival rates are expected to drop further, while no significant drops in survival rates (barring disease, insects, or other damage) are expected in plots A, B, or C (see Table 63).

a. *Shorea leprosula*

One year after planting, survival rates exceeded 80% in plots A, B, C and D planted in the north-south direction and in plots A and B planted in the east-west direction. For both north-south and east-west planting directions, survival rates were highest in plot B (2-alternating row planting) and lowest in plot E, which had the widest line width.

b. *Shorea parvifolia*

One year after planting, survival rates exceeded 80% in plots A and B planted in the north-south direction and in plots A planted in the east-west direction. On days of high precipitation, water clogging was observed in north-south plots D and E and in east-west plots B and E. The root rot caused by this excessive moisture is viewed as one of the factors for poor survival rates.

c. *Neobalanocarpus heimii*

One year after planting, survival rates exceeded 80% in plot B planted in the north-south direction and in plot A planted in the east-west direction. Although it was reported that *Neobalanocarpus heimii* seedlings, because of their low resistance to direct sunlight and dryness, should be planted in spots with a certain amount of shade, 12 months after planting, survival rates were higher than expected in plot E (55% to 65%), where relative illuminance was highest. On days of high precipitation, water clogging was observed in north-south plot A and in east-west plot B. The root rot caused by this excessive moisture is viewed as one of the factors for poor survival rates.

Table 63. Line width (relative illuminance), felling direction and survival rates

Species	Planting direction	Months after planting	Survival rates (%)				
			A (1)	B (2)	C (4)	D (8)	E (16)
Shorea leprosula	North-south	8	85.3	99.0	91.9	83.0	74.3
		12	85.3	99.0	91.9	82.1	67.7
			0.0	0.0	0.0	-0.9	-6.6
	East-west	8	88.0	91.4	76.0	73.1	60.4
		12	88.0	89.3	75.0	70.1	54.7
			0.0	-2.1	-1.0	-3.0	-5.7
Shorea parvifolia	North-south	8	88.3	85.6	67.9	*56.4	*60.0
		12	86.2	84.6	65.1	*52.4	*53.9
			-2.1	-1.0	-2.8	-4.0	-10.1
	East-west	8	91.5	*71.2	74.0	58.7	*41.7
		12	87.9	*65.4	72.1	52.9	*37.1
			-3.6	-5.8	-1.9	-5.8	-4.6
Neobalanocarpus heimii	North-south	8	*78.1	86.5	82.3	69.2	68.7
		12	*77.1	86.5	79.8	64.2	64.7
			-1.0	0.0	-2.5	-5.0	-4.0
	East-west	8	96.6	*46.2	70.2	*64.1	59.4
		12	96.6	*41.4	67.3	*53.9	55.2
			0.0	-4.8	-2.9	-10.2	-4.2

Note: Plots where water clogging was observed on days of high rainfall are indicated with an asterisk (*).

(3) Line Width (Relative Illuminance) and Height Growth

Table 64 shows the relationship of line width to height growth. It was reported that dipterocarp seedlings growth is best in shaded areas (i.e., 30 to 70 percent relative illuminance and quite poor in open land and other locations in which they are exposed to strong sunlight, and in this experiment as well, the height growth of all three species was good in plots where relative illuminance was 30 to 70 percent, and best for all three species in B-type plots where every two rows were felled and replanted. The plot with the best growth for each species are as follows: B <east-west> (*Shorea leprosula*), 133 cm.; B <north-south> (*Shorea parvifolia*), 81 cm.; and B <north-south> (*Neobalanocarpus heimii*), 40 cm. Note that the growth on Shorea leprosula and Shorea parvifolia was considerably better than that of Neobalanocarpus heimii. Table 64, the heights of all three species 12 months after planting, indicates that the following plots had the highest average tree heights 12 months after planting: B <east-west> (*Shorea leprosula*), 177 cm.; B <north-south> (*Shorea parvifolia*, 121 cm.; and B <north-south> (*Neobalanocarpus heimii*), 68 cm., all of which were plots where every two rows were felled and replanted (i.e., B-type).

Table 64. Line width (relative illuminance) and height growth

Species	Planting direction	Average height and increment					
			A (1)	B (2)	C (4)	D (8)	E (16)
Shorea leprosula	North-south	Average height (0 m)	<44>	<44>	<44>	<44>	<44>
		Average height (12 m)	148	153	114	124	80
		Height increment in one year	(104)	(109)	(70)	(80)	(33)
	East-west	Average height (0 m)	<44>	<44>	<44>	<44>	<44>
		Average height (12 m)	146	177	131	107	98
		Height increment in one year	(102)	(133)	(87)	(63)	(54)
Shorea parvifolia	North-south	Average height (0 m)	<40>	<40>	<40>	*<40>	<40>
		Average height (12 m)	115	121	118	*86	85
		Height increment in one year	(75)	(81)	(78)	*(46)	(45)
	East-west	Average height (0 m)	<40>	<40>	<40>	<40>	<40>
		Average height (12 m)	117	*120	101	92	*90
		Height increment in one year	(77)	*(80)	(61)	(52)	(50)
Neobalanocarpus heimii	North-south	Average height (0 m)	*<28>	<28>	<28>	<28>	<28>
		Average height (12 m)	*64	68	66	57	56
		Height increment in one year	*(36)	(40)	(38)	(29)	(28)
	East-west	Average height (0 m)	<28>	*<28>	<28>	<28>	<28>
		Average height (12 m)	62	*63	61	51	56
		Height increment in one year	(34)	*(35)	(33)	(23)	(28)

Note: 1. The water clogging was observed on days of high rainfall are indicated with an asterisk (*).
2. "Average height (0 m.)" indicates the average height at planting and "Average height (12 m.)" the average height 12 months after planting.

(4) Planting Direction and Survival Rates

Comparing survival rates in plots D and E, where different planting directions significantly affected amounts and duration of sunlight, we see that for *Shorea leprosula*, survival rates in east-west plots were roughly 10% lower than in north-south plots. Although the effects of water clogging in plots of *Shorea parvifolia* and *Neobalanocarpus heimii* make accurate comparison impossible, east-west plots tended to have lower survival rates (see Table 63).

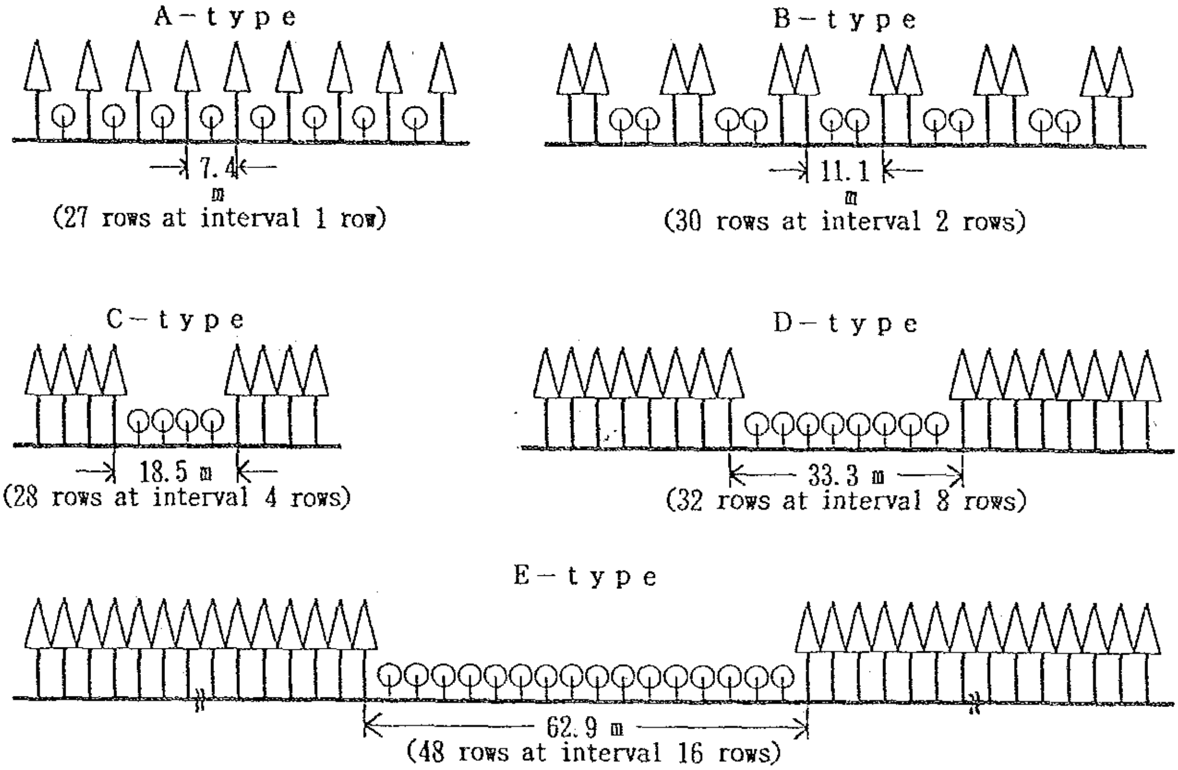
(5) Planting Direction and Height Growth

Comparing height growth in different planting directions, there were no clear differences (as of November 1993) in growth in plots D and E, where the different planting directions resulted in significantly different amounts and duration of sunlight.

7) Consideration

Summarizing the results 1 year alter planting, we see various trends in growth and survival rates among the three species. Height growth and survival rates were especially favourable in plots A B, and C (compared with plots D and E), suggesting that all three species are suited to line widths that result in a relative illuminance of 30 to 70 percent. Furthermore, it was considered that a line width roughly equivalent to tree height is optimum, i.e.., results in the desired relative illuminance of 30 to 70 percent.

As relative illuminance is the only environmental factor effecting tree growth studied thus far, we must study the various climatic conditions (e.g., temperature, sunlight and humidity) and soil conditions (such as physical and chemical properties, moisture, mycorrhiza, and soil temperature) and consider their relationship to one another, while also examining silvicultural techniques (for trees planting among pre-existing tree planted in various patterns), cost analysis and silvicultural techniques for pre-existing trees in order to develop, for each species, the most comprehensively practical method for the planting of multi-storied forests.



Remarks:
1. ⇧ indicates Fast Growing Species (e.g., *Acacia mangium*)
2. φ indicates High Quality Timber Species (e.g., *Dipterocarpaceae*)
3. Planting spacing: 3.0 m. x 3.7 m.
4. *Acacia mangium* in Block-B were planted in September - December 1989.

Fig. 16 Planting patterns at Chikus Block-B

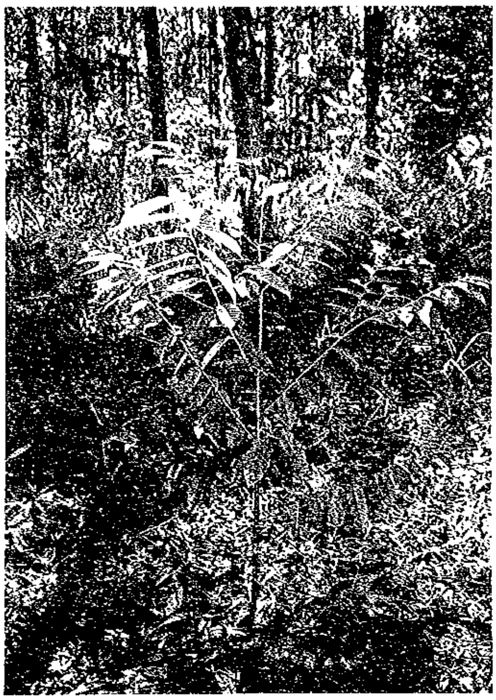


Photo I. Growth of *Shorea leprosula*
(planted in two-row lines,
12 months after planting)

Photo II. Growth of *Shorea parvifolia*
(planted in two-row lines,
12 months after planting)

Photo III. Growth of *Neobalanocarpus heimii*
(planted in two-row lines; 12 month after planting)

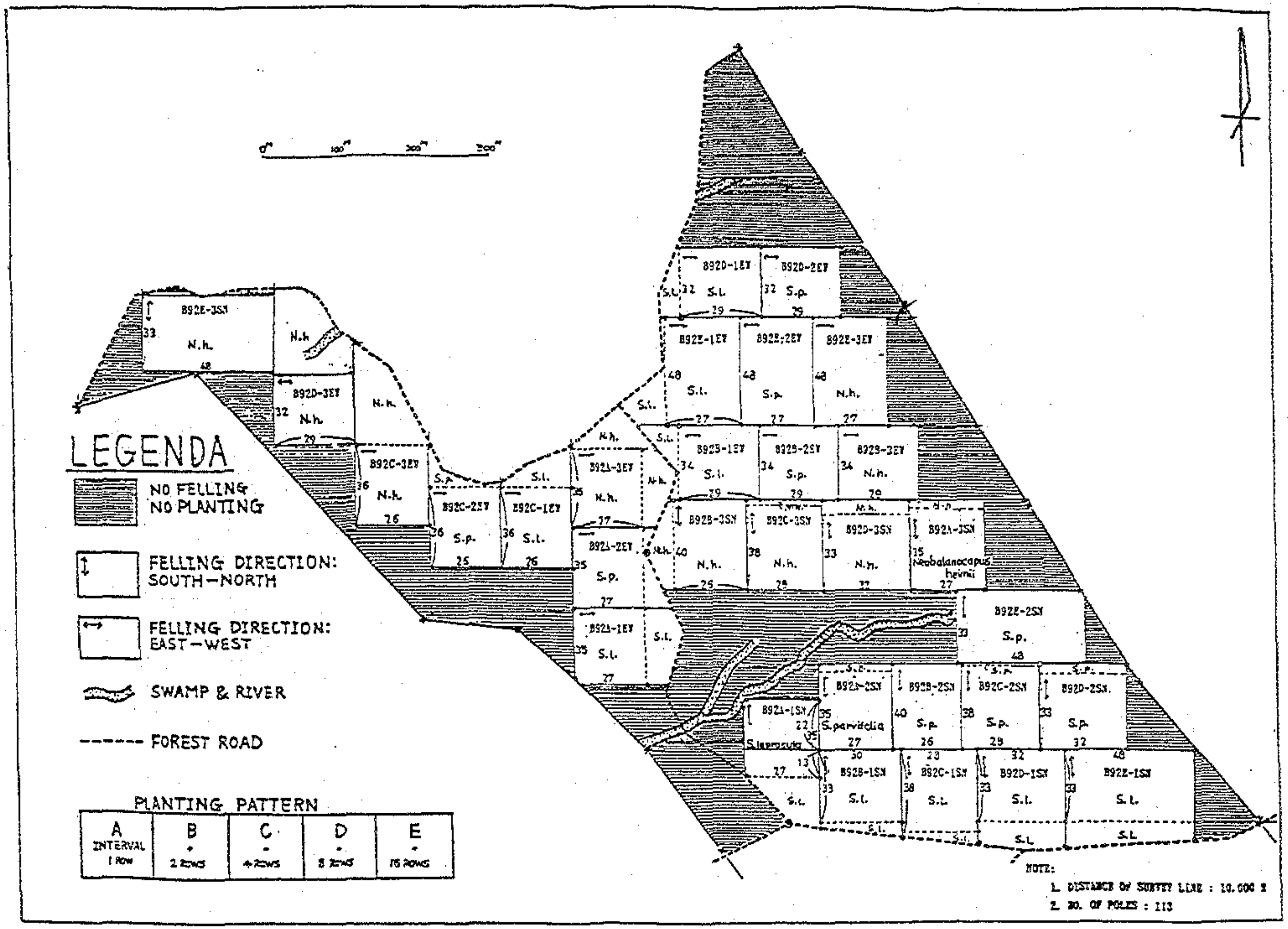


Fig. 17. Planting order in Block-B

4-2-3 The Experiment for Establishing Multi-Storied Forest In Logged-Over Natural Forest

1) Introduction

Although experimental plot preparations began in August 1993, from October to December of that year unusually heavy rainfall (the heaviest in decades) washed out project site access roads and caused bridges to collapse in Bukit Kinta, thus delaying planting at this site. As only 1.03 of the 6.61 hectares planned for 1993 had been planted as of February 1994, this report is limited to the experiment design.

2) Objectives

The objective of this experiment is to carry out the line planting of dipterocarps and other indigenous high-quality timber species in logged-over natural forests in order to determine the effects of soil and light conditions of tree growth, and to collect basic data on silvicultural techniques and cost analysis, tending and regeneration to be applied to the establishment of multi-storied forests management system.

3) Location

This experimental site is located in the Bukit Kinta forest reserve, part of compartment 146, which is under jurisdiction of the Kinta/Manjung District Forestry Office of the Perak State Forestry Department in Malaysia. Compartment 146, whose standing timber has been sold along with that in adjacent compartment 147, was selective felled from April to November 1990 under a Selective Management System. While no data is available on timber volumes from compartment 146 alone, a combined average of 6 trees per hectare were felled in each, yielding 39 $m.^3/ha.$ of timber for the cruising and 33 $m.^3/ha.$ for commercial use; average diameter at breast height was 81 cm. This felling resulted in large and small gaps, and in the 2-to-3-year period before the commencement, in January 1994, due to site preparations for this experiment, a secondary forest consisting of bamboo, ferns and palms had regenerated to a considerable degree, bamboo reaching heights of over 10 metres and the secondary forest itself a height of 4 to 5 metres.

4) Site Conditions

Classified under the Köppen system as having the climate of a tropical rainforest (Af), the area around the experimental site is an overall steep mountainous region, having gradients of 20 to 45 degrees and lying at an elevation of 300 to 600 metres. The forest type is highland dipterocarp, consisting of large numbers of *Shorea curtisii*, *Shorea parvifolia*, *Shorea leprosula*, and other species. Although no meteorological data on this region is available, the Tapah weather station located at an elevation of 35 m. approximately 60 km. (linearly) south-southwest of the Bukit Kinta site, reports an annual average precipitation of 3.313 mm., an annual average temperature of 27.6 °C, an annual average low temperature of 21.7 °C, an annual average high temperature of 33.3 °C, and an annual average of 168 days of rainfall. Geologically this area is comprised of granite, with advanced weathering resulting in large amounts of clay predecessor material. The soil category is not known.

5) Methods

(1) Experimental Plots

Experimental plots will be set-up in gaps of varying topographic conditions (i.e., soil conditions) and sizes (i.e., of varying light conditions) within this logged-over natural forest. Roughly 50 hectares of planting is scheduled over a 4-year period (see Table 65).

Table 65. Experiment plan

Parameter/Year	1993	1994	1995	1996	Total
Experimental plots area (ha.)	6.6	(14)	(20)	(10)	(50.6)
Number of species to be planted	1	(1)	(2)	(1)	(5)

Note: Figures in parentheses represent planned results.

(2) Measuring Items

a. Tree growth
b. Light conditions (relative illuminance)
c. Site soil conditions
d. The appearance and survival of naturally regenerating trees (high-quality timber species) following site preparation.
e. The growth of naturally regenerating trees (high-quality timber species) prior to site reparation.

Measurements of tree growth, light conditions, soil conditions, and the growth of naturally regenerating trees (high-quality timber species) prior to site preparation are scheduled for one month after planting (1st.) and every six months after planting (2nd. and beyond). Soil conditions will be investigated before planting. For investigations of the appearance and survival of naturally regenerating trees (high quality timber species) following site preparation, plots with usable timber species of pre-existing trees likely to yield suitable volumes of seeds will be selected, and measurements begun once seedlings appear.

(3) Planting Species

Of the many high-quality timber species growing in Bukit Kinta, five or so species with readily available seedlings will be selected.

(4) Site Preparation

a. In site preparation, all naturally regenerating trees (including seedlings/saplings and small-, medium-, and large-diameter trees) of high-quality timber species (i.e., the 43 preferred species listed among those species designated for "the regeneration sampling list of 1974" in the "Pocket Check List of Timber Trees," Malayan Forest Record No. 17) will generally be left.
b. In addition to these preferred species, all trees with a diameter at breast height of 5 cm. or more will also be left in order to reduce felling costs and avoid rapid environmental changes.

c. Felled trees, bamboo, palms and other vegetation with be collected along contour lines so as not to hamper planting.

(5) Planting Direction and Planting Spacing

Generally, seedlings will be planted along contour lines 2.5 metres apart in rows 5 metres apart, resulting in a density of 800 trees/ha.

6) An Overview Of 1993 Experimental Plots

(1) Species Planted And Seedlings Characteristics

The species planted was *Shorea parvifolia*, the seedlings of which were nursed at Chikus nursery from seeds collected from a highland dipterocarp forest in the Bentong region of the state of Pahang in March 1993. These seedlings were 9 months old at planting and had an average height of 32 cm.

(2) Locations And Conditions Of Area

Planting involves 7 plots totalling 6.61 hectares in surface area (Fig. 18.). All seven plots are situated on. a north-eastern slope, with Plots D, F and G in the lower section of the slope (a ravine), near which the Lu river flows. Plot A is located on a ridge at the top of the slope, with plots B, C, and E located below the crest of the ridge.

(3) Date Of Planting

Plot D was planted in February 25, 1994.

Photo I. ***Shorea parvifolia*** **one month after planting in a gap (plot D) in a selective cut natural forest**

Photo II. ***Shorea parvifolia*** **seedlings one month after planting (plot D)**

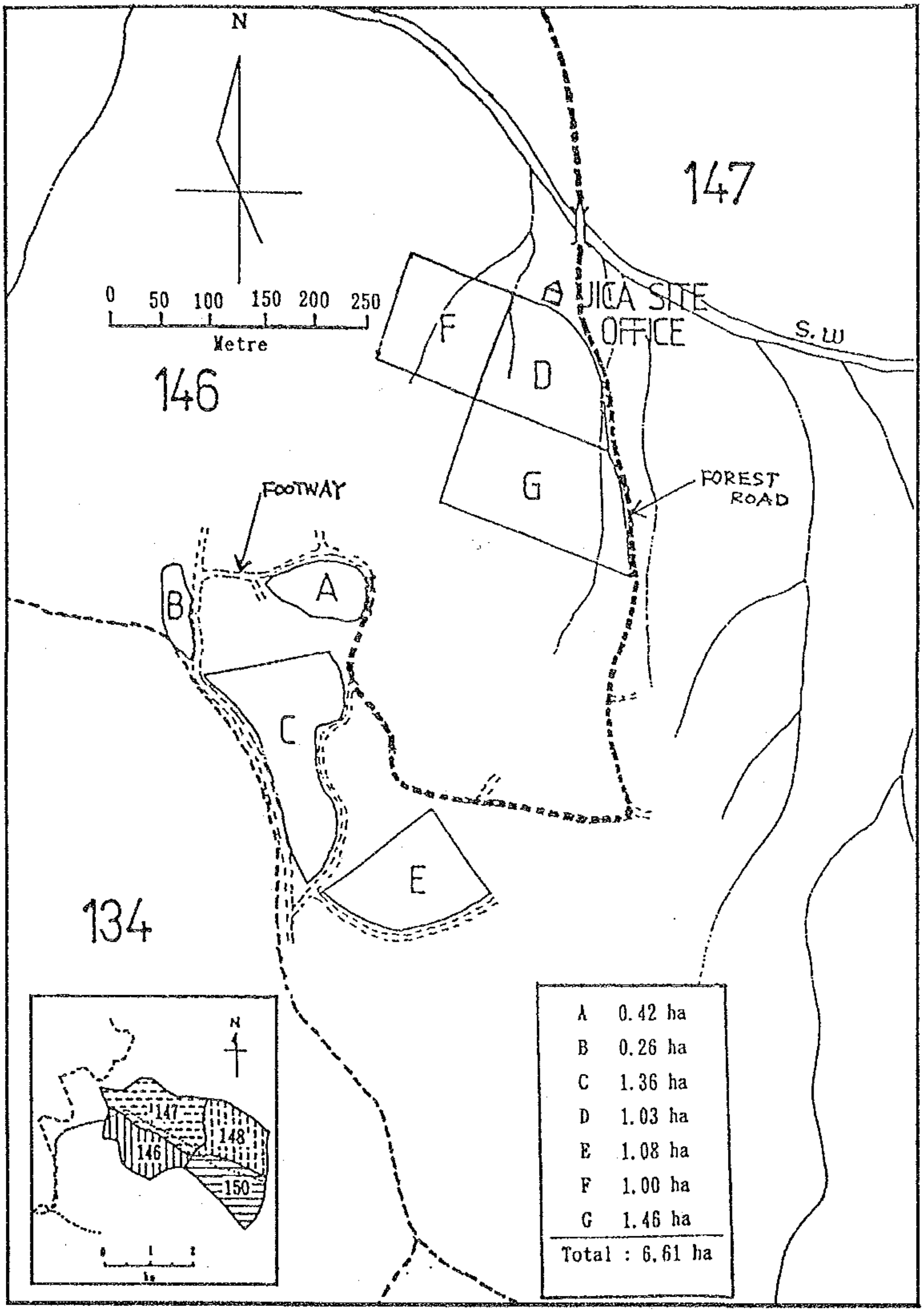


Fig.18. Proposed planting area in Bukit Kinta

4-2-4 The Experiment for Establishing Arboretum

1) Introduction

This report concerns data collected so far on the survival rates and growth of the 21 species (9 dipterocarps and 12 non-dipterocarps) of seedlings planted up to late December 1993.

2) Objectives

The objective of this experiment is to establish an arboretum of roughly 50 species of trees (including indigenous species and exotic species) in order to get a fundamental understanding of the physiological and ecological characteristics of these species and collect fundamental data to be applied to the selection of species for the future planting of multi-storied forests.

3) Site Location

The test site is located in the Chikus forest reserve, which is under jurisdiction of the South Perak District Forest Office of Perak State Forestry Department in Malaysia. This area, which originally consisted of lowland dipterocarps, was clear-cut from June 1988 to March 1989 to convert the area to high-productivity *Acacia mangium* man-made forest. During the subsequent 2-and-a-half-year period up to October 1992 during which this area laid idle, a secondary forest predominated by *Macaranga* spp. (3 to 4 metres high) and other pioneer species had regenerated.

4) Site Conditions

Under Köppen meteorological classifications, this area is categorized in a tropical rainforest climate (Af). The Tapah weather station, the closest to the experimental site (approximately 10 km. to the north), reports an annual average precipitation of 3,313 mm., an annual average temperature of 27.6 °C, an annual average low temperature of 21.7 °C, an annual average high temperature of 33.3 °C, and an annual average of 168 days of rainfall. The area, with an elevation of 30 m., has a flat topography and numerous marshes. The adjacent forest reserve consists of lowland dipterocarps such as Shorea leprosula, Neobalanocarpus heimii, etc. Geologically, the area is made up of sedimentary and metamorphic rock from the Silurian through Ordovician periods, and the soil is classified as acrisols under FAO/UNESCO classifications.

5) Methods

(1) Experimental Plots

Experimental plot at least 0.48 hectares (48 m. x 99 m.) in size and capable of containing at least 429 trees (at a density of 900 trees/ha.) was set-up for each species in open land (clear-cut site). At the centre of each plot a permanent plot with a minimum capacity of 100 trees was set-up for measurement. The first measurement of survival rates, tree height, and diameter (at a height of 5 cm. above ground level) is scheduled for one month after planting, and subsequent measurements for every 6 months after planting. In addition, personnel will periodically inspect the trees each month after planting to determine, primarily, physiological and ecological characteristics and the presence of any disease or insect problems.

(2) Planting Species

Roughly 50 species are scheduled for planting, including indigenous and exotic species.

(3) Planting Direction And Planting Spacing

Although no special planting direction is planned, seedlings will be planted 3 m. apart in rows 3.7 metres apart, in accordance with the planting spacing of *Acacia mangium* man-made forest

6) Results

(1) Planting Species and Site Preparation

By late December 1993, 21 species (9 dipterocarps and 12 non-dipterocarps) had been planted (Table 66), prior to which, from October 1992 to January 1993, the secondary forest was cleared, the timber collected and burned, and the site was prepared. The soil was cultivated with four species only: *Toona sureni*, *Cinamomum* spp., *Alstonia* spp., and *Endospermum malaccense*. Site preparation was scheduled for completion by November 1992, but the poor performance of contractor resulted in a two-month delay.

Table 66. Species of seedlings planted in the arboretum

Dipteropcarps	Detail of seedlings (region of origin / seedling or wilding / procured from <location>)
1. *Hopea odorata*	Negeri Sembilan (Mantin) / wilding / State Forestry Department nursery <Mantin>
2. *Shorea leprosula*	Perak (Chikus) / wilding / directly managed production <Chikus>
3. *Shorea dolichocarpa*	Pahang (Jerantut) / wilding / State Forestry Department nursery <Raub>
4. *Shorea ovalis*	Pahang (Jerantut) / wilding / State Forestry Department nursery <Raub>
5. *Shorea acuminata*	Negeri Sembilan (Sg. Menyala, PD) / wilding / State Forestry Department nursery <Mantin>
6. *Hopea odorata*	Terengganu (Kuala Berang private nursery) / wilding / private nursery <Kuala Berang>
7. *Neobalanocarpus heimii*	Terengganu (Kuala Berang) / seedling and wilding / private nursery <Kuala Berang>
8. *Dryobalanops aromatica*	Selangor (Kanching) / seedling / private nursery <Banting>
9. *Shorea parvifolia*	Perak (Manong) / wilding / State Forestry Department nursery <Manong> Negeri Sembilan (Sg. Menyala, PD) / wilding / State Forestry Department nursery <Mantin>

Non-dipteropcarps	Detail of seedlings (region of origin / seedling or wilding / procured from <location>)
1. *Scaphium macropodum*	Negeri Sembilan (Pelangai) / wilding / State Forestry Departmen nursery <Mantin>
2. *Durio spp.*	Kedah (Kota Setar) / wilding / private nursery <Kota Setar>
3. *Swietenia macrophylla*	Negeri Sembilan (Jelebu) / seedling and wilding / State Forestry Department nursery <Mantin>
4. *Hevea brasiliensis*	Selangor (RRIM, Sg. Buluh) / seedling and wilding / State Forestry Department nursery <Mantin>
5. *Pentaspadon motleyi*	Perak (Chikus) / wilding / directly managed production <Chikus
6. *Tectona grandis*	Perak (Gerik) / stamp / State Forestry Department nursery <Gerik>
7. *Parkia spp.*	Kedah (Kota Setar) / seedling / private nursery <Kota Setar>
8. *Intsia palembanica*	Perak (Gerik) / wilding / State Forestry Department nursery <Gerik>
9. *Toona sureni*	Kedah (Kota Setar) / seedling / private nursery <Kota Setar>
10. *Cinamomum spp.*	Kedah (Kota Setar) / seedling / private nursery <Kota Setar>
11. *Alstonia spp.*	Selangor (Sg. Buluh) / seedling / private nursery <Sg. Buluh>
12. *Endospermum malaccense*	Negeri Sembilan (Mantin) / seedling / State Forestry Department nursery <Mantin>

Note: Both *Neobalanocarpus heimii* and *Swietenia macrophylla* were delivered mixed together seedlings and wildings.

(2) Date of Planting

See Table 67 for the planting date. The 16 species originally scheduled for 1992 were planted between January and August 1993 after a considerable delay due to poor contractor performance. Of the 16 species scheduled for 1993, one was planted in May and 4 in October 1993.

(3) Date of Measurements

Because of shortage of manpower and other factors, the first measurement, of the 16 species planted between January and June 1995 were carried-out all at once in August 1993, instead of one month after planting as originally planned. Measurements scheduled for 6 months after planting and beyond were carried-out as scheduled, as were measurements of plots planted since August 1993, which contained five species.

7) Discussion

(1) Survival Rates

Overall, survival rates were extremely poor. Only two of the 17 species planted at least six months ago had survival rates exceeding 80%: dipterocarp *Hopea odorata* (83% at 12 months) and non-dipterocarp *Tectona grandis* (95% at 6 months). Of these, *Tectona grandis* is a light-demanding species that normally grows well in harsh sunlight, and although some lost all leaves because of excessive sunlight, its high survival rate is believed to be due to its suitability to planting as a stamp, and to its ability to generate new leaves. It was reported that *Shorea leprosula*, said to have relatively high resistance to drying even in harsh sunlight, had an extremely poor survival rate (14%). This is believed to be due primarily to insufficient hardening before planting and to inadequate nursing (these were large [66 cm.] wildings). The survival rate of *Hevea brasiliensis* (Para rubber tree), also generally suited to open land, was very poor, 16%, conceivably because of epinasty and cattle grazing. Factors contributing to these low survival rates for nearly all species include climatic conditions, soil conditions and the following:

a. "Sunburn" (in all species) due to insufficient hardening prior to planting

b. Trampling by cows (in all species)

c. Damage by leaf-eating insects (*Shorea* spp.)

Thus, the coinciding of these factors is believed to be responsible for these extremely poor survival rates. The high survival rate of *Hopea odorata* despite inadequate hardening (as with the other tree species) reflects a greater resistance to harsh sunlight and dryness than the other dipterocarps.

Table 67. Survival rates of each species in arboretum

	Months after planting (unit: %)												Date
Dipteropcarps	1	2	3	4	5	6	7	8	9	10	11	12	planted
1. *Hopea odorata*							85		84			83	Feb. 1993
2. *Shorea leprosula*							16					14	Feb. 1993
3. *Shorea dolichocarpa*				56		48							May 1993
4. *Shorea ovalis*				50		37							May 1993
5. *Shorea acuminata*				34		21							May 1993
6. *Hopea odorata*				84		75							May 1993
7. *Neobalanocarpus heimii*				63		58							May 1993
8. *Dryobalanops aromatica*				44		34							May 1993
9. *Shorea parvifolia*	90					36							Aug. 1993
	Months after planting (unit: %)												**Date**
Non-dipteropcarps	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**planted**
1. *Scaphium macropodum*								51		40		28	Jan. 1993
2. *Durio spp.*				70		65							May 1993
3. *Swietenia macrophylla*				53		44							May 1993
4. *Hevea brasiliensis*				35		16							May 1993
5. *Pentaspadon motleyi*				30		22							May 1993
6. *Tectona grandis*			99			95							Jun. 1993
7. *Parkia spp.*			61			33							Jun. 1993
8. *Intsia palembanica*			50			39							Jun. 1993
9. *Toona sureni*	97												Oct. 1993
10 *Cinamomum spp.*	96												Oct. 1993
11 *Alstonia spp.*	95												Oct. 1993
12 *Endospermum malaccense*	91												Oct. 1993

(2) Height Growth

As shown in Table 68 (height growth at the time of measurement either 1 year or six months after planting), overall growth after planting was not good. In fact, only five of the 17 species planted showed any growth after planting: *Pentaspadon motleyi* (5 cm. in six months), *Hopea odorata* (4 cm. in six months), *Tectona grandis* (4 cm. in six months), and *Dryobalanops aromatica* (2 cm. in six months). *Hopea odorata* and *Tectona grandis* had high survival rates and were found to have grown since planting while *Pentaspadon motleyi* and *Dryobalanops aromatica* had survival rates (25% and 41%), which, although low reflect the steady growth of surviving seedlings. Survival rates and growth are expected to worsen among species with already low survival rates because of non-existent of height growth and low seedlings height due die-back and wilting at top shoot.

Table 68. Height growth

Dipterocarps	Months after planting 1	2	3	4	5	6	7	8	9	10	11	12	Height increment (Unit: cm)
1. *Hopea odorata*	(64)						66		68			71	+7 (12 months)
2. *Shorea leprosula*	(66)						61					30	-36 (12 months)
3. *Shorea dolichocarpa*	(67)			66		64							-3 (6 months)
4. *Shorea ovalis*	(72)			68		62							-10 (6 months)
5. *Shorea acuminata*	(59)			57		53							-6 (6 months)
6. *Hopea odorata*	(30)			31		34							+4 (6 months)
7. *Neobalanocarpus heimii*	(53)			51		47							-6 (6 months)
8. *Dryobalanops aromatica*	(39)			40		41							+2 (6 months)
9. *Shorea parvifolia*	44					41							-3 (6 months)
Non-dipteropcarps	**Months after planting 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Height increment (Unit: cm)**
1. *Scaphium macropodum*	(43)							39		39		32	-11 (12 months)
2. *Durio spp.*	(74)			73		73							-1 (6 months)
3. *Swietenia macrophylla*	(59)			57		53							-6 (6 months)
4. *Hevea brasiliensis*	(54)			42		38							-17 (6 months)
5. *Pentaspadon motleyi*	(19)			22		25							+6 (6 months)
6. *Tectona grandis*	(21)					25							+4 (6 months)
7. *Parkia spp.*	(45)		23			40							-5 (6 months)
8. *Intsia palembanica*	(69)		45			61							-8 (6 months)
9. *Toona sureni*	52		68										-
10 *Cinamomum spp.*	55												-
11 *Alstonia spp.*	30												-
12 *Endospermum malaccense*	44												-

Note: 1. Heights after one month in parentheses are average heights calculated from the random sampling of 50 seedlings in the corresponding plot.
2. Height increment is the difference between the heights recorded at the time of the first measurement (1 month after planting) and the most recent measurement.

8) Consideration

The many general environmental factors that affect seedlings growth include climatic conditions (e.g., temperature, sunlight, and humidity) and soil conditions (such as physical and chemical properties, moisture, mycorrhiza and soil temperature). We must consider which of these factors most inhibit seedlings growth and develop a system for hardening in the nursing stage, which is a major determinant of post-planting survival rates.

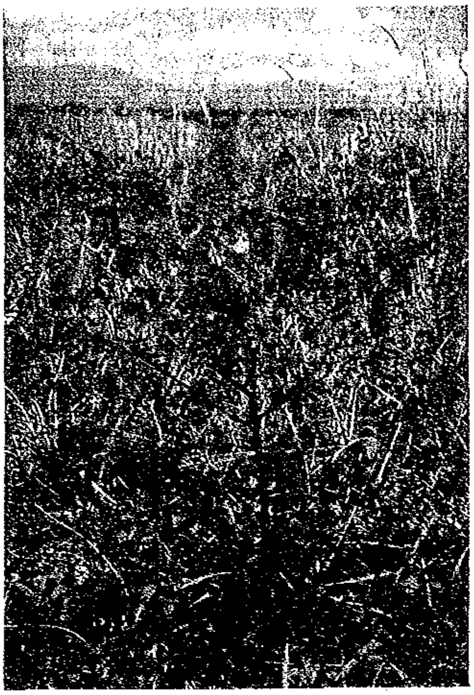


Photo I. ***Hopea odorata***
(1 year after planting)

Photo II. ***Neobalanocarpus heimii***
(6 months after planting)

Photo III. ***Tectona grandis***
(6 months after planting)

Photo IV. ***Durio*** **spp.**
(6 months after planting)

4-2-5 Soil Cultivation and Fertilization Experiment

1) Introduction

As this experiment has been begun only recently, this report is limited to objectives, data obtained so far; considerations and conclusions will be suspended until additional data becomes available.

2) Objectives

The objective of this experiment is to determine the effect of soil cultivation and fertilization on the initial survival rates and subsequent growth of seedlings planted in large scale open land and other bare locations. Because of the harsh sunlight in tropical regions, many seedlings planted in bare fields wither and die due to water stress caused by high temperatures, dryness and other factors, while the generally large scale and poor location of commercial plantation for timber tend to be unconducive to proper nursing and maintenance.

Although healthy, robust seedlings capable of withstanding these harsh conditions are thus an important prerequisite for seedlings nursing. inadequate quality control and short supplies (especially of high-quality timber species) in seedlings nursing of Peninsular Malaysia have led to the planting of inferior seedlings and thus in many cases of poor performance in plantation projects. Consequently, it is necessary to determine whether it would be possible to enhance the survival rates of seedlings of consistent quality under current conditions by fertilizing and improving the physical properties of soil to promote root development.

3) Location

The site is located in the Chikus forest reserve, which is under jurisdiction of the South Perak District Forest Office of Perak State Forestry Department in Malaysia. This area, which originally consisted of lowland dipterocarps was clear-cut from June 1988 to March 1989 to convert the area to high-productivity *Acacia mangium* man-made forest. During the subsequent 2-and-a-half-year period, up to October 1992, during which this area laid idle, a secondary forest predominated by *Macaranga* spp. (2 to 3 metres high) and other pioneer species had regenerated.

4) Site Conditions

Under Köppen meteorological classifications, this area is categorized in a tropical rainforest climate (Af). The Tapah weather station, the closest to the experimental site (approximately 10 km. to the north), reports an annual average precipitation of 3,313 mm., an annual average temperature of 27.6 °C, and an annual average low temperature of 21.7 °C, an annual average high temperature of 33.3 °C, and an annual average of 168 days of rainfall. The area, with an elevation of 30 m., has a flat topography and numerous marshes. The adjacent forest reserve consists of lowland dipterocarps such as *Shorea leprosula, Neobalanocarpus heimii* and etc.

Geologically this area is comprised of sedimentary and metamorphic rock from the Silurian through Ordovician periods, and the soil is classified as acrisols under FAO/UNESCO classifications.

5) Methods

(1) Experimental Plots

In the three plots set-up (a control plot, cultivated and unfertilized plot, and cultivated and fertilized plot), a high-quality timber species and fast-growing species (both used in this project) were mix-planted in alternate rows. See Table 69 for the planting area and number of trees.

Cultivation was carried out twice with a farm tractor. The second time, the soil was cultivated in the direction perpendicular to that of the first cultivation. The depth of cultivation was roughly 30 cm. For each *Dryobalanops aromatica* seedling 150 grams of fast-acting compound fertilizer (containing N, P and K at a ratio of 15:15:15) was used. Each 150-gram dose was evenly divided among four 5-cm.-deep holes dug at a radius of 15 cm. from the seedling. Seedlings in the fertilized plot were fertilized in this manner every three months for the first year.

Table 69. Experimental plot

Plot	Planting area (ha)	Number of seedlings
a. Control plot (uncultivated and unfertilized)	0.52	150
b. Cultivated and unfertilized plot	0.74	150
c. Cultivated and fertilized plot	0.98	160

(2) Planting Species

Alternating rows of *Dryobalanops aromatica* (Kapur) and *Acacia mangium* were planted simultaneously. Each row was 3.7 m. apart, and seedlings in each row 3.0 m. apart.

(3) Date of Planting

Planting was carried out under the following schedule in order to synchronize it with commemorative planting by visitors.

a. Control plot (uncultivated and unfertilized): August 25, 1993
b. Cultivated and unfertilized plot: September 16, 1993
c. Cultivated and fertilized plot: November 9, 1993

(4) Date of Measurements

The first measurement of the survival rate, height and base diameter of *Dryobalanops aromatica* only was carried out one month after planting, with subsequent measurement of the same items scheduled for every three

6) Results

(1) Survival Rates and Height Growth

As shown in Table 70 the survival rate after three months was 91% in the cultivated and fertilized plot, 72% in the cultivated and unfertilized plot, and 51% in the control (uncultivated and unfertilized) plot. In the control plot this survival rate had dropped to 29%, by the sixth month. Although the cultivated and fertilized plot currently displays good growth, further data collection is necessary. The main reason for low heights is wilting at the top shoot.

Table 70. Survival rates and height growth

Unit: (%), (cm.)

		1	3	6
a. Control plot (uncultivated and unfertilized)	Survival rate	83	51	29
	Height	(49)	(49)	(47)
b. Cultivated and unfertilized plot	Survival rate	93	72	
	Height	(41)	(43)	
c. Cultivated and fertilized plot	Survival rate	99	91	
	Height	(52)	(54)	

Note: This data is for *Dryobalanops aromatica* only.

Photo: A *Dryobalanops aromatica* seedling in the cultivated and fertilized plot three months after planting

4-2-6 Results Of Investigations Of Remaining Trees, Etc., In Selectively Logged-Over Natural Forest

1) The Purpose Of This Investigation

The section was scheduled for planting in 1993 fiscal year as part of this project; current progress and an overview of the plantation plan are as covered in previous pages.

In any tree felling in Permanent Forest Reserve under jurisdiction of the State Forestry Department, it is the policy of the Malaysian government to perform a pre-felling inventory two to three years before felling and a post-felling inventory two to three years after felling.

However, because of inadequate budgetary allocations from the Forestry Department, as well as other reasons, it causes low percentage of these Pre-Felling inventories carried out to be lower than targeted.

Due to this factor, the data needed in enrichment planting and other experiments were not available.

Therefore, it was decided to determine the state of the forest before felling from data of harvest surveys carried out by the Forestry Department before felling, and to perform new post-felling investigations to determine the current state of the forests.

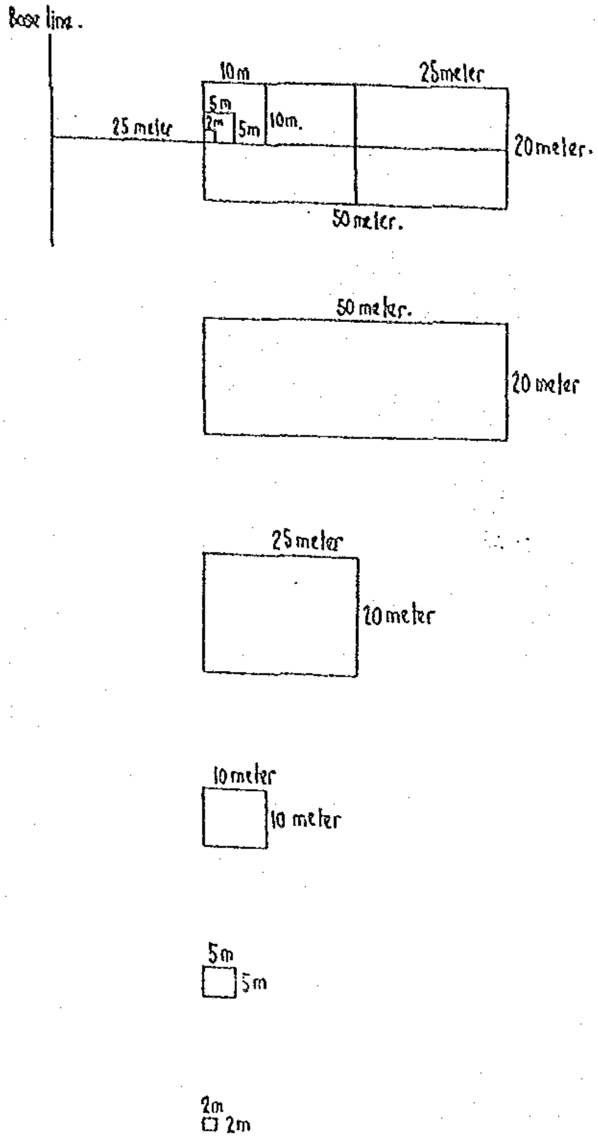
2) Inventory Schedule And Implementor

Forest Inventory & Management Sdn. Bhd., a Malaysian commercial inventory firm with a broad spectrum of experience in post-felling inventories and other forestry matters was engaged in February, 1993 to do a Post-Felling inventory on this study area.

3) Plot Selection

Inventory plots, each comprised of five differently shaped rectangular components (50 x 20 m., 25 x 20 m., 10 x 10 m., 5 x 5 m. and 2 x 2 m.), were established at even intervals throughout the entire compartment (125.55 hectares); see Figs. 19 and 20.

A total of 118 plots were inventoried, representing roughly 9% of the total felling area of the compartment: (50 m. x 20 m. x 118 x 100/125.55 x 10,000 $m.^2$ = 9.3%).



Main quadrant

- 0.1 hectare
- 30cm diameter and above

Sub-plot

- 0.05 hectare
- 15cm to 30cm diameter

10m X 10m plot

- 0.01 hectare
- 5cm to 15cm diameter

5m X 5m plot

- 0.0025 hectare
- 1.5m height and above, less than 5cm diameter.

2m X 2m plot

- 0.0004 hectare
- 15cm height to 1.5m height.

Fig. 19. Sampling plot layout

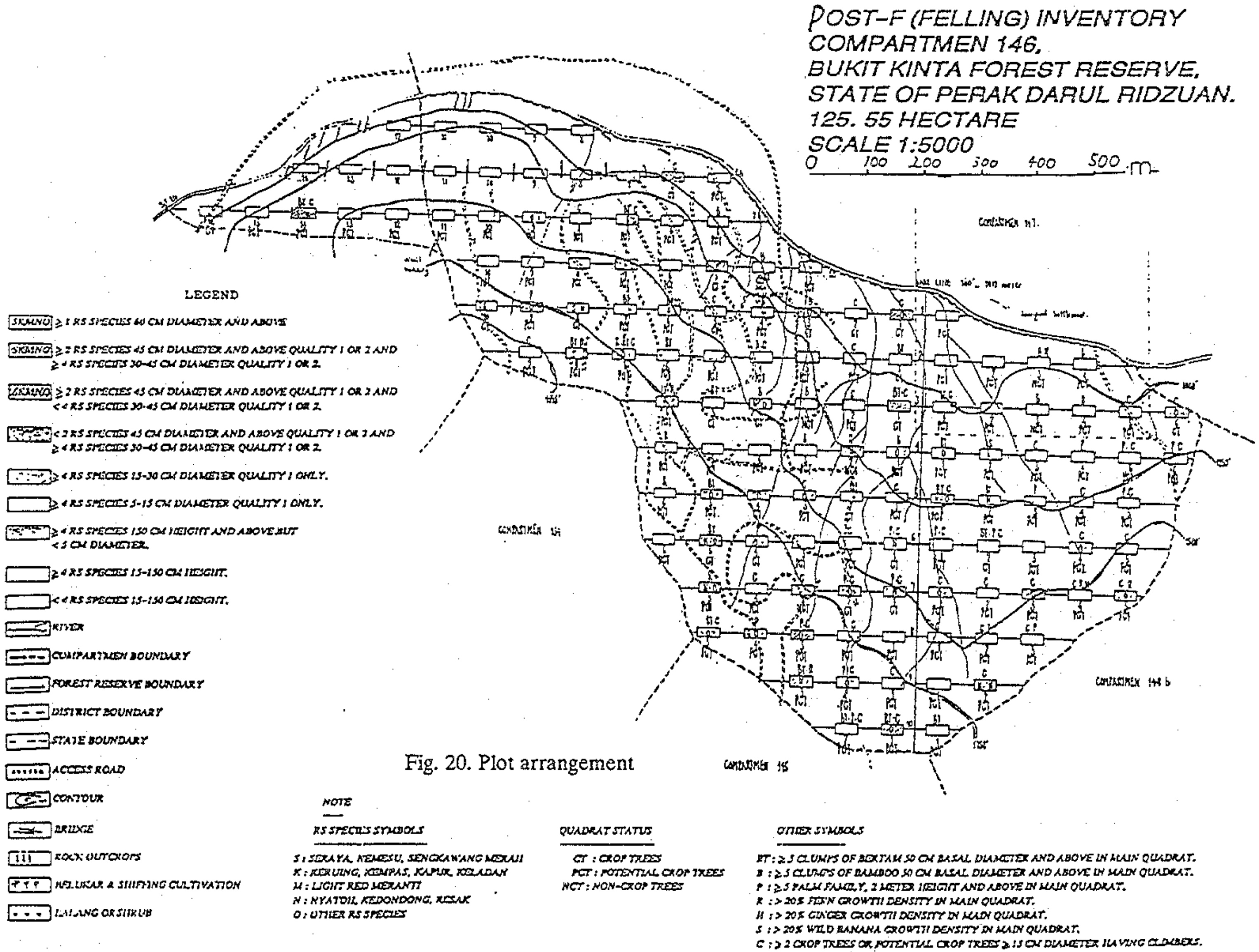


Fig. 20. Plot arrangement

4) Inventory Parameters

Table 71 shows the inventory parameters.

Table 71. The post-felling inventory parameters

	Inventory parameters	Plot size	No.	DHB	Species Name	Species RS Category	Q	S	D	H	C	Remarks
Seedling	15 < H <150 cm.	2 m. x 2 m.	o	-	o	o	-	-	-	-	-	
Saplings	H > 150 cm., D < 5 cm.	5 m. x 5 m.	o	-	o	o	-	-	-	-	-	
Mature trees	5 cm. < D < 15 cm.	10 m. x 10 m.	o	o	o	o	-	-	-	o	-	
Mature trees	15 cm. < D < 30 cm.	25 m. x 20 m.	o	o	o	o	o	o	o	-	-	
Mature trees	30 cm. < D	50 m. x 20 m.	o	o	o	o	o	o	o	-	-	
Bertam	-	50 m. x 20 m.	o	-	-	-	-	-	-	-	-	
Bamboo	-	50 m. x 20 m.	o	-	-	-	-	-	-	-	-	
Palms	-	50 m. x 20 m.	o	-	-	-	-	-	-	-	-	
Ferns	-	50 m. x 20 m.	-	-	-	-	-	-	-	-	o	
Ginger	-	50 m. x 20 m.	-	-	-	-	-	-	-	-	o	
Bananas	-	50 m. x 20 m.	-	-	-	-	-	-	-	-	o	

Legend: 1. DBH: Breast height diameter:
2. There are three RS classifications:
1) RS (Regenerating Sampling), 2) Non-RS, and 3) Miscellaneous Species.
3. Q: Quality (three categories).
4. S: Status (three categories).
5. D: Dominant (five categories).
6. H: Healthiness (three categories).
7. C: Percentage of area covered (five categories).

5) Results Of Inventory

① Radius Distribution Of Remaining Trees (15 cm.< DBH)

As shown in Table 72, the per-hectare distribution of remaining trees with a breast height diameter of 15 cm. or more, remaining trees numbered 123, with a volume: of 89.20 cubic metres.

A total of 80 species were found throughout the inventoried area, the predominant ones being Kelat (*Eugenia* spp.), Keledang (*Artocarpus* spp.; hereinafter "RS species"), Medang (family of *Lauraceae*) and Perah (*Elateriospermum tapos*; hereinafter "Non-RS species"). Dipterocarps were few, numbering only four per hectare.

The term "RS species" used here refers to species of high economic value and ranked as A, B, or C in "The Regeneration Sampling List of 1974" (see sample table), prepared by the Forestry Department.

Table 72. Diameter distribution of remaining species in each group (per hectare)

Bukit Kinta 146 compartment standing tree (per hectare)									
	Diameter class (cm)						Total no.	Total	Total basal
Species	15-	30 -	45-	60 - 74	75 - 90	90 -	of trees	volume	area (cm.^{2})
HHW	5	3	1	0	0	0	10	7.22	10,296.00
MHW	28	9	4	1	1	0	44	28.62	40,860.59
LHW	32	15	7	3	1	1	59	50.77	65,855.15
Others	8	2	0	0	0	0	11	2.59	5,464.73
Total	73	29	13	4	2	1	123	89.20	122,476.47
Dip.	1	1	1	0	0	0	4	7.56	7,878.30
Non-dip.	64	26	13	4	2	1	109	79.05	109,133.44
Others	8	2	0	0	0	0	11	2.59	5,464.73
Total	73	29	13	4	2	1	123	89.20	122,476.47
RS	36	14	7	3	1	1	62	52.29	67,765.47
Non-RS	29	13	6	1	1	0	51	34.32	49,246.27
Others	8	2	0	0	0	0	11	2.59	5,464.73
Total	73	29	13	4	2	1	123	89.20	122,476.47

② The State Of Young Remaining Trees (5 cm.< DBH <15 cm.)

With over 90% of young remaining trees (i.e., those having a breast height diameter between 5 and 15 cm.) having some type of damage or injury, this group of trees cannot be considered healthy (Table 72).

③ Saplings/Seedlings Regeneration

Here, young trees with a breast height diameter of 5 cm. or less are called saplings if the height is more than 150 cm. and seedlings if shorter than 150 cm.

Regarding their regeneration, saplings were found in 11% of those 2 x 2 m. plots ([118-105] x 100/118 = 11.0) inventoried, and saplings in 23% of those 5 x 5 m. plots ([118-91] x 100/118 = 22.9); see Tables 74 and 75.

Table 73. The state of young remaining trees

(Unit: trees/ha)

	Species	Non-RS species	Total	
Healthiness 1	5.93	0.00	5.93	2.6%
Healthiness 2	27.97	181.36	209.33	91.5%
Healthiness 3	0.00	13.56	13.56	5.9%
Total	33.90	194.92	228.82	100%

Table 74. Number of plots containing saplings

(young trees with a breast height diameter of 5 cm. or less and a height of 150 cm. or more)

Number of saplings / Species group	0	1	2	3	4	5	6	7	8	9	Total
RS species	91	15	6	2	4	0	0	0	0	0	118
Non-RS species	35	16	23	16	6	5	4	2	1	10	118

Table 75. Number of plots containing seedlings

(young trees with a breast height diameter of 5 cm. or less and a height below 150 cm.)

Number of saplings / Species group	0	1	2	3	4	5	6	7	8	9	Total
RS species	105	9	2	1	0	0	0	1	0	0	118
Non-RS species	91	11	8	1	2	3	1	0	1	0	118

6) Conclusions

The above-mentioned is the outline of the post-felling inventory of compartment 146.

By the way it is very important to understand the history of past forestry activity (especially the state of the forest before felling or clearing) in discussing the proper handling of trees. However, details of the pre-felling state of trees in compartment 146 are not available because pre-felling inventory there was not carried on time.

It has therefore been decided to base our consideration of future forestry activity by comparison of the results of our post-felling inventory in compartment 146 and the results of harvest inventories performed in compartments 146 and 147 before felling in 1990.

Table 76 is the overview of records by the Perak State Forestry Department on the felling carried out in these compartments between 1990 and 1993.

Table 76. Overview of harvest inventory in compartments 146 and 147

Division	Unit	Contents
Felling area	ha.	229.81 (169.81)
Date fo felling		Apr. 1, 1990 - Nov. 7, 1990
Trees inventoried	tree	1,026
Commercial timber volume	$m.^3$	5,533.93
Timber volume per hectare	$m.^3$	32.59
Volume of timber inventoried	$m.^3$	6,601.83
Average diameter of trees inventoried	cm.	81
Extension of operation road	m.	6,040
Income from felling	RM	216,546.70

Fig. 21 shows the number of RS and non-RS species felled according to diameter and Fig. 22 shows the number remaining after felling (according to diameter). Fig. 23 and 24 are comparisons between dipterocarps and non-dipterocarps.

Fig. 21 shows that seedling of RS species numbered roughly 500 per hectare, which, although considerably lower than natural regeneration standards for Japan's beech forests, is more than the Perak State Forestry Department's post-completion regeneration standard of at least 100 remaining RS species per hectare. The enrichment planting of timber species is performed when this standard is not met. From the viewpoint of the number of seedlings, there seem to be no major problems concerning regeneration.

Nevertheless, a comparison of remaining trees and harvest inventory trees reveals a low percentage RS species among remaining trees and the excessive scarcity of dipterocarps as a percentage of remaining trees (Figs. 23 and 24).

Unit: Thousands of trees

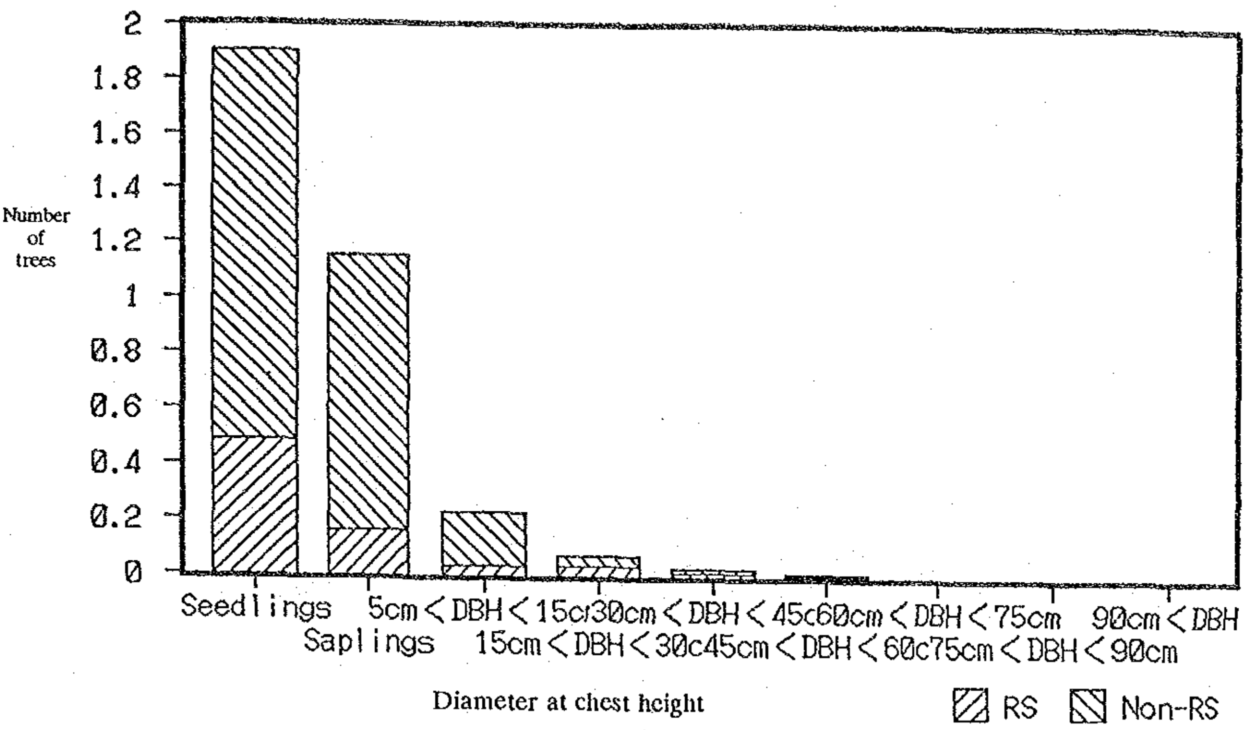


Fig. 21. Number of remaining RS and non-RS species (per hectare) in compartment 146

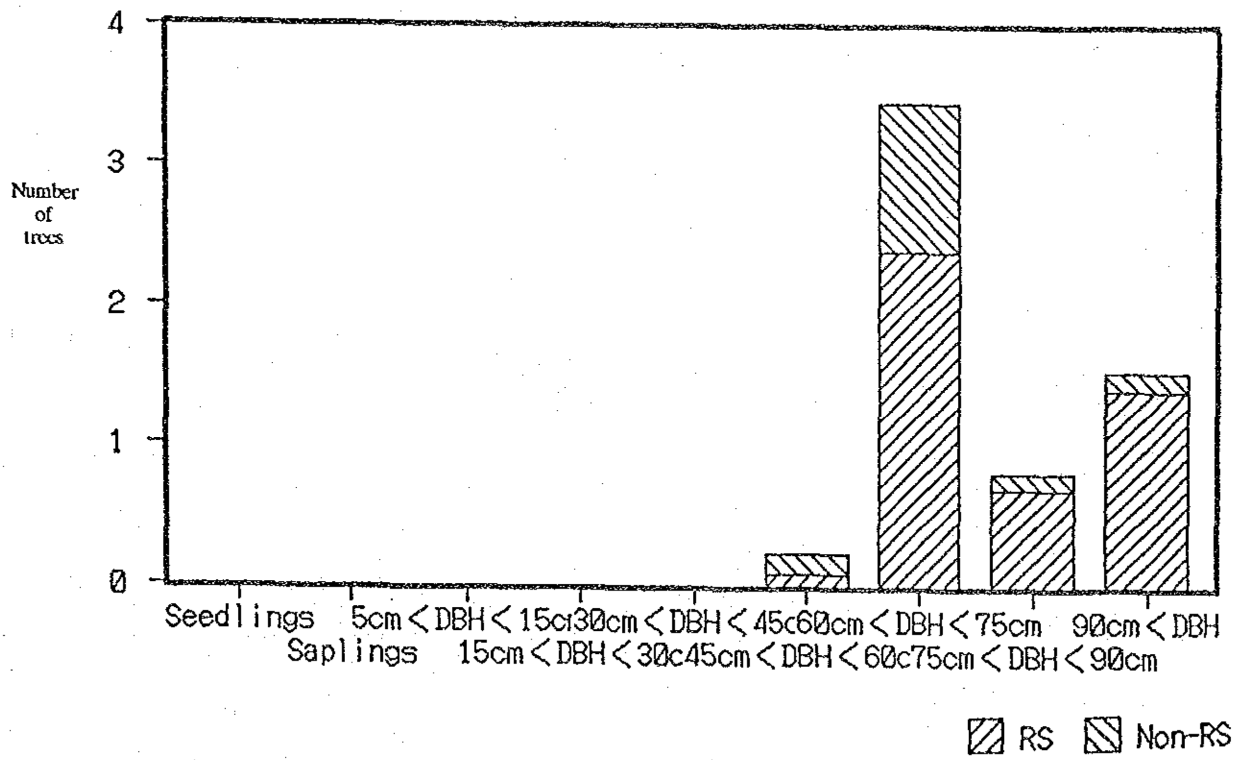


Fig. 22. Number of harvest inventory RS and non-RS species (per hectare) in compartments 146 and 147

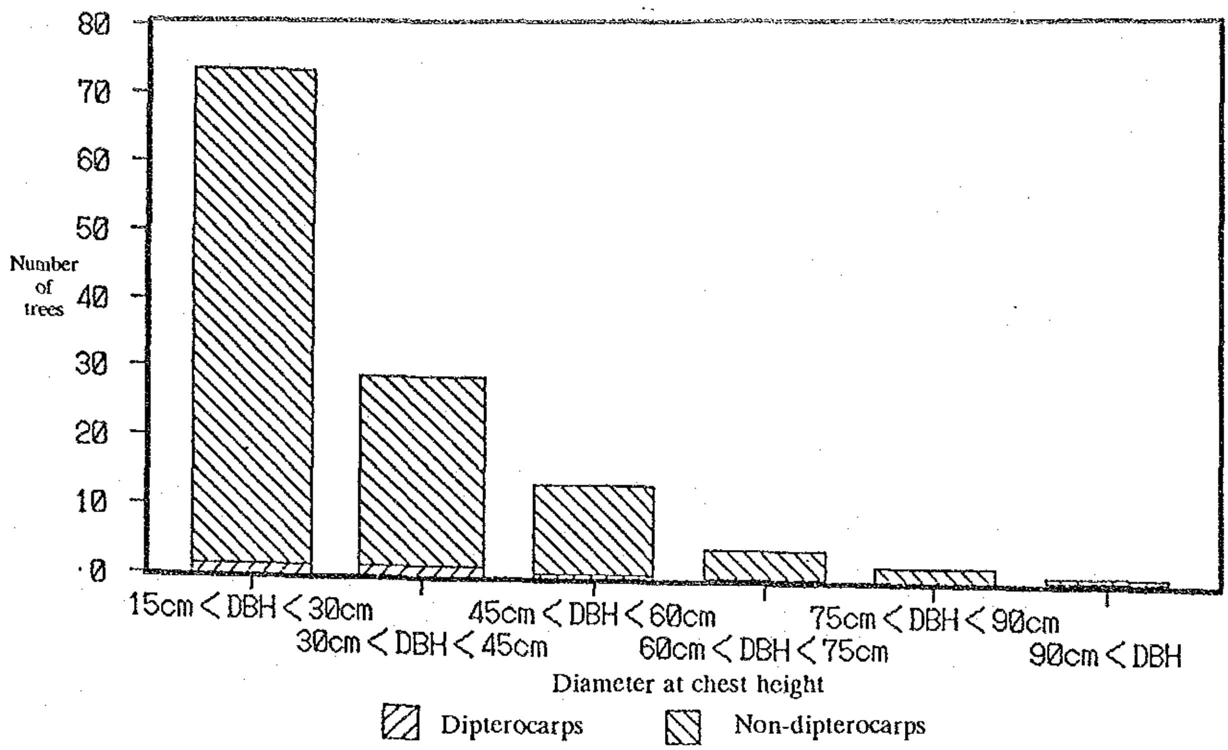


Fig. 23. Number of remaining dipterocarps and non-dipterocarps species (per hectare) in compartment 146

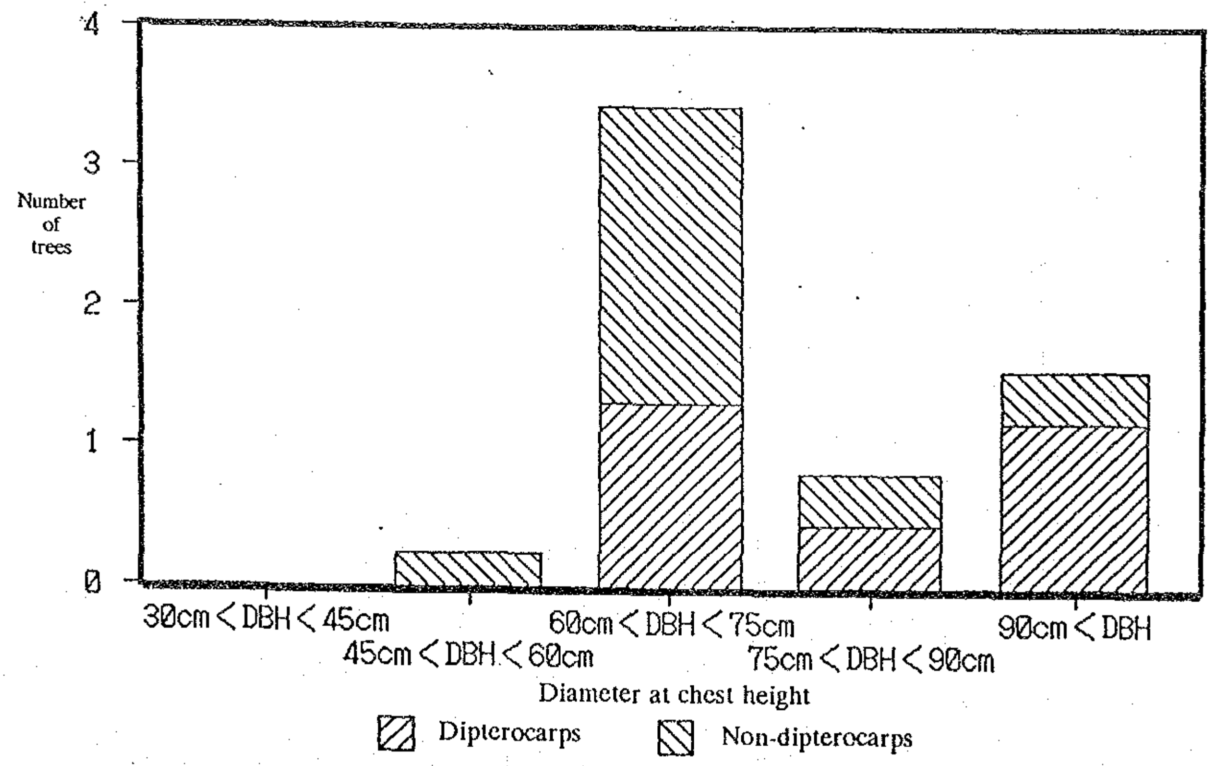


Fig. 24. Number of harvest inventory dipterocarps and non-dipterocarps species (per hectare) in compartments 146 and 147

Lastly, let us examine Fig. 25, which shows the changes in percentages of RS species and dipterocarps among the remaining trees and harvest inventory trees in compartment 146.

This graph shows that the share of RS species among post-felling inventory is similar to that of harvest inventory.

However, dipterocarps accounts for an extremely low share of remaining trees compared with the harvest inventory.

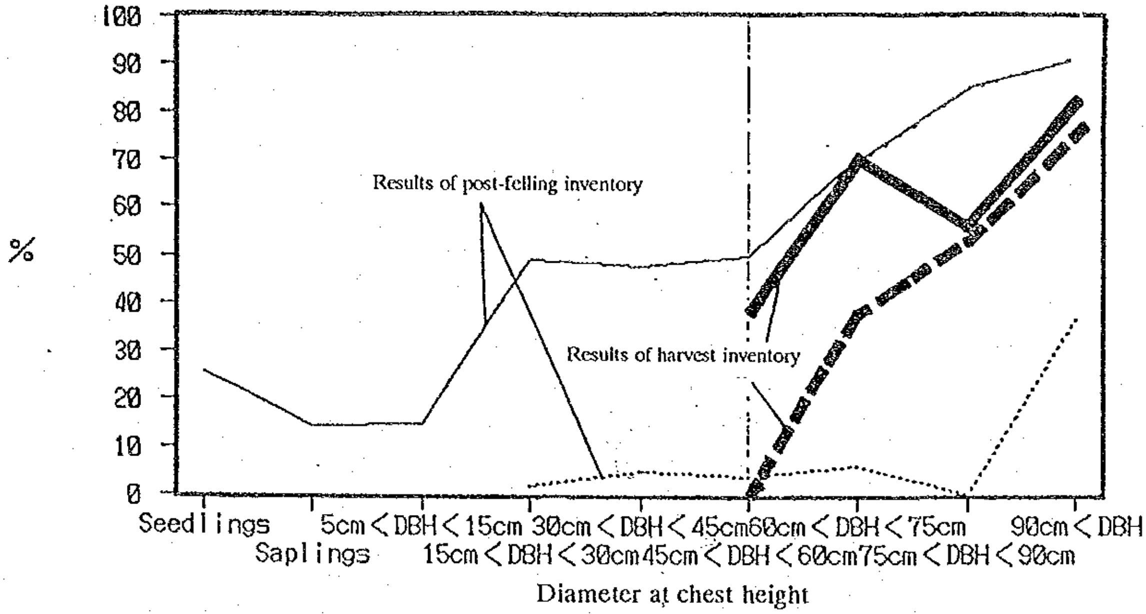


Fig. 25. Percentage of RS trees and dipterocarps

Legend
- ——— RS trees (compartment 146): result of post-felling inventory
- ·········· Dipterocarps (compartment 146): result of post-felling inventory
- ▬▬▬ RS trees (compartments 146 and 147): result of harvest inventory
- ▪ ▪ ▪ ▪ Dipterocarps (compartments 146 and 147): result of harvest inventory

The above demonstrates that the effective means of planting high-quality timber species is needed in order to achieve the objective of this project, to establish multi-storied forests that are viable in terms of sustainable management.

Also it is felt that the results of these post-felling inventories will continue to be of great help in forecasting future forestry quantities from the results of planting experiments in natural forests.

5 Cost Analysis of Multi-Storied Forests Management

5-1 Multi-Storied Forest Management Models

1) Introduction

In the third year of this project, we have to begin to create several practical models and examine them from a broad perspective using existing data from multi-storied forest. However, the number of options for creating these models is infinite because of the diversity of tropical forest. For this reason, we have decided to begin to create simple models composed of several important factors by defining several general pre-requisites.

2) Pre-Requisites For Examining Multi-Storied Forest Models

(1) Using Plantation Of *Acacia Mangium*

In this investigation it is assumed that multi-storied forests will be established in selectively logged-over natural forests, plantation *of Acacia mangium* and open lands which are felled clearly. Therefore, we have to create a different multi-storied forest management model based on the type of location. However, so far we do not have sufficient data because of the poor results of seedlings growth at Chikus Block-A and so on. Thus, at present we will propose a few Multi-Storied Forest Models based on the plantation of *Acacia mangium.*

(2) The Role Of *Acacia Mangium* In The Multi-storied Forest

Ultimately, established multi-storied forest will be predominated by dipterocarps. Fast-growing *Acacia mangium* will be used here to establish these dipterocarps forests, although they may be substituted with other fast-growing species when the circumstances require.

Acacia mangium are used to achieve the following:

① To serve as nurse trees that provide dipterocarps with the shade which they require at the initial growth stage.

② To secure the interim revenue that will be needed before dipterocarps and other target species can be harvested.

Interim revenue will sometimes be secured with *Acacia mangium* alone and sometimes with combinations of *Acacia mangium* and timber species planted for interim felling. Although fruits, rattan and other cash-crops are also useful for interim revenue, this will be considered later on.

(3) Felling Patterns

Strip felling, the method which is now being used at the Chikus site will be adopted. Taking into consideration the efficiency in tree felling and extraction and the state of lower-story trees, upper-story trees will be felled in two and four alternate rows.

The reason why the above-mentioned two and four rows pattern were adopted are based on the conclusion of experimental plot at Chikus.

Conclusions Based On Project Experimentation

- Dipterocarps are not suitable for planting in open land but rather in fields under pre-existing trees where relative illuminance is 30 to 70 percent.

- Regarding strip width, seedlings have shown encouraging growth when planted in the two-alternate rows (2 rows felled and 2 rows retained) and strip of eight rows. As the condition is similar to those of an open land, the seedlings survival rate and growth is not so good.

(4) Species, Felling Period And Growth Rate

Although forecasting the growth rate of each species and establishing an appropriate felling period are pre-requisites for model creation, the fundamental data in these areas are not enough. Therefore, we have referred to some reports of "SABAH RE-AFFORESTATION TECHNICAL DEVELOPMENT AND TRAINING PROJECT (JICA)" for growth forecasts and felling period of *Acacia mangium*, and "Planting Quality Timber Trees In Peninsular Malaysia" (S. Appanah & G. Weinland) for other species.

3) Multi-Storied Forest Management (3 Storied Type)

Model-I (It is further divided into 2 types, A and B, according to the width of felling) is the model selected among the Stripe-Type Multi-Storied Forest, which gives the. highest possibility of implementation,

(1) Species

The select species are *Acacia mangium* as upper trees, *Shorea parvifolia* and *Shorea leprosula* as lower trees.

(2) Felling Width

The result of the silvicultural study shows, 2 rows felling gives the best rate of survival and height growth.

However, 4 rows felling is also practically useful because planted trees require more sunlight after initial growth stage. And, it is also important to raise the efficiency of felling work and to reduce damage to lower trees at the time of upper trees' felling. This is why 2 rows and 4 rows types as a base of the models were adopted.

(3) Felling Period

According to the studies/surveys of various countries, it is found that *Acacia mangium* grows incredibly fast for the initial 10 years and the growth will slow down from around 15 years after planting.

Man-made forests of *Shorea parvifolia* and *Shorea leprosula* in Forest Research Institute, Kepong show that is takes about 40 - 50 years for average trees to reach 50 cm. of diameter at breast height. Therefore, it was decided to choose 50 years as the last felling period.

(4) Regeneration Period And Frequency

Continuous felling except for thinning must be followed by planting *Shorea parvifolia* or *Shorea leprosula*. Before final felling, planting for regeneration is carried out 3 times, and the forest of *Acacia mangium* is converted to the 3 storied forest of indigenous species. Figs. 1 and 2 show the Multi-storied Forest Management Model-I.

4) Multi-Storied Forest Management Model-II (4 Storied Type)

This model is set up based on overall consideration after studying the result of the project implemented and also experiment results from other sources.

The main differences from Model-I are as follows:

a) Medium-Term Felling Species are introduced
b) The Initial Felling Period is 5 years
c) It is a 4 storied forest

(1) The Introduction Of Medium-Term Felling Species

The Medium-Term Felling Species are introduced because no income can be expected after the harvesting of *Acacia mangium* within a period of more than 30 years. Hence, the purpose of introducing the Medium-Term Felling Species is to provide income before the *Dipterocarpaceae* comes into maturity.

(2) To Extend The Initial Felling Period

The Initial Felling Period has been changed to 5 years because the 3-year old *Acacia mangium* has very limited utilization.

(3) Medium-Term Felling Species

The species for Medium-term Felling are still not finalized. However, *Khaya ivorensis*, *Swietenia macrophylla*, *Tectona grandis*, etc. or even *Durio zibethinus* which can produce cash crop as well as good timber are under consideration Multi-Storied Forest Management Model-II is shown in Fig. 3.

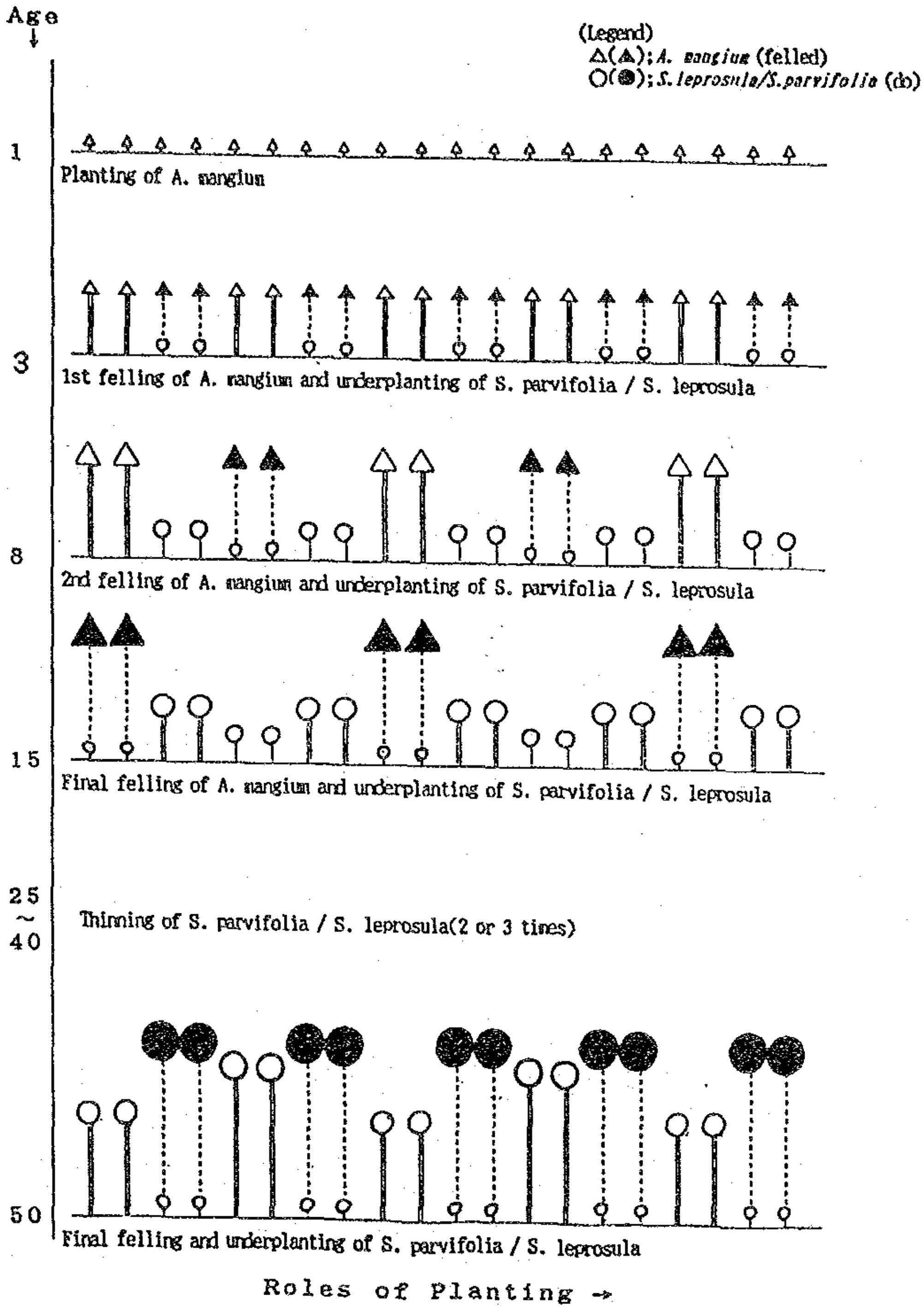


Fig. 26. Model of multi-storied forest management (Model-I A)

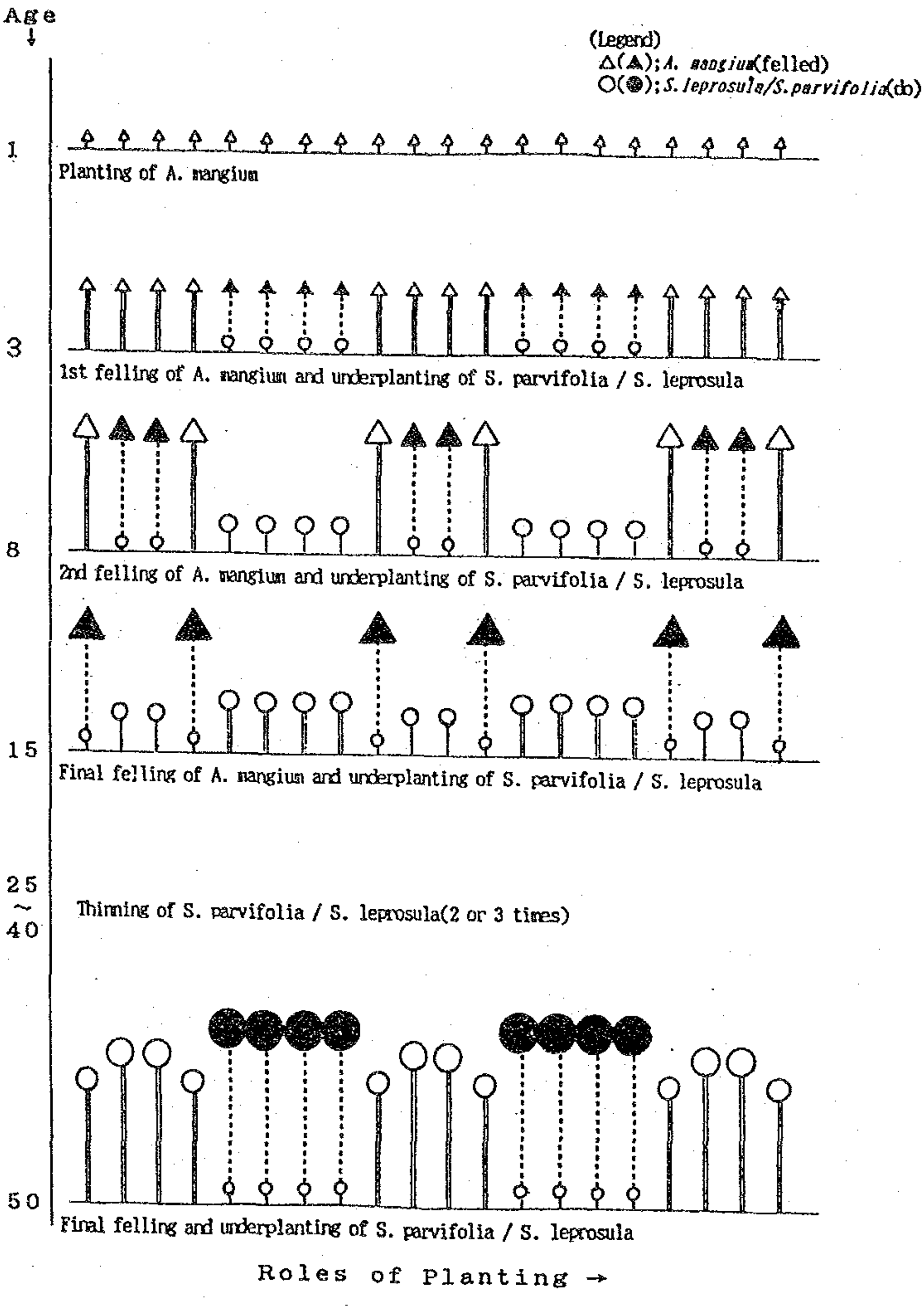


Fig. 27. Model of multi-storied forest management (Model-I B)

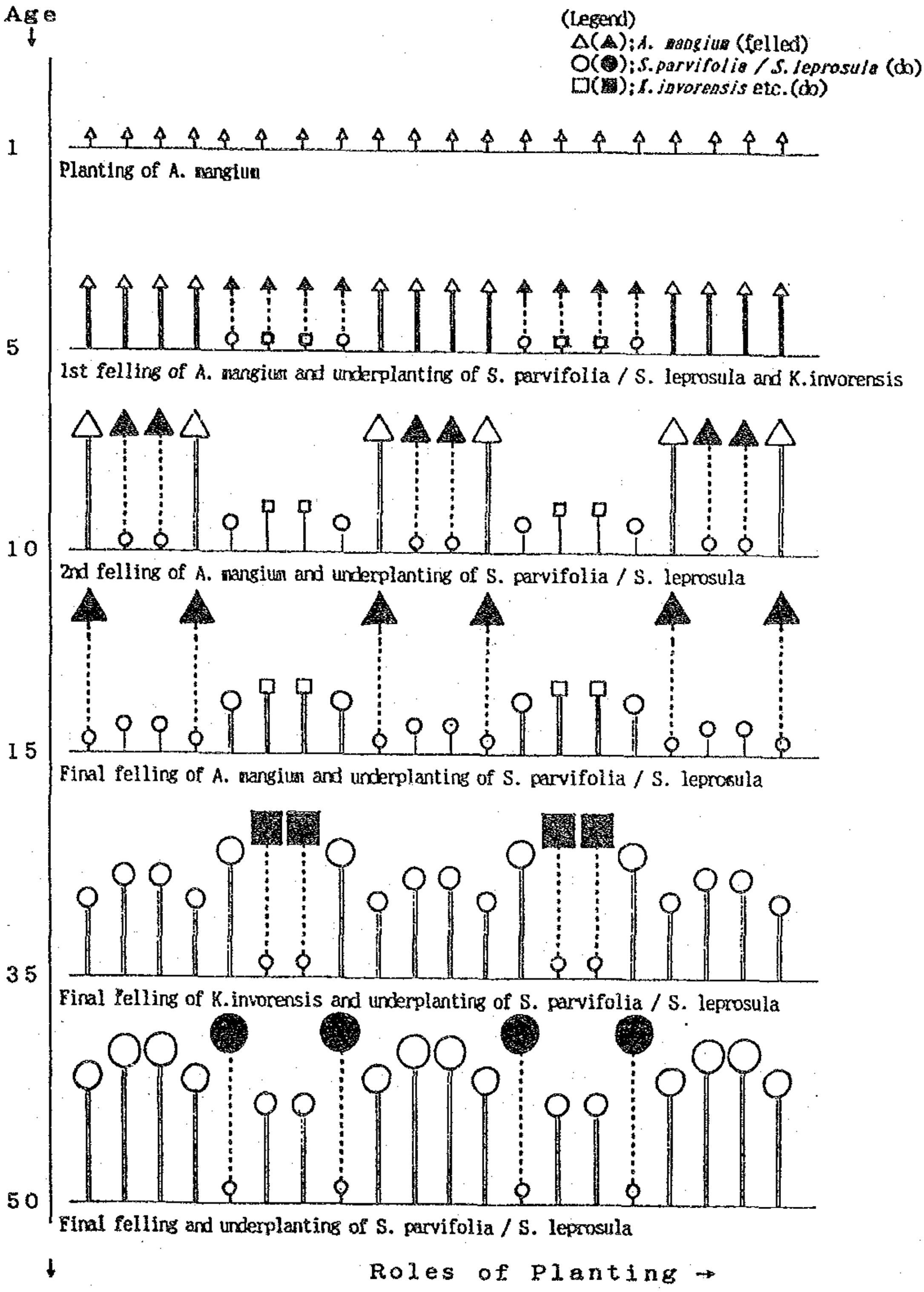


Fig. 28. Model of multi-storied forest management (Model-II)