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報 文

タイ国の森林破壊地における生態学を基礎とした森林回復戦略*

Ecologically-based Strategies for Forest Restoration to Meet the Challenge of Deforestation in Thailand*

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Synopsis

Thailand is one of the remarkable countries where forest ecology has been rapidly changing, as a result of economic development, agriculture, social changes and so on. Rehabilitation with indigenous species, which differs from conventional reforestation, has been attempted in Thailand since 1991, then the methodology and strategies for forest recovery based on phytosociology were examined in rural Thailand. This paper is a complete description of the first method for tropical rehabilitation in Thailand. Unfortunately, for the first 3 years (1991-1993), the species selection was based on villagersknowledge. For reforestation, canopy species such as *Sindora siamensis, Afzelia xylocarpa* and *Pterocarpus macrocarpus* have been selected by local villagers. In 1994 a survey of potential natural vegetation was carried out to determine natural vegetation types. Since then, the species selection has been based on field survey. The broad concepts of ecology are applied for a practical restoration system.

The planting density is 2-3 individual seedlings per square metre. Mixed-species plantation using potted seedlings, and mulching with rice straw have been applied. The restoration and management have been participated in by rural clients. There is a highly significant difference of planted seedlings between weed control treatment and unweed control treatment. Not only does weed control effect growth rate, both diameter and height, but also survival rate. In 1994 meteorological instruments were set up to measure micro-climate changes. As a result, the plantation forest can keep soil moisture better than bare land. Plantation forestry and its environment are gradually developing to naturalness. This promising approach implies the possibility to cope with rural ecological restoration for tropical regions.

Introduction

Thailand is a tropical country situated from latitude 5° 30′ to 21° N and longitude 97° 30′ to 105° 30′ E. It covers about 320 million rai or 513,115 sq.km, approximately the same size as France. Consequently, Thailand has rich aquatic and terrestrial habitats which contain approximately 7 % of the world' species of plants and animals (Science Society of Thailand and Scientific Research Society of Thailand, 1991). Species of vascular plants, in

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particular, are estimated to number at least 10,000 species (Santisuk et al., 1991)

Inevitably, human land use and forest exploitation in Thailand, and even its Asian neighbors, are serious problems that confront these regions at present. The misuse of forest lands and deforestation in the past and even nowadays causes erosion, floods, drought, loss of biodiversity and soil fertility, climatic changes and so on. Importantly, strategies for rehabilitation of tropical forest ecosystems are the least known but the most urgently needed.

New scheme for ecological restoration

By definition, "restoration" refers to the re-creation, reconstruction, recovery, or return of an ecosystem to its original pre-damaged condition, with dominance by a group of native organisms that are within the natural limits for the structure and function of the ecosystem for the local geographic area (Cairns and Buikema, 1984; Howell, 1986).

For the tropics, restoration with fast-growing species is most commonly seen. Monoculture is most popular. This leads to ecological imbalance. A good illustration is even-aged stands. In addition, monoculture stands are easily damaged by insects and diseases.

In 1991, Professor Kazue Fujiwara, eminent Professor Akira Miyawaki, Professor Shunji Murai and Dr. Yoshiaki Honda, in cooperation with the Office of HRH Princess Maha Chakri Sirindhorn's Projects, Chitralada Palace Bangkok Thailand, launched the Re-Green Movement (RGM) in Thailand. The principle of RGM is to foster the creation of native forests which have high biodiversity. There are three main purposes: first, the biological effects to conserve species and green environments for humanity; second, the physical objective to conserve the water balance, to protect against soil erosion and to prevent fire; finally, the chemical aim to produce oxygen and to reduce air pollution.

Objectives of study

Objectives of study are the following:

1. To develop technology for restoration of tropical forest ecosystems,
2. To recreate native forests based on ecological approaches (understanding natural forest ecosystems),
3. To upgrade deforested areas,
4. To educate and promote the participation of school students and local people in interpreting forest values and the impacts from deforestation,
5. To promote biodiversity

Project sites

The project's sites are 3 areas, as follow (Figure 1):

1. Ban Bor Wee Suan Phung District, Ratchaburi Province

This area is located in the west of the country (180 km west of Bangkok), about 10 km from the Thai-Myanmar Border. The annual precipitation is about 1300-1400mm. Average temperature is approximately 28 degrees Celsius. In addition, the elevation is 200m above mean sea level. Formerly this area was covered with dry evergreen forest. From effects of human use of the environments over 30 years ago, this land is degraded toward savannas and shows other symptoms of environmental degradation. Vegetation covers are dominated by grass species such as *Imperata cylindrica*, *Eupatorium odoratum* and other weed species. This site is representative of abandoned rural areas.

2. Ban Na Nok Peed Pakchom District, Loie Province

The location of this site is in the northeast of the country. It is another site representing the rural Northeast Region. The annual rainfall is 1300-1400mm, with average temperature around 29 degrees Celsius. The elevation is 500 m above mean sea level. This area is, at present, degraded by shifting cultivation and human activities over years.

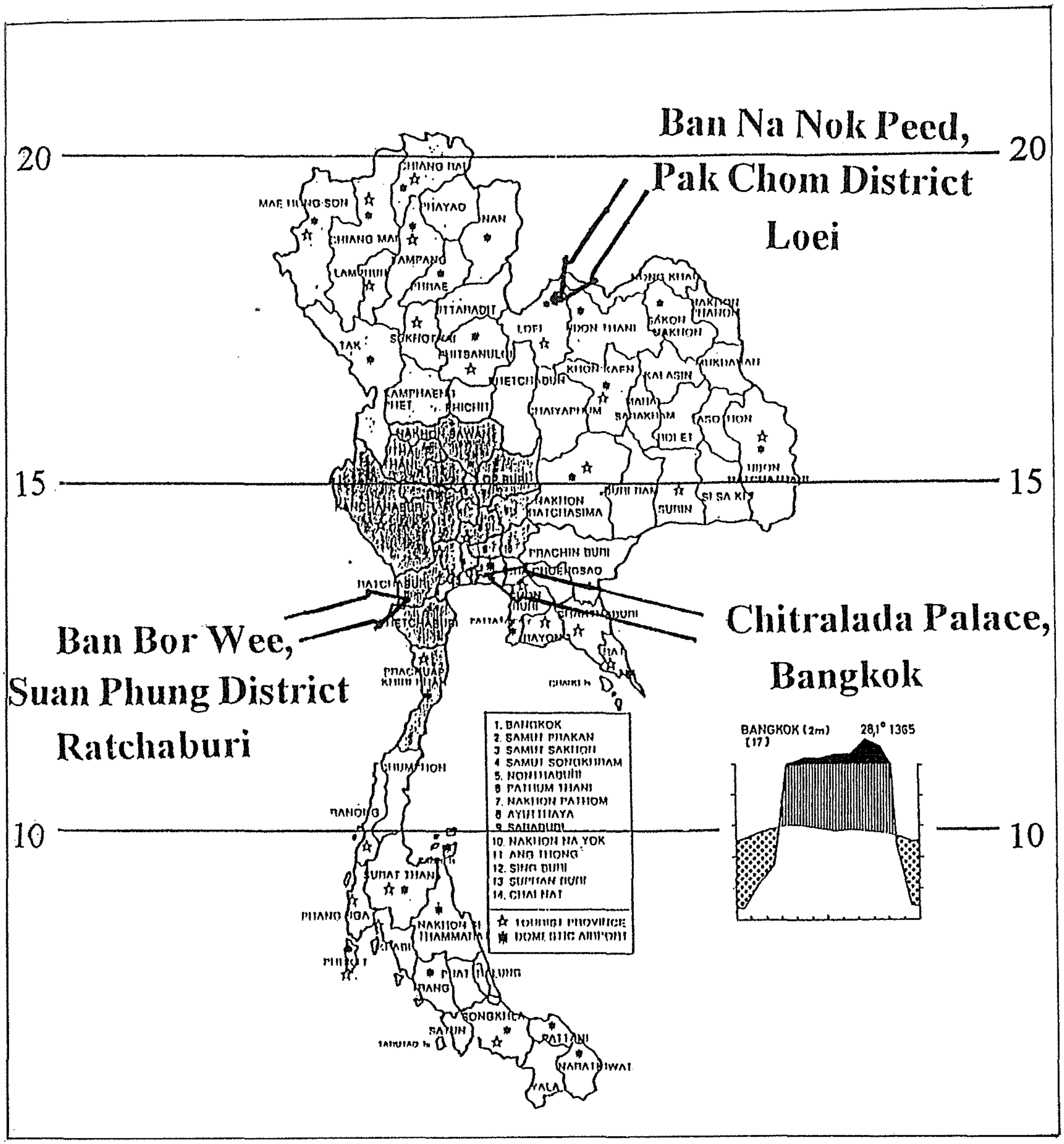

Figure 1. Location of project sites.

3. Chitralada Palace, Bangkok.

This site is in the metropolis of Bangkok. Thus it represents an urban area for study. Annual precipitation is about 1200-1300 mm; average temperature is around 28 degrees Celsius. This is a flat area of the central plain.

Review of vegetation covers of Thailand

Thailand has a monsoonal climate. It has a wet period from May to October, during the southwestern monsoon, and a dry period from November to April, with dry continental north-east monsoon (Donner, 1978). Thus, several types of humid tropical forest vegetation occur in Thailand. Actually, the plant biodiversity very much depends on geography, elevation, physiography, and climate. Generally, the forest of Thailand can be divided into 2 categories: Evergreen and Deciduous. The description of vegetation types in Thailand, based on

FAO (1981), Sabhasri (1984), and Whitmore (1984), is presented in this paper.

A. Evergreen forests

The evergreen forest includes various degrees of species richness. This type of vegetation can be subdivided into several types:

1) Tropical evergreen rainforest

This type of forest occurs along the wet belt of the country, with very high precipitation (2500 mm upward). It is found in the south peninsula which is affected by the monsoon from the southwest. This forest type is continuous from the Malay Peninsula up to latitude 5° N in Thailand. The main tree stratum is very diverse and about 24-36m high. *Dipterocarpus* dominate in the emergent stratum, especially *Shorea curtisii, Shorea leprosula, Shorea parvifolia, Balanocarpus heimii* and *Dyera costulata* (FAO, 1981).

2) Dry evergreen forest

The dominant form of evergreen forest in Thailand is the dry evergreen forest. This type of forest is scattered all over the country, where annual rainfall is between 1000 and 2000mm. Dominant species are *Dipterocarpus* spp., *Hopea* spp., *Shorea* spp., *Intsia* spp., *Anisoptera* spp., *Dalbergia cochinchinensis, Fagraea cochinchiensis, Cinnamomum* spp., and *Lagerstroemia* spp. (FAO, 1981). This forest is another so-called seasonal rain forest because each year is broken into wet and dry weather conditions (Santisuk, 1988). The latitude of this forest is approximately 5° -20′ N.

In addition, there is also Hill Evergreen Forest. This forest type occurs to an elevation above 1000m. It is mostly found in the north mountainous country. Dominant species are *Quercus* spp., *Lithocarpus* spp., *Castanopsis* spp. The climate is very humid and the rainfall is 1500-2000mm per annum. Coniferous Forest or Pine Forest occurs in small pieces of land in the northeast highlands (Korat plateau) and in the north highlands, at elevation between 200-1300m. The annual rainfall is approximately 1000-1500mm. Only 2 species of conifer occur in these forests: *Pinus kesiya* and *Pinus merkusii.* Fresh Water Swamp Forest occurs along the depressions inland. The soil is either alluvial or sandy. Main species are *Hydnocarpus anthelinticus*, and *Xanthophyllum glaucum.* Mangrove Forest, which is a unique type of forest, is found along the estuaries of rivers and muddy seashores, where the soil is deep alluvium with a high saline content. This forest is inundated daily by the tide. In addition, this forest is found on the west coast and within the Gulf of Thailand. Dominant species are *Rhizophora* spp., *Bruguiera* spp., *Xylocarpus* spp., *Ceriops* spp. and *Avicennia* spp. Strand Forest occurs on the coastal sand dunes, rocky seashores and elevated seashore coasts, most commonly along the east coast. Most species are *Casuarina equisetifolia, Terminalia catappa* and *Calophyllum inophyllum* (Sabhasri, 1984; Miyawaki, et al. 1985).

B. Deciduous forest

Deciduous forest occurs along the dry belt of the country where rainfall is under 1000mm and the climate is more seasonal. During the dry season trees shed their leaves. Such forest can be subdivided into 3 main sub-types: Mixed Deciduous Forest consists of various deciduous species in a mixed association. A common species is *Tectona grandis*. Dry dipterocarp forest, is found on undulating peneplains and ridges where the soil is either sandy or gravely. Species of the family Dipterocarpaceae dominate in this forest. Further, the forest is rather open, with common species being deciduous *Dipterocarpus* spp., deciduous *Shorea* spp., *Terminalia* spp., and *Pentacme* spp. Savanna forest occurs as a result of slash-and-burning. It is most common in the northeastern and northern region where shifting cultivation has been practiced (Figure 2). Annual precipitation is relatively low (about 50-500mm). Small pieces of savanna of different stages are found all over the country. Common trees are *Gardenia erythroclada* and *Careya arborea* (Sabhasri, 1984).

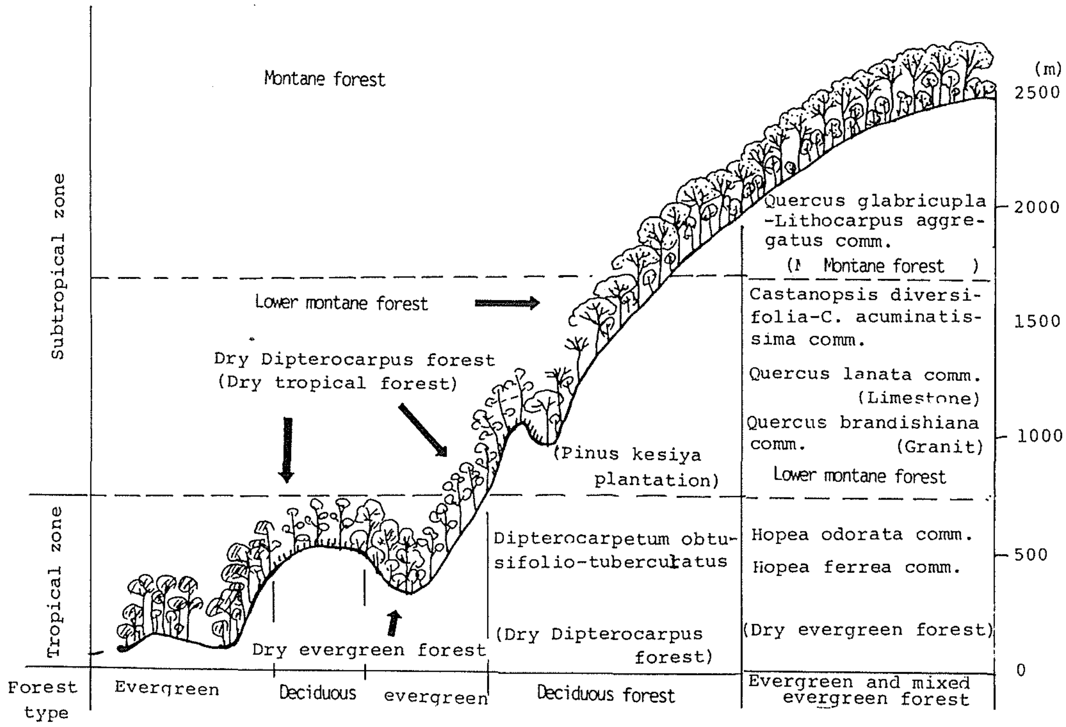

Figure 2. Distribution of forest types in central to north Thailand (Fujiwara, 1993).

Problems of deforestation

In Thailand approximately 489,600 hectares or 4896 sq.km (3.06 million Rai) of forest has been cleared per year (Paivinen et al., 1991). The National Forest Policy of the country proposed 40% of the total land as forest area (Office of the National Economic and Social Development Board, 1992). Yet, the forest area is at present approximately 27% of the total land (Table 1, Figure 3).

Table 1. Forest area in Thailand (1938 - 1991).

years	forest areas (sq. km)	% of total land	average rate of depletion per year (sq. km)
1938	369, 440	72. 00	
1947	359, 200	70. 00	1, 137. 77
1954	307, 840	60. 00	7, 337. 14
1961	273, 628	53. 33	4, 887. 42
1973	221, 707	43. 22	4, 326. 75
1976	198, 417	38. 67	7, 763. 33
1978	175, 224	34. 15	11, 596. 50
1982	156, 600	30. 52	4, 656. 00
1985	150, 866	29. 40	1, 911. 33
1988	143, 803	28. 03	2, 354. 33
1989	143, 417	27. 95	386. 00
1991	136, 698	26. 64	3360

Source: Royal Forest Department (1989) Paivinen, et al., 1991
Note: total areas of the country is 513,115 sq. km.

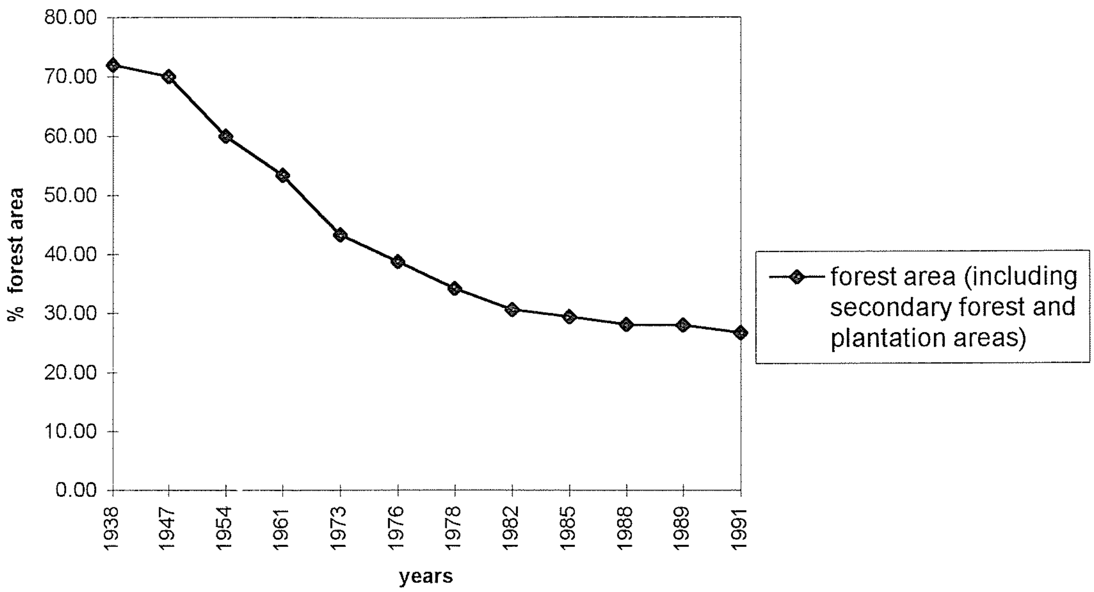

Figure 3. Change of total remaining forest area 1938 - 1991 (data based on table 1).

Causes and effects of deforestation

The causes of forest depletion are mainly human impacts. Generally, shifting cultivation is the main cause for forest disappearance, but like other developing countries, other causes are agricultural expansion, industrial development, destructive logging, illegal forest land occupation (for resorts/golf courses), dam projects, highways into forested areas and tourism.

The main resulting problems are erosion and floods. The erosion is a more serious problem, particularly in the north of Thailand where there are mountainous watershed areas. The central region encounters floods, especially in Bangkok (Figure 4).

Methodology and process of restoration system

The ecological restoration method (ERM) is to restore native forest ecosystems by plantation of canopy tree species. Firstly, this method was applied in Thailand in 1991. In addition, the methodology is based on ecological approaches of potential natural vegetation. Intentionally, natural forest will be restored in a shorter time than through natural succession.

In other words, it is an attempt to assist the natural regeneration system. The process for practical implementation is shown in figure 5.

Feasibility study

The preliminary work for a restoration system is a feasibility study of environmental conditions and necessary related information.

In practice, the activities can be divided into sub-groups as follow:

1) Phytosociological survey

Phytosociological field survey benefits not only the recognising and defining of plant communities, but also comprehensive recording of vegetation samples as basic units of natural environments and various scientific studies. The popular method for field survey, classification and description of vegetation is based on Braun-Blanquet and the "Tüxen school" of

Causes of deforestation in Thailand

Effects of deforestation in Thailand

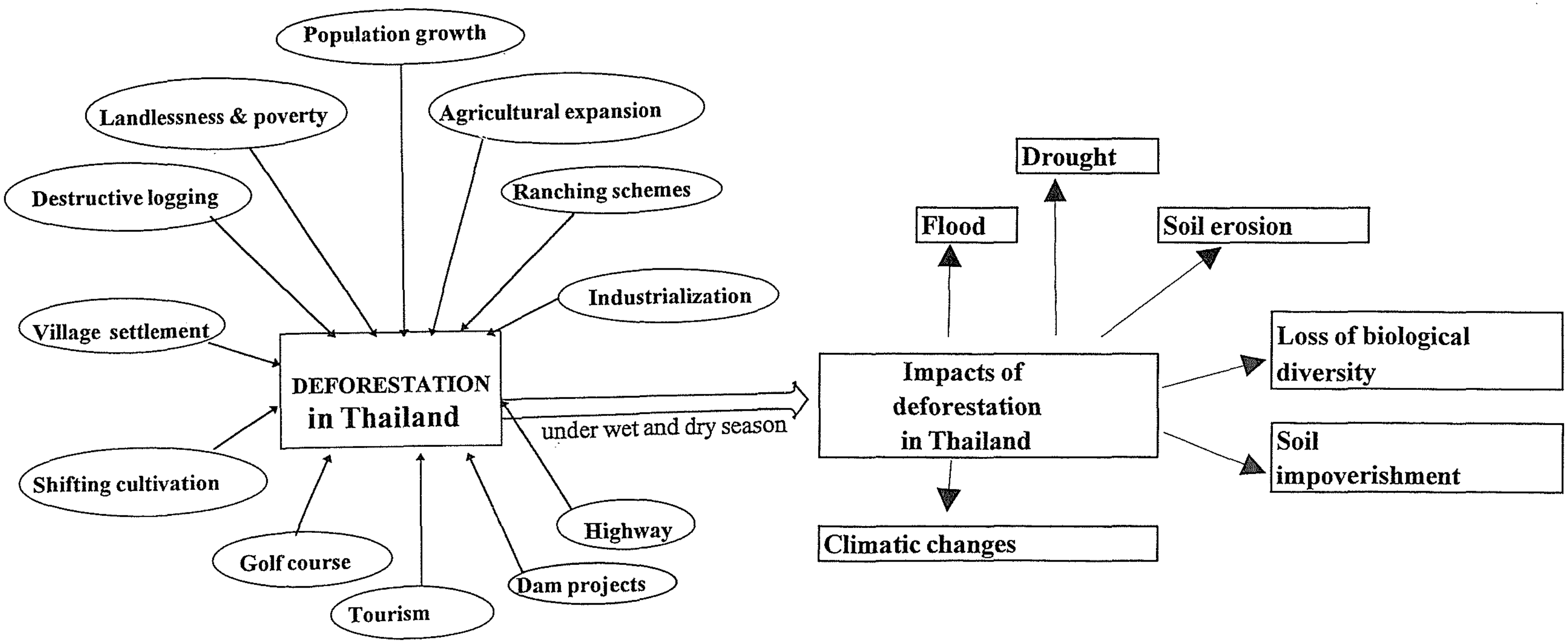

Figure 4. Csused and effects of deforestation in Thailand.

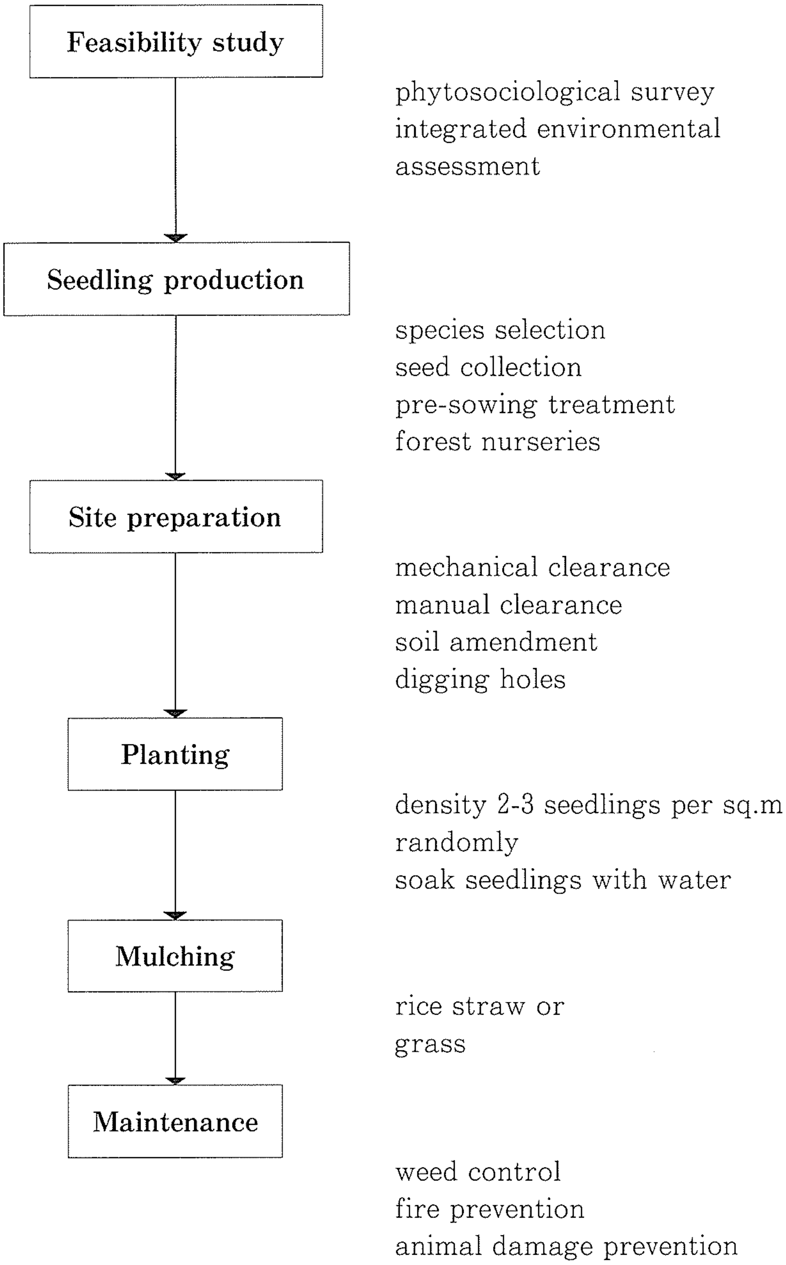

Figure 5. Flow diagram of ecological restoration plantation.

phytosociology. Importantly, the key points deal with: 1) the selection of optimal field survey locations; 2) measurement of the "total estimate" (cover plus abundance), sociability, and their relationship; 3) the correct method of tablework and its simplification; 4) description of plant communities; and 5) development and application of the results (Fujiwara, 1987). From synthesis and classification of field surveys leads to species selection for rehabilitation of ecosystems.

Unfortunately, during the first 3 years (in 1991-1993), phytosociological surveys were not implemented. Species selection was based on local peoples' knowledge. In June, 1994, a phytosociological survey was carried out. Consequently, species for plantation have been selected based on field survey. In practice, complete process for restoration system is shown in figure 5.

2) Integrated environmental assessment

Apart from phytosociological survey, other related environmental information is also needed. A checklist of comprehensive information and data which should be collected can be classified into 2 main groups as follows:

General information is essential, such as socio-cultural aspects, political institutional situation, economic, occupation, incomes, education, attitude towards forests, population, labor force, employment, willingness to cooperate and acceptance by local population.

Environmental information is, for instance, site evaluation, soil map, existing vegetation cover, water resource, precipitation, nutritional value, and other related environments.

Finally, all information should be integratively processed and analyzed for active work.

Soil type of Ban Bor Wee plantation site is Muak Lek loam with 5-12 % slope. Soil depth is shallow (below 50 cm. deep). Textural profile is loam from gravely fine sandy clay loam to very gravely clay loam with color profile of dark brown/very dark grayish brown to strong brown. Further, the physical properties are well drained, moderate permeability (Figure 6).

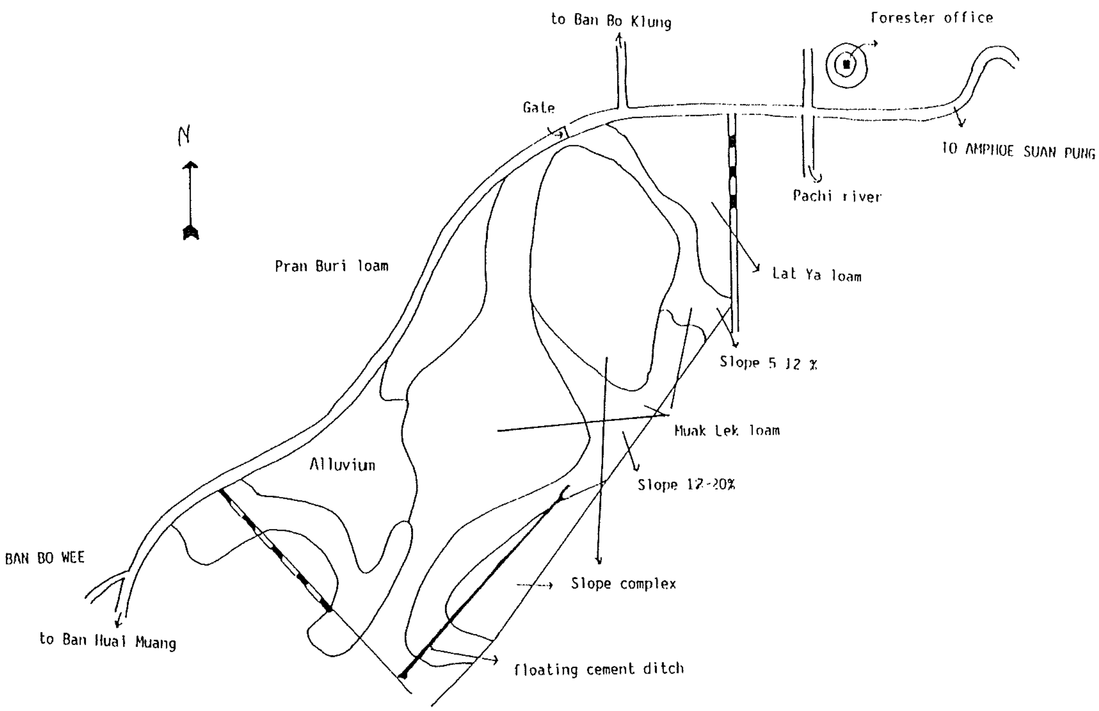

Figure 6. Soil map Ban Bor Wee, Suan Phung District Ratchaburi Province (source: Fujiwara,1993.).

The soil pH range tends to be from lightly acid to neutral, as shown in table 2 at depth of 0-100 cm. Soil organic matter (OM) is ranging from 0.98 to 2.78 which is a medium level. Nevertheless, nitrogen and phosphorus elements are low. Available potassium is very high, which maybe caused by repeated slash-and-burn (Table 2).

Table 2. Soil properties of Ban Bor Wee plantation site.

sample	depth (cm)	pH	OM	N (ppm)	P (ppm)	K (ppm)
1	0 - 30	5. 7	1. 34	0. 09	2. 5	240. 0
2	0 - 30	6. 2	2. 59	0. 15	7. 0	330. 0
3	0 - 30	5. 5	2. 40	0. 14	2. 1	125. 0
4	0 - 30	6. 3	2. 12	0. 15	4. 9	195. 0
5	0 - 30	6. 3	2. 78	0. 18	4. 6	130. 0
6	0 - 30	6. 4	1. 88	0. 12	4. 7	270. 0
7	0 - 30	6. 0	1. 98	0. 13	4. 6	215. 0
8	0 - 30	7. 9	0. 98	0. 08	9. 9	150. 0
9	0 - 30	6. 1	2. 19	0. 13	7. 5	310. 0
10	0 - 30	6. 2	2. 59	0. 15	7. 8	385. 0
11	50 - 100	6. 4	1. 59	0. 09	3. 0	150. 0
12	50 - 100	5. 8	1. 26	0. 09	2. 6	280. 0

Seedling production

1) Species selection

Which species should be planted? This is one of the most important decisions. The main objective is based on ecological approach. The selection of plant species is therefore confined to indigenous species. Reasonably, such a species is already adapted to the environment and appropriate for natural regeneration. Its benefit is also in protection from diseases and pest damage. Furthermore, it is clearly of more ecological value than exotic species for biodiversity. The site for plantation is also considered with species (site-species selection). However, in the project initiated, limitations in availability of species occurred. Therefore few indigenous were planted. Later, more canopy species have been increasingly planted. The list of species planted is shown in table 3.

2) Seed collection

Seeds of canopy trees from natural forests were picked up during harvesting time. The proper time for harvest of individual species is different from one to another. Therefore seed source, timing, and methods of collection are technically considered. Seeds can be collected by picking up natural fallen seeds from mother trees, cut twigs with seeds, pick seeds from branch, and so on. Seed collecting method depends on individuals species. One of the possible ways to collect seeds is by school students. The teachers, who are trained by the forest propagation station, teach how to select mother trees for seeds and guide students for seed collection trip. Apart from obtaining seeds, school students gain practical knowledge.

As soon as seeds are obtained, techniques on seed cleaning and extraction are immediately practiced. Seeds are sown into a seed bed which is filled with a fertile medium. Some species need pre-sowing treatments, for instance, the wings of dipterocarp seeds should be taken off.

After germination (about 1 month) baby seedlings are transferred in plastic pots of 11cm in diameter which are filled with fertile soil.

Table 3. Species for planting.

Species	Family	phase 1	phase 2	phase 3	phase 4
		(planted in 1991)	(planted in 1992)	(planted in 1993)	(planted in 1994)
* *Afzelia xylocarpa*	Caesalpiniaceae	+	+	+	+
Pterpcarpus macrocarpus	Papilionaceae	+	+	+	+
Sindora siamensis	Caesalpiniaceae	+	+	+	+
* *Xylia xylocarpa*	Mimosaceae		+		+
* *Lagerstroemia calyculata*	Lythraceae		+		+
Peltrophorum pterocarpum	Caesalpiniaceae		+		
Dalbergia cochinchinensis	Papilionaceae		+		+
Lagerstroemia speciosa	Lythraceae		+		
Lagerstroemia tomentosa	Lythraceae		+		+
* *Terminalia bellerica*	Combretaceae		+		
Swietenia macrophylla	Meliaceae		+		
* *Mesua ferrea*	Guttiferae				+
* *Diospyros mollis*	Ebenaceae				+
* *Dipterocarpus alatus*	Dipterocarpaceae				+
* *Hopea odorata*	Dipterocarpaceae				+
* *Syzygium cumini*	Myrtaceae				+

Note: * **Natural canopy species**

All pots are placed in nursery. After 6 months, baby seedlings can grow 40-70 cm in total height.

The advantages for transferring baby seedlings in plastic pots are that the root system can be well developed and easily handled for transportation.

Site establishment and preparation

Locating the plantation site in the field and setting its boundaries is the first step in the plantation process. Such important work can prevent land conflict with nearby peoples' land. Then, the open-air site is ploughed by tractor and followed up by manual clearance by the local people. The existing vegetation cover of the site must be preserved and protected from ploughing. There is no burning involved in the site preparation, since burning increases weed occurrence. Since Ban Bor Wee site is a gentle slope (about 5-12%), additional substrate construction is not needed.

Since the soil has low fertility, adding compost fertilizer is necessary. The rate for filling is around 2 tons per Rai (6.25 Rai= 1 hectare).

Small holes (2 times bigger than the seedling pots) should be dug before planting. This activity is done by local villagers and school students (Figure 7).

Planting Day Arrangement

Planting should of course be done at the beginning of the rainy season, during June and July. Each year, the number of participants is about 600 local people, villagers, school students, and teachers (Figure 8).

Before planting, the participants are instructed in the value of the forest and impacts from deforestation. Village leaders, who are already trained in planting techniques, are the foremen and help the unexperienced volunteers on how to plant seedlings. Facilities such as transportation and lunch are supplied to them free of charge by Royal Development Division.

Planting techniques

Planting is an important operation. Poor techniques and unskilled planting cause high mortality. The planting techniques are different from conventional planting in Thailand. The main difference is that the spacing of individuals is dense and random. A density of 2-3 seedlings/sq.m is employed. The seedlings have to be soaked in water before planting, in order to increase moisture for the plant in its first few days. There are several other guidelines: 1) avoid damaging roots by breaking and crushing, 2) plant seedlings in the soil up to root collar, 3) press around seedlings with hands, not feet (Figure 9).

Mulching

After young seedlings are planted, mulching with grass and rice straw is necessary. The rice straw/grass of the plantation forest are functionally like the litter in the natural forest. The advantages of mulching are as follow: 1) to prevent high evaporation and keep soil moisture, 2) to prevent erosion and rapid runoff on steep slopes, 3) to decompose and become good fertilizer for newly planted seedlings, for example, nutrients for plant to take up in developing its root system in the earlier stages, 4) to reduce weed growth.

At present the demand for rice straw is increasing. Its cost is also higher because the demand has increased. For example, large ranching schemes need rice straw to feed cattle during the dry season. Instead, grass such as alang alang (*Imperata cylindrica*) can be used for mulching.

Quality control after planting

To improve the quality of the planting, careful checking just after planting is needed. For example filling with soil to cover newly planted individuals is not good. Some forgotten seedlings have not been planted yet. Sometimes,

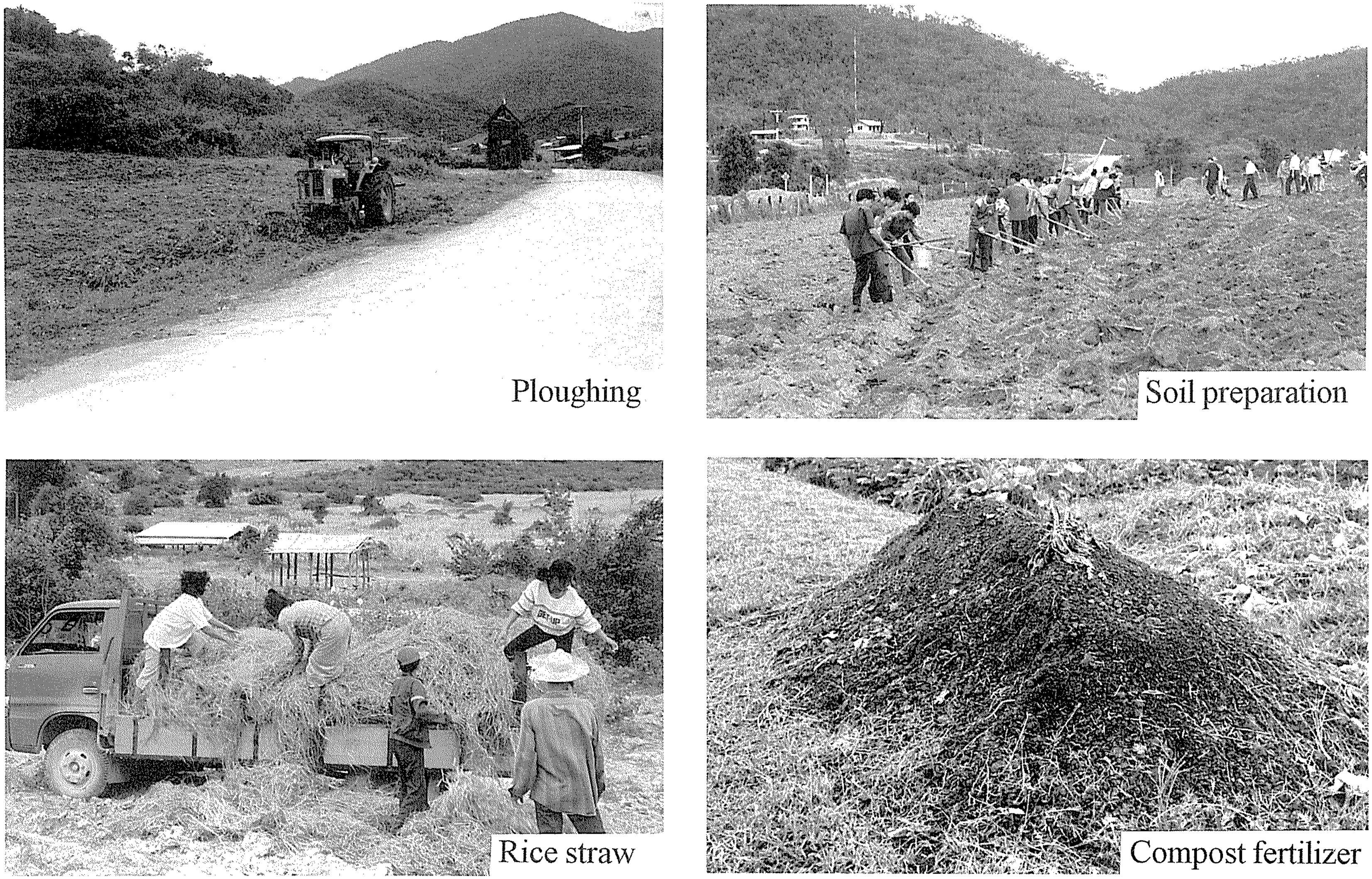

Figure 7. Preparation before planting.

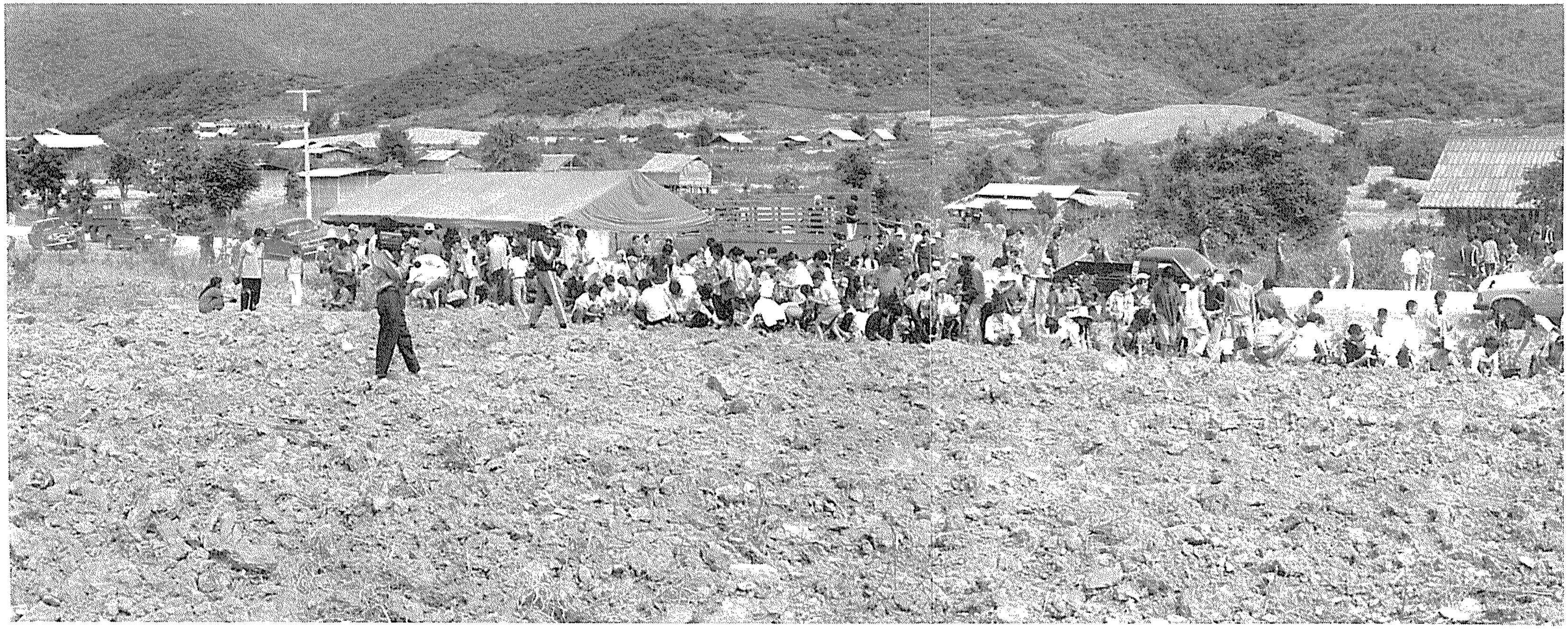

Figure 8. Planting Day.

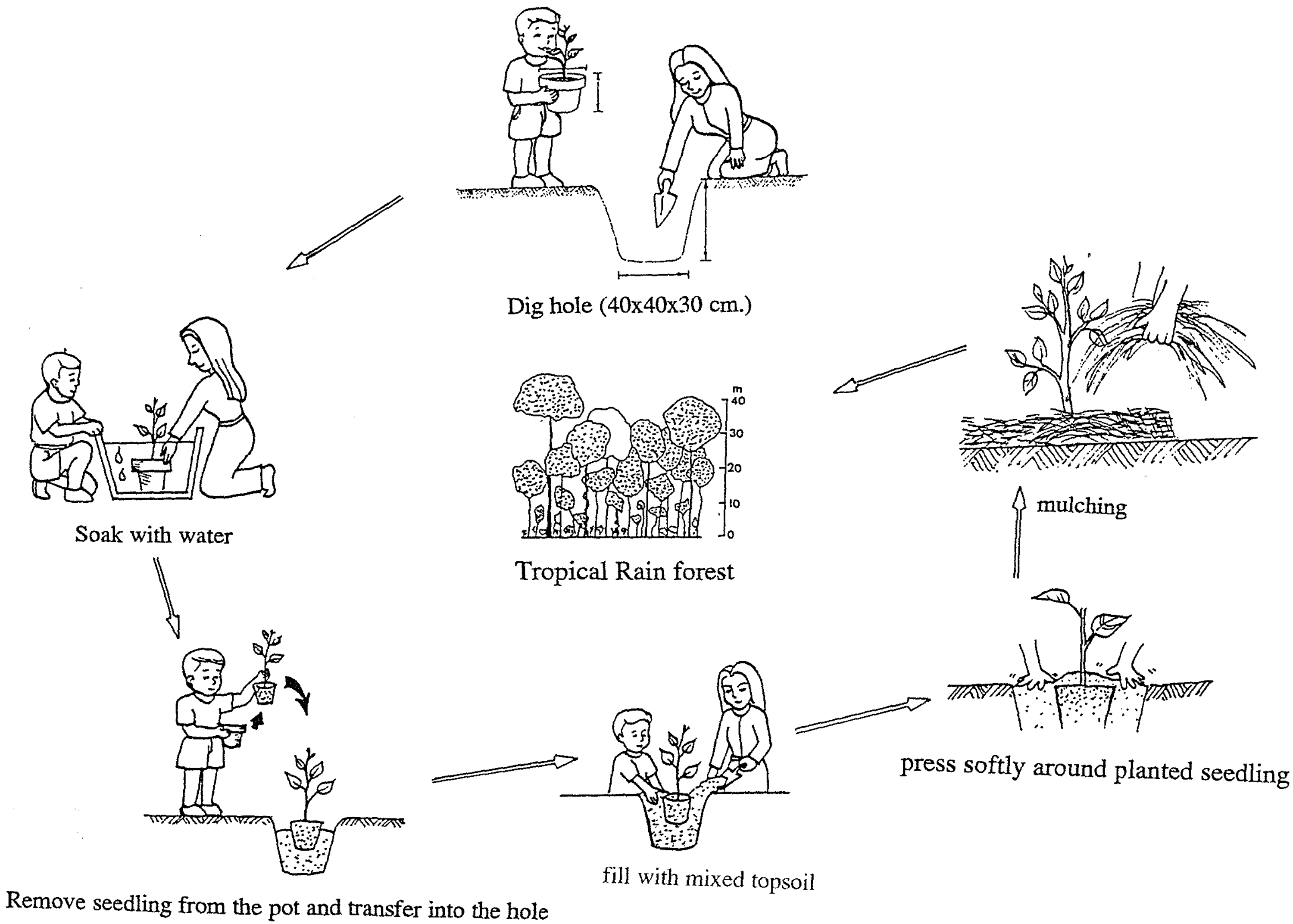

Figure 9. Planting techniques.

mulching materials cover the top or some parts of seedlings. Plastic bags have not been taken out properly. Those seedlings which are not well planted must be re-planted. While walking to check the plantation avoiding stepping on just-planted seedlings and pay more attention to soil compaction.

Maintenance

Maintenance was done by school students, parents and villagers, mainly weed control, fire prevention and animal damage. Weed control has to be conducted because grasses, herbs and shrubs, unwanted trees, creepers, and perennials grow faster than newly planted seedlings. Weeds and the other unwanted species are harvested by the labor force. Manual weeding by hoeing with bushknives or brush hooks is done. This temporary control by hooks, however, involves some risk of cutting. There is no chemical weed control, in order to reduce soil pollution and other side-effects.

Weed community and weed control

Only one week after planting, various weeds emerge and grow rapidly (Table 4). If the rice straw mulch is applied in a thick layer, weed growth tends to be lower, since weeds need more sun light for germination. There are both annual and perennial weeds. Annual weeds die in the dry season (in March-May), but their fallen seeds can germinate in the following rainy season.

Table 4. List of weeds of the plantation area.

Species		1 year plot	2 years plot	3 years plot
Euphorbia hirta	herb	+	+	
Elusine indica	grass	+	+	
Passiflora foetida	climber	+	+	
Dactyloctenium aegyptiacum	grass	+	+	
Cenchrus echinatus	grass	+		
Euphorbia geniculata	herb	+		
Echinochloa crus - galli	grass	+	+	
Pennisetum polystachyon	grass	+	+	
Mimosa pigra	herb		+	
Eupatorium odoratum	shrub		+	+
Amaranthus sycyathuya	herb			+
Sida rhombifolia	sub - shrub			+
Abutilon sp.	sub - shrub			+
Leersia hexandra	grass			+
Clitoria sp.	climber			+
Celastrus paniculatus	climber			+
Passiflora edulis	climber			+
Tridax procumbens	herb			+
Solanum negrem	shrub	+	+	+
Digitaria biformis	grass	+	+	+

Fire prevention

Fire prevention is very important. Fire, which mainly is caused by humans, can destroy the efforts of years within a few minutes. Burning may alter the composition of the pioneer flora and will reduce the amounts of vegetative sprouts and surviving seedlings (Whitmore, 1990). Evergreen forest species hardly recover after fire, and deciduous species easily catch fire. Thus fire prevention, has to be practiced in dry season, particularly in March to April, for instance, making fire- break strips, fire observation.

Animal damage

Animal damage, particularly from grazing domestic animals, such as cattle is sometimes a main problem with planted seedlings. Not only do animals eat grass including the planted seedlings but they also compact the soil.

Results

Plantation on phase 1-4 was done as Table 5.

Table 5. Project progress (as of November 1994).

Place	stage	planted	area	planted seedlings
Ban Bor Wee	phase 1	25 June 91	0.8 ha	17,250 seedlings
	phase 2	20 June 92	0.6 ha	10,000 seedlings
	phase 3	20 June 93	0.8 ha	12,000 seedlings
	phase 4	2 July 94	1 ha	20,000 seedlings
Ban Na Nok Peed	phase 1	16 August 91	0.5 ha	7000 seedlings
	phase 2	12 August 92	0.3 ha	5,000 seedlings
Chitralada Palace		13 June 1994	3x10 sq.m.	250 seedlings

1. Growth rate of mixed-species stands of planted seedlings

To collect raw data on the growth rate of planted seedlings, permanent quadrants (PQ) of 4x4 m or 5x5 m had been set up on the plantation site.

1) Height growth rate

The growth of individual planted seedlings in total height and its increments are shown, for plot PQ1-1, in Figure 10 and Table 9. The average height is 57.21cm, 134.96cm, and 174.42cm in the first, second and third years respectively. *Sindora siamensis* had the greatest height, followed by *Pterocarpus macrocarpus* and *Afzelia xylocarpa*.

2) Diameter growth rate

The average basal diameter and its increments are shown, for plot PQ1-1, in Figure 11 and Table 10. The average basal diameter is 1.11 cm, 2.03 cm, and 3.31 cm in the first, second and third years respectively. *Afzelia xylocarpa*, which has a characteristic good stem form, has the greatest basal diameter, followed by *Pterocarpus macrocarpus* and *Sindora siamensis* respectively.

2. Comparison of weed control and an unweeded control plot

This research focuses on whether weed control is vitally needed for implementation or not, based on study of growth performance of planted seedlings in a weeded control plot (PQ1-2) and an unweeded control plot (PQ1-3). The growth rates of the two plots are shown in Table 11-14 and Figure 12.1, 12.2, 13.1 and 13.2.

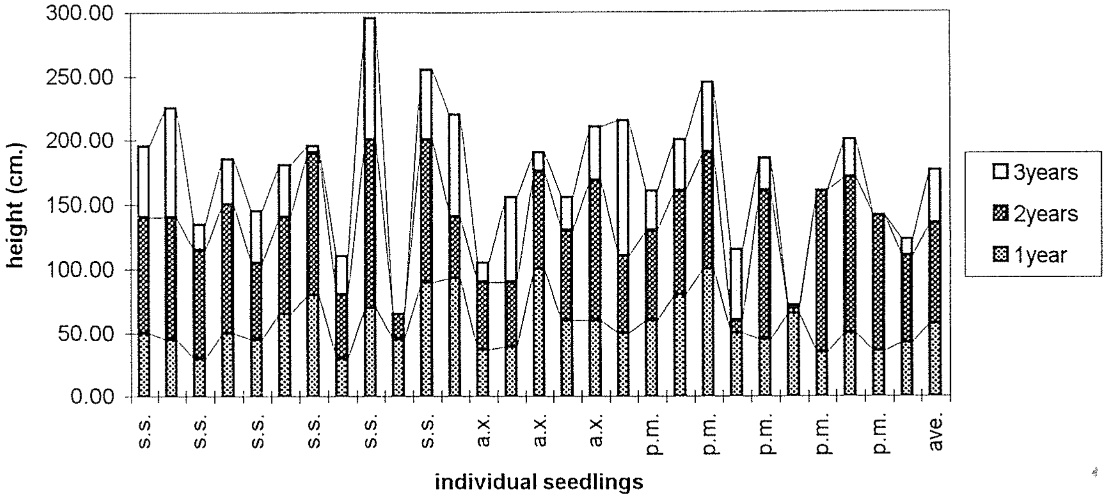

Figure 10. Height growth in Plot PQ1 - 1.

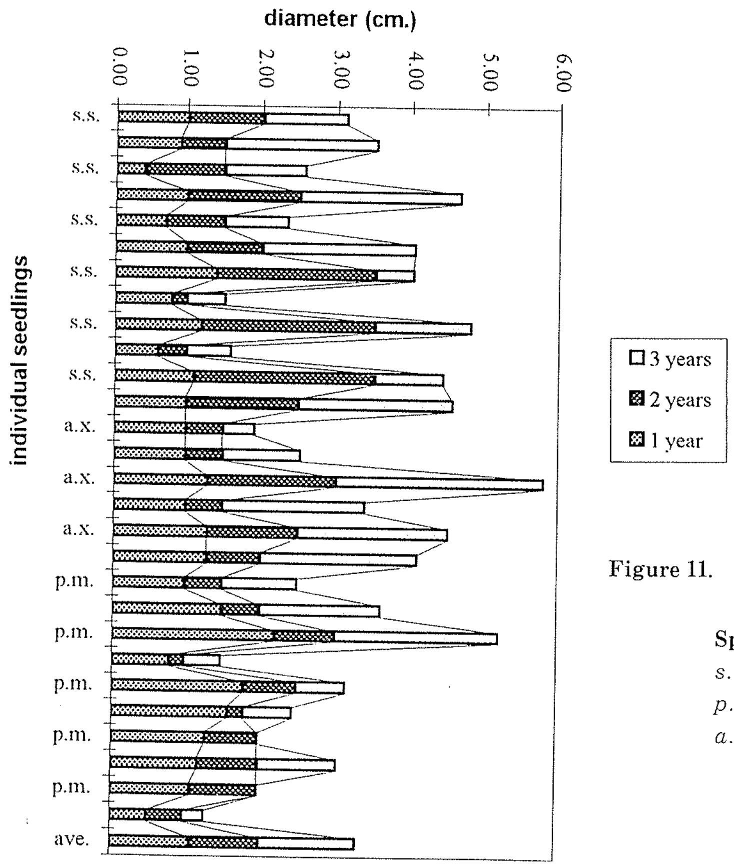

Figure 11. Diameter growth in plot PQ1 - 1.

Species
s.s. = *Sindora siamensis*
p.m. = *Pterocarpus macrocarpus*
a.x. = *Afzelia xylocarpa*

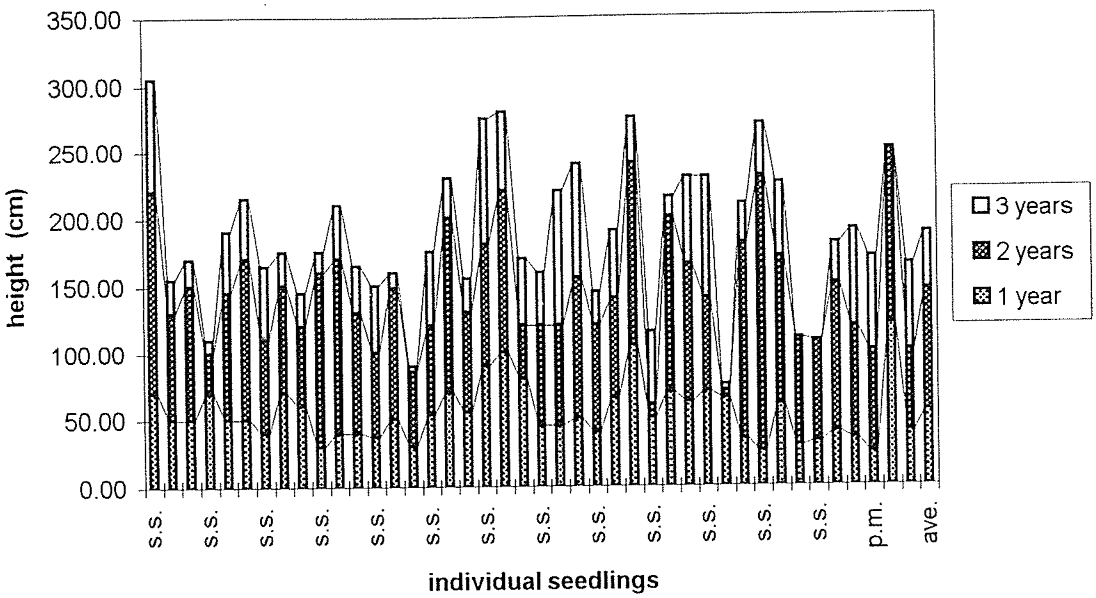

Figure 12. 1. Height growth in plot PQ1 - 2.
(weed - control plot)

s.s.=Sindora siamensis
p.m.=Pterocarpus macrocarpus
a.x.=Afzelia xylocarpa

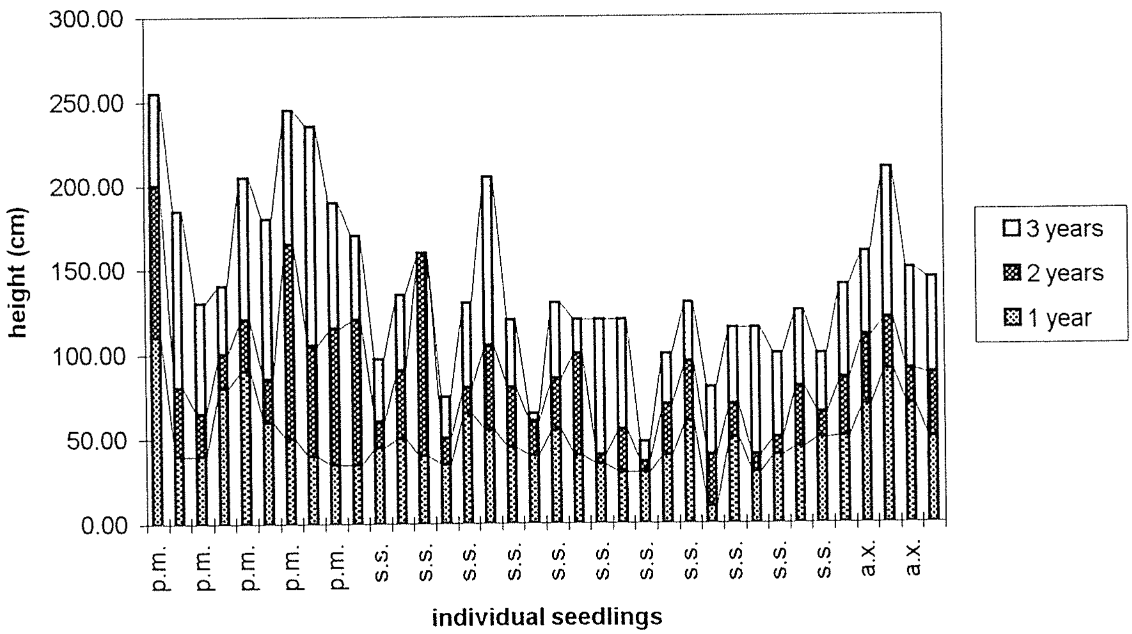

Figure 12. 2. Height growth in plot PQ1 - 3.
(unweeded control plot)

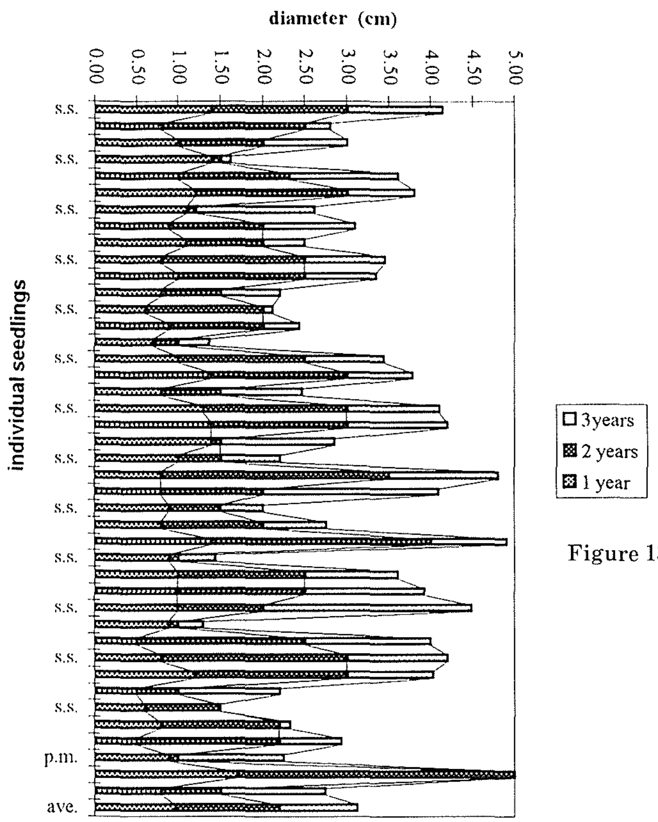

Figure 13. 1. Diameter growth in plot PQ1 - 2 (weed - control plot)

Species

s.s.=Sindora siamensis

p.m.=Pterocarpus macrocarpus

a.x.=Afzelia xylocarpa

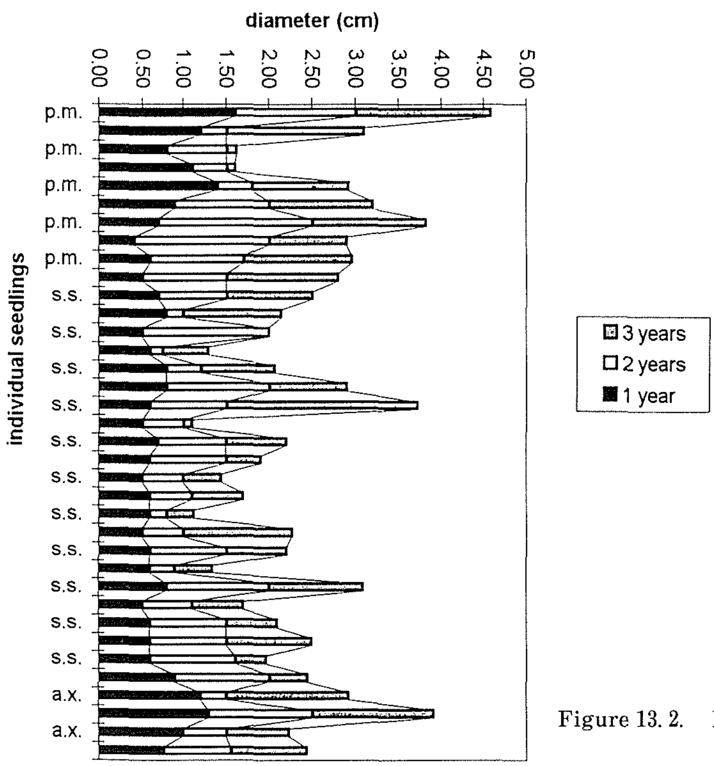

Figure 13. 2. Diameter growth in plot PQ1 - 3 (unweeded control plot)

The average heights of the weed control plot were 54.67cm, 145.35cm, and 185.50cm, in the first, second and third years respectively. Corresponding values of the unweeded control plot were 50.03cm, 87.74cm, and 141.91cm.

The average diameters of the weed control plot were 0.97cm, 2.19cm, and 3.08cm, in the first, second and third years respectively. Corresponding values of the unweeded control plot were 0.76cm, 1.56cm, and 2.42cm.

A T-test was used to determine significant differences between the weed control treatment and unweeded control treatment at 1, 2 and 3 years respectively (Table 6). The probability associated with a Student's t-test (P) < 0.05 shows significant difference at the 95% confidence level.

Table 6. T- distribution test.

source of variation	1 year	2 years	3 years
diameter	p= 0.00208	p=0.000153	p=0.0025
height	p=0.33	p: very few	p=0.0008

Based on the table above, weed control very significantly affects the diameter growth rate of planted seedlings during the first 3 years ($p<0.05$). Nevertheless, weed harvesting appears not significant for height growth in the first year ($p> 0.05$), although it appears very highly significant in the second and third years. This is because, in the first year, planted seedlings need to establish their root system. Height growth differences in the weed-control treatment and unweeded treatment were therefore not significant.

3. Survival rate and viability

The percentage survival rate is shown in Table 7. Obviously, survival of planted seedlings is relatively high. Similarly, the viability is also high and there are no insects and disease.

Table 7. Average growth and survival percentage of planted trees.

phase	planted	plot	ave. dia (cm)			Height (cm)			% survival		
			1 year	2 years	3 years	1 year	2 years	3 years	1 year	2 years	3 years
1	1991	PQ 1 - 1	1.11	2.03	3.31	57.21	134.96	174.42	87.50	87.50	81.25
		PQ 1 - 2	0.97	2.19	3.08	54.67	145.35	185.50	87.50	87.50	83.33
		PQ 1 - 3	0.76	1.56	2.42	50.03	87.74	141.91	72.92	72.92	70.83
		PQ 1 - 4	0.58	1.01	2.03	33.34	64.00	123.67	66.67	56.25	50.00

4. Dynamics of stand growth

Tree growth is non-uniform and depends on both genetic control and environment factors. The dynamics of growth of planted seedlings is thus continually changing. The stand growth, which is spectacular, is shown in Figure 16. In the first year, newly planted seedlings need root system development and adjust to environment conditions in the new site. There is high competition among root systems for moisture and nutrients, between planted seedlings and a variety of weeds, particularly during the first 4-8 months. In the second year, stand development is rapid. Interestingly, light competition occurs when neighboring seedlings begin to touch and overlap. Some trees are slower than others. A range of tree sizes emerges, with different crowns.

5. Some ecological factors from ERM method

Vegetation left over after ploughing grow fast. There are some species of ants, earthworms and termites which have functions in the plantation site. In most soils termites are a major component of the so-called soil macrofauna (Whitmore, 1990). Besides, seedlings around termite- made mounds grow well.

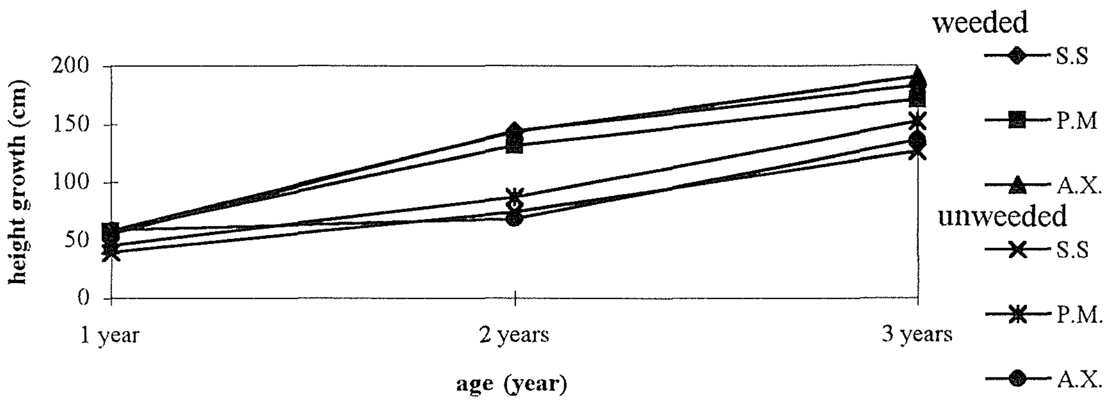

Figure 14. Height growth of individual species.

S.S. = Sindora siamensis
P.M. = Pterocarpus macrocarpus
A.X. = Afzelia xylocarpa

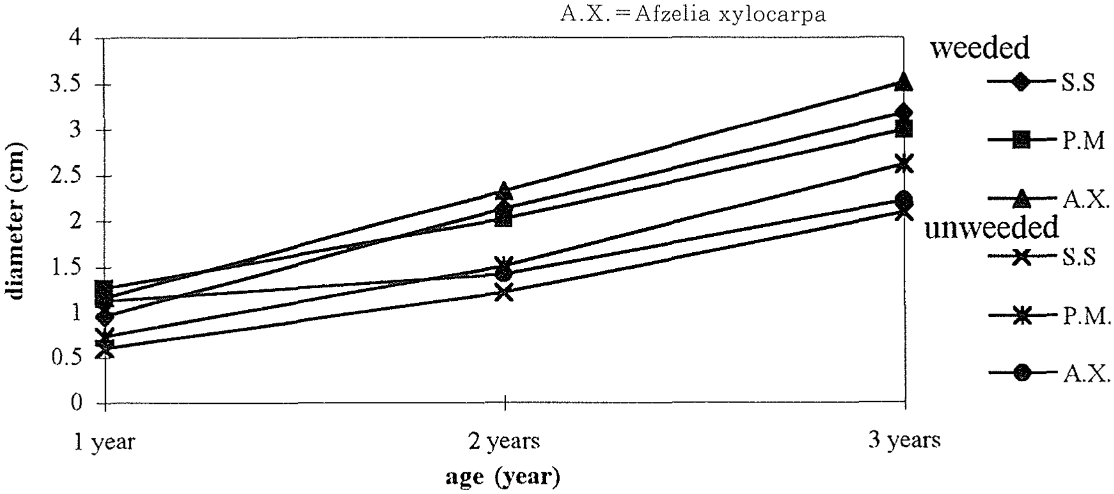

Figure 15. Diameter growth of individual species.

Figure 16. Growth dynamics of mixed - species stands.

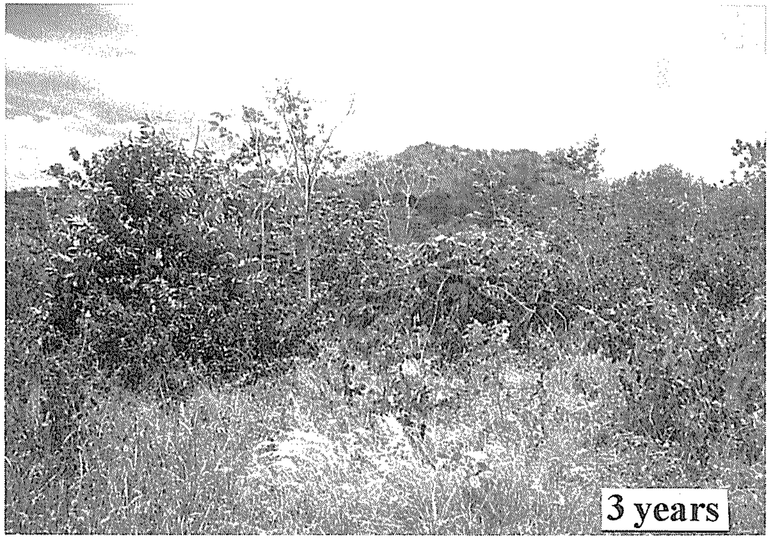

Figure 16. (continued).

Growth dynamics of mixed - species stands.

6. Urban rehabilitation and micro-environmental changes at Chitralada Palace Site

This site started in June 1994. The main focus is rehabilitation in urban Bangkok. The site is also representative of flat areas with high water level.

1) Planting technique on flat areas

The planting technique on flat sites is, of course, different from that on sloping sites. Mound construction is needed to increase suitability for plants. In the middle of the mound, materials such as dead wood, trunks, coconut leaves and other decomposing materials are used. The mound is then covered with soil. Topsoil of 30 cm thickness should be added in case soil is of low fertility and nutrition. The mound height is approximately half of the base width. Planting on the mound is done with canopy species. Then rice-straw mulch is added.

To compare environmental changes due to planting, meteorological instruments for temperature, soil moisture and rainfall are set up on the plantation area and bare land. The data are recorded regularly.

Figure 17. Plantation forest and meteorological instruments at Chitralada Palace site.

2) Growth rate

The growth performance of planted seedlings at Chitralada Palace site is shown in Tables 15 and 16 and Figures 18 and 19.

The average height is 48.44cm and 61.39cm with average diameter of 0.68cm and 1.09cm after 1.5 and 5 months respectively.

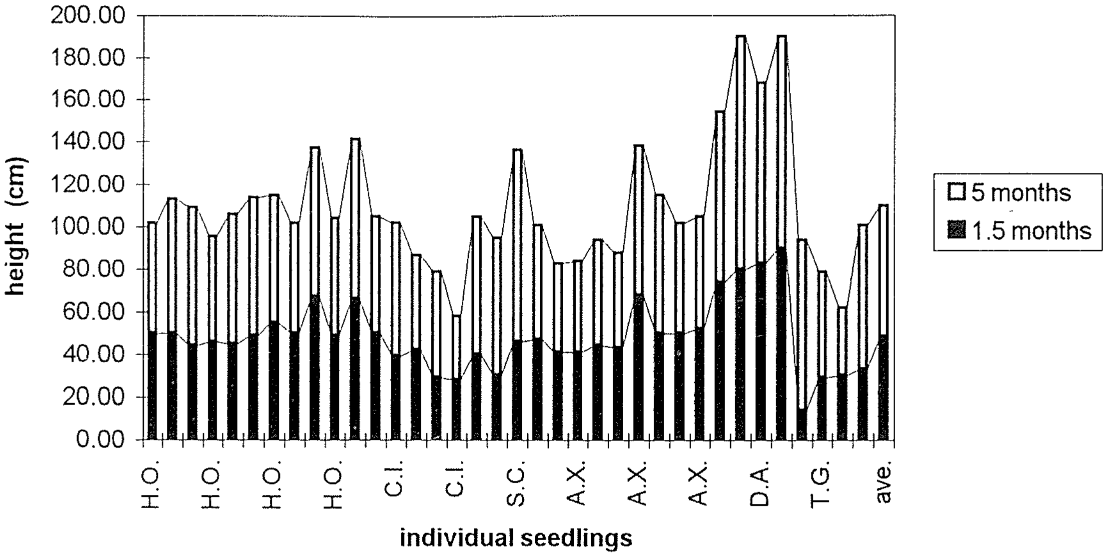

Figure 18. Height growth at Chitralada Palace site, Bangkok.

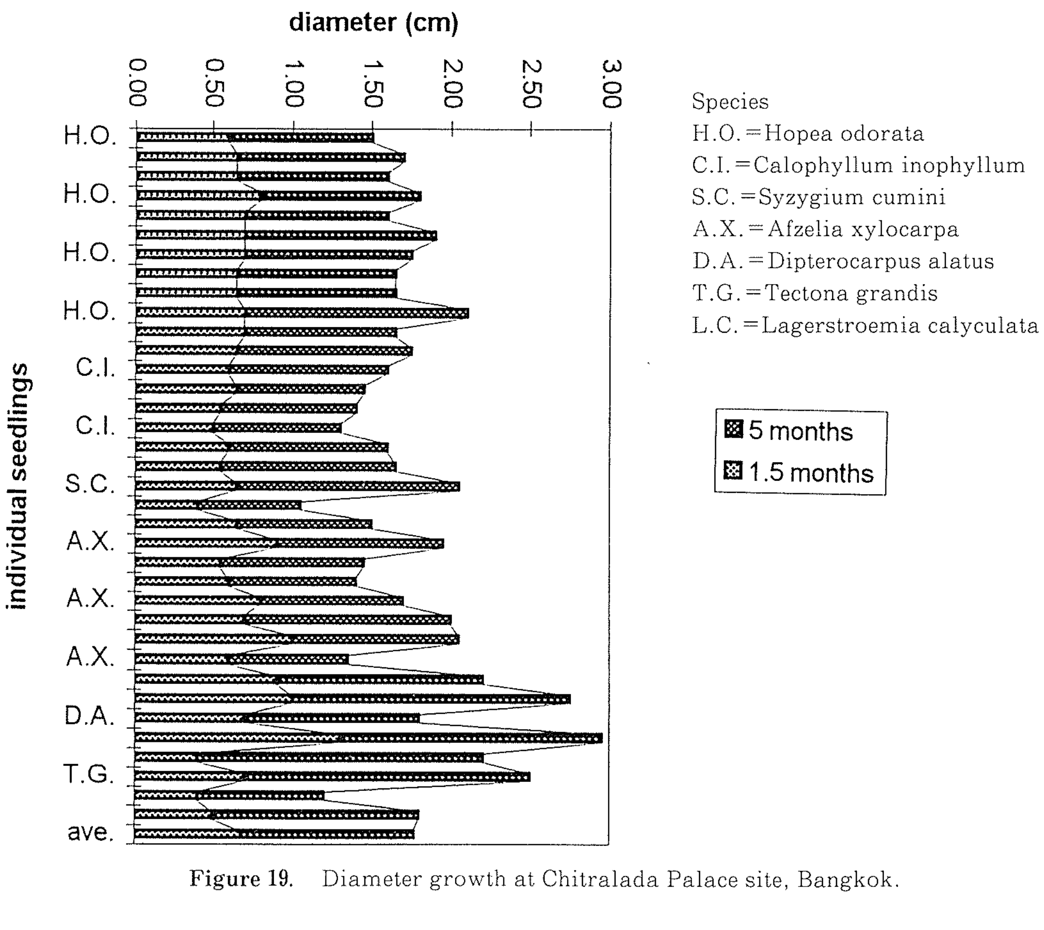

Figure 19. Diameter growth at Chitralada Palace site, Bangkok.

7. Climatic changes

1) Temperature

Temperature of the plantation forest at Chitralada Palace site Bangkok, during 13 June- 12 November 1994, is shown in Figure 20.1 and 20.2.

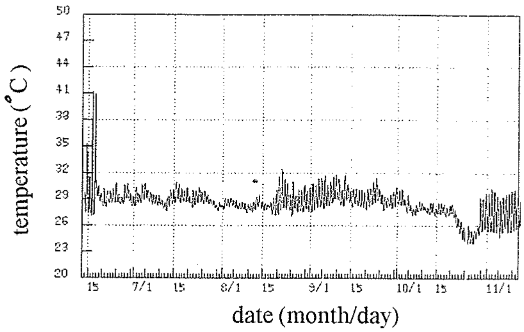

Figure 20. 1. Daily hourly temperature in the plantation area.

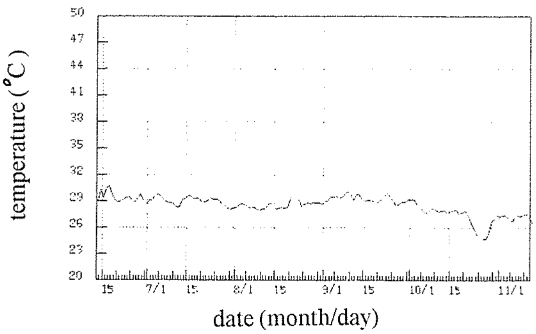

Figure 20. 2. Mean daily temperature in the plantation area.

From the above figures, the daily hourly temperature of the plantation forest is ranging from 24.0° C to 41.2° C, with the mean temperature in a day from 24.5° C to 30.5° C, during 13 June- 12 November 1994.

2) Soil moisture

Soil moisture of the plantation area and lawn at Chitralada Palace site Bangkok, during 13 June- 12 November 1994, is shown in figure 21.1-21.4.

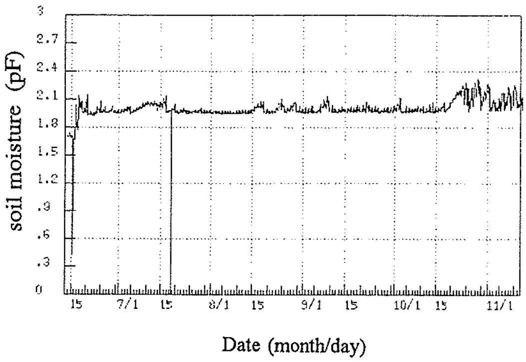

Figure 21. 1. Daily hourly soil moisture of plantation area.

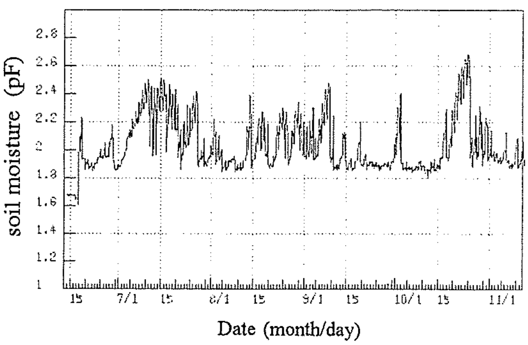

Figure 21. 2. Daily hourly soil moisture in the lawn area.

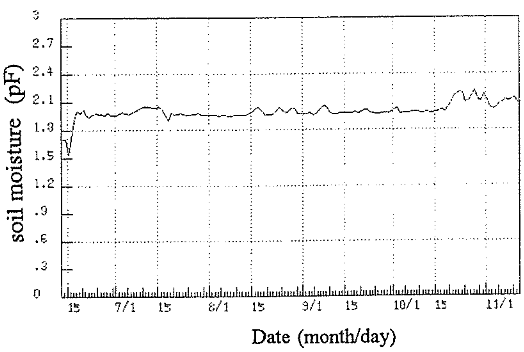

Figure 21. 3. Mean daily soil moisture of plantation area.

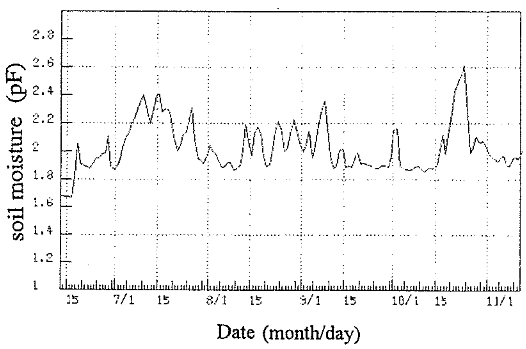

Figure 21. 4. Mean daily soil moisture in the lawn area.

The soil moisture of the plantation area varies less than that of lawn area. Even young seedlings can keep the soil moisture more than lawn area.

3) Air humidity

Air humidity of plantation forest and control at Chitralada Palace site Bangkok, during 13 June- 12 November 1994,is shown in figure 22.1-22.4.

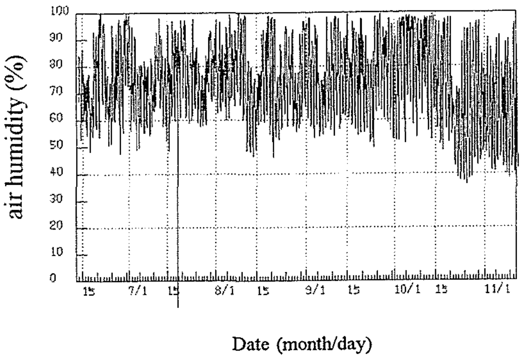

Figure 22. 1. Daily hourly air humidity of plantation area.

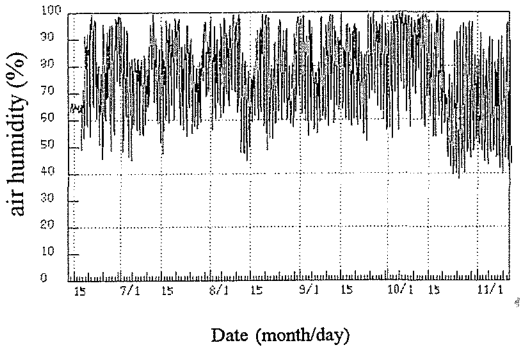

Figure 22. 2. Daily hourly air humidity of lawn.

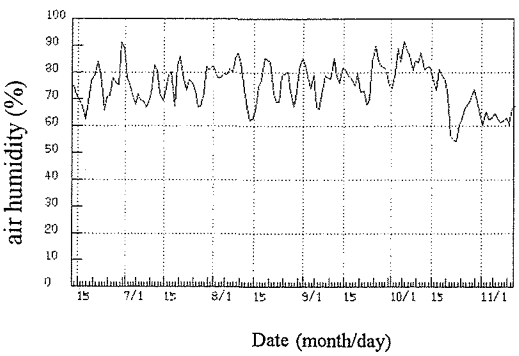

Figure 22. 3. Mean daily air humidity of plantation area.

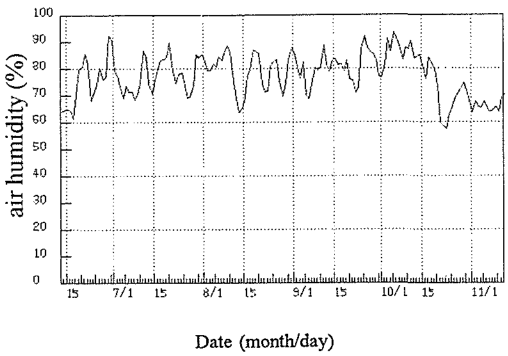

Figure 22. 4. Mean daily air humidity of lawn.

From the above figures, the air humidity of plantation forest and open air are similar. A reason for this is that planted seedlings are still young (only 5 months, with an average 61.39cm. in total height). In contrast, the air moisture instrument was set at 1.30 m.

4) Rainfall

Rainfall at the plantation forest at Chitralada Palace site Bangkok, during 13 June-12 November 1994, is shown in figure 23.1-23.2.

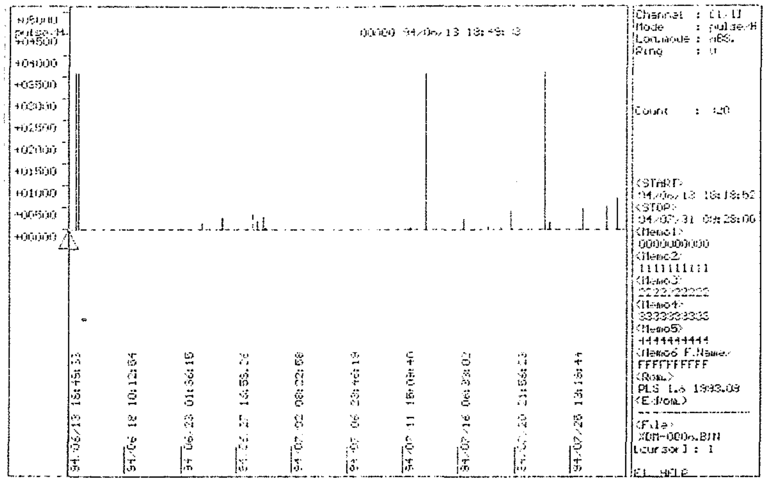

Figure 23. 1. Rainfall of plantation forest during 13 June to 31 July 1994.

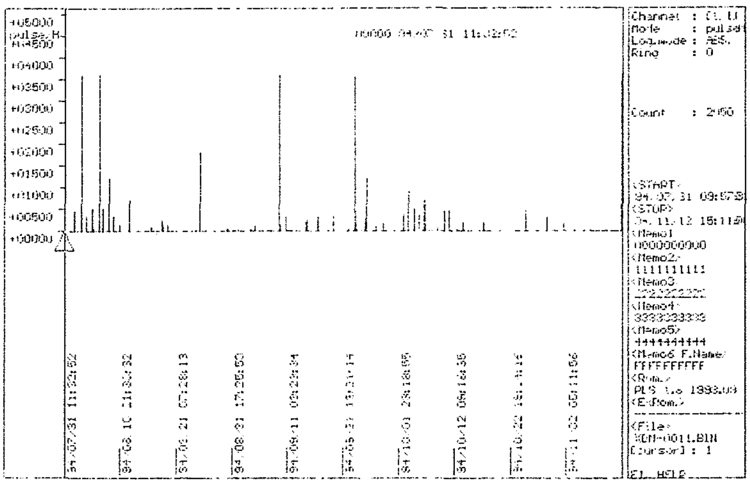

Figure 23. 2. Rainfall of plantation forest during 31 July to 12 November 1994.

The pattern of rainfall in plantation forest shows that the beginning of August is the peak period of precipitation. Yet there is rainfall from July to October. Unfortunately, there is no precipitation instrument set on bare land to compare with the plantation forest.

8. Comparison of conventional reforestation programme and ecological restoration programme

The ecological restoration method (ERM), which is applied in this study, is different from conventional reforestation programme, as shown in Table 8.

1) Planting culture

The planting method is a multiculture with mixed species. In contrast, the existing method is monoculture. As a result of the ERM, the plantation forest develops into a mixed stand.

2) Species

The species which have been planted are natural canopy species, while ordinary plantations focus on fast-growing species. There are

Table 8. Differences between the conventional and ERM methods for restoration.

Issue	Conventional Method	Ecological Restoration Method	Advantage
Planting	monoculture	mixed species	higher diversity
species	fast - growing species	indigenous species	more natural
density	lower density	higher density	less weeding
planting technique	less intensive	more intensive	greater survival and growth rate
mulching	no mulching	mulching	keep moisture and increase fertilizer
seedling	non - selected	selected	rapid establishment
thinning	thinning	no thinning	low cost
pruning	pruning	no pruning	low cost
chemical	pesticide use	no pesticides	low cost

Eucalyptus camaldulensis, *Azadiracta indica*, *Melia azedarach*, *Gmelina arborea*, *Acacia catechu*, *Leucaena leucocephala*, and so on. The canopy species which have been selected gradually develop into a more natural forest and show higher ecological productivity.

3) Density

The ERM technique is a dense method, with 2-3 seedlings per sq. m. The aim is to let free competition of sunlight occur.

4) Planting technique

The intention of planting is more specific than usual. This includes soaking seedlings with water before planting, taking care with seedlings during real planting, and softly pressing around seedlings with hands. Such intensive planting shows high survival and growth rate.

5) Mulching

Mulching with rice straw and grass are practiced in this method, in order to reduce high evaporation and keep soil moisture for new seedling growth.

6) Seedling selection

The seedlings for ready planting should have well developed root systems and be healthy. With such selection, the rapid establishment of newly planted seedlings can be obviously seen.

7) Low maintenance

Major maintenance which is done by local people is needed for only 2-3 years after planting, after which nature itself can continuously contribute. Silviculture practices such as thinning and pruning are not necessary. These are done naturally, and the cost for maintenance is therefore relatively low.

8) Chemical pollution

There are not any chemical (pesticide and insecticide) applications. Thus soil pollution is avoided. Micro-organisms can function. Besides, the plantation cost is less.

Conclusion

Growth rate and growth dynamics of stands , planted in 1991, provide some indication of possible performance in ecological restoration.

Weed control is needed for 3 years. The frequency and timing are as follow: 1) year 1 : 3 weedings (in September, December and March), 2) year 2 : 2 weedings (in June and December), 3) year 3: 1 weeding (in June), and 4) after 3 years, there is little management.

Local participation is essential to implement the activities. Through educational process, local people are willing and want to participate. The target groups of participants, unlimited in age and sex, are school students, parents, villagers and people outside the village.

The natural potential species, planted in Chitralada Palace site, have grown and developed well. The plantation area can keep soil moisture better than lawn area which maybe caused by mulching with rice straw.

Discussion

The Ecological Restoration Method (ERM) is an appropriate technology because of its simplicity and low cost. The help from local people contributed to the project activities. The application of this method can be suitably practiced for agro-forestry, community forestry, extensive forestry, and other multipurpose planting for sustainable utilization.

From project experience, the integration of both methodology and people-participation strategies to rehabilitate degraded areas is possible but also need more effort and energy.

Further, multi-disciplinary approaches of scientific ecological knowledge should be taken into account. Yet, restoration is a very hard task, costly and time consuming. Therefore, the best is to prevent degradation.

Acknowledgments

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Table 9. Height growth and increments (cm) of plot PQ 1 - 1 at 1, 2, and 3 years.

No.	Botanical Name	1 year	increment	2 years	increment	3 years
1	*Sindora siamensis*	50.00	90.00	140.00	55.00	195.00
2	*Sindora siamensis*	45.00	95.00	140.00	85.00	225.00
3	*Afzelia xylocarpa*	37.00	53.00	90.00	15.00	105.00
4	*Afzelia xylocarpa*	39.00	51.00	90.00	65.00	155.00
5	*Afzelia xylocarpa*	100.00	75.00	175.00	15.00	190.00
6	*Pterocarpus macrocarpus*	60.00	70.00	130.00	30.00	160.00
7	*Afzelia xylocarpa*	60.00	70.00	130.00	25.00	155.00
8	*Sindora siamensis*	30.00	85.00	115.00	20.00	135.00
9	*Sindora siamensis*	50.00	100.00	150.00	35.00	185.00
10	*Sindora siamensis*	45.00	60.00	105.00	40.00	145.00
11	*Afzelia xylocarpa*	60.00	108.00	168.00	42.00	210.00
12	*Pterocarpus macrocarpus*	80.00	80.00	160.00	40.00	200.00
13	*Pterocarpus macrocarpus*	100.00	90.00	190.00	55.00	245.00
14	*Sindora siamensis*	65.00	75.00	140.00	40.00	180.00
15	*Sindora siamensis*	80.00	110.00	190.00	5.00	195.00
16	*Pterocarpus macrocarpus*	50.00	10.00	60.00	55.00	115.00
17	*Sindora siamensis*	30.00	50.00	80.00	30.00	110.00
18	*Sindora siamensis*	70.00	130.00	200.00	95.00	295.00
19	*Afzelia xylocarpa*	50.00	60.00	110.00	105.00	215.00
20	*Pterocarpus macrocarpus*	45.00	115.00	160.00	25.00	185.00
21	*Pterocarpus macrocarpus*	65.00	5.00	70.00	2.00	72.00
22	*Pterocarpus macrocarpus*	35.00	125.00	160.00	dead	dead
23	*Pterocarpus macrocarpus*	50.00	120.00	170.00	30.00	200.00
24	*Sindora siamensis*	45.00	20.00	65.00	0.00	65.00
25	*Pterocarpus macrocarpus*	36.00	105.00	141.00	dead	dead
26	*Sindora siamensis*	90.00	110.00	200.00	55.00	255.00
27	*Sindora siamensis*	93.00	47.00	140.00	80.00	220.00
28	*Pterocarpus macrocarpus*	42.00	68.00	110.00	13.00	123.00
	Average	57.21	77.75	134.96	40.65	174.42

Table 10. Diameter growth and increments (cm) of plot PQ 1 - 1 at 1, 2, and 3 years.

No.	Botanical Name	1 year	increment	2 years	increment	3 years
1	*Sindora siamensis*	1.00	1.00	2.00	1.11	3.11
2	*Sindora siamensis*	0.90	0.60	1.50	2.01	3.51
3	*Afzelia xylocarpa*	1.00	0.50	1.50	0.42	1.92
4	*Afzelia xylocarpa*	1.00	0.50	1.50	1.03	2.53
5	*Afzelia xylocarpa*	1.30	1.70	3.00	2.80	5.80
6	*Pterocarpus macrocarpus*	1.00	0.50	1.50	1.00	2.50
7	*Afzelia xylocarpa*	1.00	0.50	1.50	1.88	3.38
8	*Sindora siamensis*	0.40	1.10	1.50	1.07	2.57
9	*Sindora siamensis*	1.00	1.50	2.50	2.16	4.66
10	*Sindora siamensis*	0.70	0.80	1.50	0.84	2.34
11	*Afzelia xylocarpa*	1.30	1.20	2.50	2.01	4.51
12	*Pterocarpus macrocarpus*	1.50	0.50	2.00	1.60	3.60
13	*Pterocarpus macrocarpus*	2.20	0.80	3.00	2.20	5.20
14	*Sindora siamensis*	1.00	1.00	2.00	2.04	4.04
15	*Sindora siamensis*	1.40	2.10	3.50	0.52	4.02
16	*Pterocarpus macrocarpus*	0.80	0.20	1.00	0.50	1.50
17	*Sindora siamensis*	0.80	0.20	1.00	0.52	1.52
18	*Sindora siamensis*	1.20	2.30	3.50	1.30	4.80
19	*Afzelia xylocarpa*	1.30	0.70	2.00	2.10	4.10
20	*Pterocarpus macrocarpus*	1.80	0.70	2.50	0.65	3.15
21	*Pterocarpus macrocarpus*	1.60	0.20	1.80	0.65	2.45
22	*Pterocarpus macrocarpus*	1.30	0.70	2.00	dead	dead
23	*Pterocarpus macrocarpus*	1.20	0.80	2.00	1.05	3.05
24	*Sindora siamensis*	0.60	0.40	1.00	0.60	1.60
25	*Pterocarpus macrocarpus*	1.10	0.90	2.00	dead	dead
26	*Sindora siamensis*	1.10	2.40	3.50	0.94	4.44
27	*Sindora siamensis*	1.00	1.50	2.50	2.06	4.56
28	*Pterocarpus macrocarpus*	0.50	0.50	1.00	0.30	1.30
	Average	1.11	0.92	2.03	1.28	3.31

Table 11. Height growth and increments (cm) of plot PQ 1 - 2 at 1, 2, and 3 years.

No.	Botanical Name	1 year	increment	2 years	increment	3 years
51	*Sindora siamensis*	70.00	150.00	220.00	85.00	305.00
52	*Sindora siamensis*	50.00	80.00	130.00	25.00	155.00
53	*Sindora siamensis*	50.00	100.00	150.00	20.00	170.00
54	*Sindora siamensis*	70.00	30.00	100.00	10.00	110.00
55	*Pterocarpus macrocarpus*	25.00	75.00	100.00	70.00	170.00
56	*Sindora siamensis*	50.00	95.00	145.00	45.00	190.00
57	*Sindora siamensis*	50.00	120.00	170.00	45.00	215.00
58	*Sindora siamensis*	40.00	70.00	110.00	55.00	165.00
59	*Sindora siamensis*	70.00	80.00	150.00	25.00	175.00
60	*Pterocarpus macrocarpus*	120.00	130.00	250.00	dead	dead
61	*Sindora siamensis*	60.00	60.00	120.00	25.00	145.00
62	*Sindora siamensis*	30.00	130.00	160.00	15.00	175.00
63	*Sindora siamensis*	40.00	130.00	170.00	40.00	210.00
64	*Sindora siamensis*	40.00	90.00	130.00	35.00	165.00
65	*Sindora siamensis*	37.00	63.00	100.00	50.00	150.00
66	*Sindora siamensis*	50.00	98.00	148.00	12.00	160.00
67	*Pterocarpus macrocarpus*	40.00	60.00	100.00	65.00	165.00
68	*Sindora siamensis*	30.00	55.00	85.00	5.00	90.00
69	*Sindora siamensis*	53.00	67.00	120.00	55.00	175.00
70	*Sindora siamensis*	70.00	130.00	200.00	30.00	230.00
71	*Sindora siamensis*	55.00	75.00	130.00	25.00	155.00
72	*Sindora siamensis*	90.00	90.00	180.00	95.00	275.00
73	*Sindora siamensis*	100.00	120.00	220.00	60.00	280.00
74	*Sindora siamensis*	80.00	40.00	120.00	50.00	170.00
75	*Sindora siamensis*	45.00	75.00	120.00	40.00	160.00
76	*Sindora siamensis*	45.00	75.00	120.00	100.00	220.00
77	*Sindora siamensis*	50.00	105.00	155.00	85.00	240.00
78	*Sindora siamensis*	40.00	80.00	120.00	25.00	145.00
79	*Sindora siamensis*	65.00	75.00	140.00	50.00	190.00
80	*Sindora siamensis*	105.00	135.00	240.00	35.00	275.00
81	*Sindora siamensis*	50.00	10.00	60.00	55.00	115.00
82	*Sindora siamensis*	70.00	130.00	200.00	15.00	215.00
83	*Sindora siamensis*	62.00	103.00	165.00	65.00	230.00
84	*Sindora siamensis*	70.00	70.00	140.00	90.00	230.00
85	*Sindora siamensis*	65.00	5.00	70.00	5.00	75.00
86	*Sindora siamensis*	35.00	145.00	180.00	30.00	210.00
87	*Sindora siamensis*	26.00	204.00	230.00	40.00	270.00
88	*Sindora siamensis*	60.00	110.00	170.00	55.00	225.00
89	*Sindora siamensis*	30.00	80.00	110.00	- 60.00	50.00
90	*Sindora siamensis*	33.00	75.00	108.50	dead	dead
91	*Sindora siamensis*	40.00	110.00	150.00	30.00	180.00
92	*Sindora siamensis*	35.00	83.00	118.00	72.00	190.00
	Average	54.67	90.67	145.35	41.85	185.50

Table 12. Diameter growth and increments (cm) of plot PQ 1 - 2 at 1, 2, and 3 years.

No.	Botanical Name	1 year	increment	2 years	increment	3 years
51	*Sindora siamensis*	1.40	1.60	3.00	1.14	4.14
52	*Sindora siamensis*	0.80	1.70	2.50	0.30	2.80
53	*Sindora siamensis*	1.00	1.00	2.00	1.00	3.00
54	*Sindora siamensis*	1.40	0.10	1.50	0.12	1.62
55	*Pterocarpus macrocarpus*	0.90	0.10	1.00	1.25	2.25
56	*Sindora siamensis*	1.00	1.30	2.30	1.30	3.60
57	*Sindora siamensis*	1.20	1.80	3.00	0.80	3.80
58	*Sindora siamensis*	1.10	0.10	1.20	1.41	2.61
59	*Sindora siamensis*	0.90	1.10	2.00	1.10	3.10
60	*Pterocarpus macrocarpus*	1.70	3.30	5.00	dead	dead
61	*Sindora siamensis*	1.10	0.90	2.00	0.50	2.50
62	*Sindora siamensis*	0.80	1.70	2.50	0.95	3.45
63	*Sindora siamensis*	1.00	1.50	2.50	0.84	3.34
64	*Sindora siamensis*	0.80	0.70	1.50	0.70	2.20
65	*Sindora siamensis*	0.60	1.40	2.00	0.11	2.11
66	*Sindora siamensis*	0.90	1.10	2.00	0.43	2.43
67	*Pterocarpus macrocarpus*	0.80	0.70	1.50	1.25	2.75
68	*Sindora siamensis*	0.70	0.30	1.00	0.37	1.37
69	*Sindora siamensis*	1.00	1.50	2.50	0.94	3.44
70	*Sindora siamensis*	1.40	1.60	3.00	0.78	3.78
71	*Sindora siamensis*	0.80	0.70	1.50	0.97	2.47
72	*Sindora siamensis*	1.30	1.70	3.00	1.10	4.10
73	*Sindora siamensis*	1.40	1.60	3.00	1.20	4.20
74	*Sindora siamensis*	1.40	0.10	1.50	1.35	2.85
75	*Sindora siamensis*	1.00	0.50	1.50	0.70	2.20
76	*Sindora siamensis*	0.80	2.70	3.50	1.31	4.81
77	*Sindora siamensis*	0.80	1.20	2.00	2.09	4.09
78	*Sindora siamensis*	0.90	0.60	1.50	0.50	2.00
79	*Sindora siamensis*	0.80	1.20	2.00	0.76	2.76
80	*Sindora siamensis*	1.40	2.60	4.00	0.90	4.90
81	*Sindora siamensis*	0.90	0.10	1.00	0.44	1.44
82	*Sindora siamensis*	1.00	1.50	2.50	1.10	3.60
83	*Sindora siamensis*	1.00	1.50	2.50	1.42	3.92
84	*Sindora siamensis*	1.00	1.00	2.00	2.49	4.49
85	*Sindora siamensis*	0.90	0.10	1.00	0.30	1.30
86	*Sindora siamensis*	0.50	2.00	2.50	1.50	4.00
87	*Sindora siamensis*	0.80	2.20	3.00	1.20	4.20
88	*Sindora siamensis*	1.20	1.80	3.00	1.03	4.03
89	*Sindora siamensis*	0.50	0.50	1.00	1.20	2.20
90	*Sindora siamensis*	0.60	0.90	1.50	dead	dead
91	*Sindora siamensis*	0.80	1.40	2.20	0.13	2.33
92	*Sindora siamensis*	0.50	1.70	2.20	0.74	2.94
	Average	0.97	1.22	2.19	0.94	3.08

Table 13. Height growth and increments (cm) of plot PQ 1 - 3 at 1, 2, and 3 years.

No.	Botanical Name	1 year	increment	2 years	increment	3 years
1	*Pterocarpus macrocarpus*	110.00	90.00	200.00	55.00	255.00
2	*Sindora siamensis*	45.00	15.00	60.00	37.00	97.00
3	*Sindora siamensis*	50.00	40.00	90.00	45.00	135.00
4	*Pterocarpus macrocarpus*	40.00	40.00	80.00	105.00	185.00
5	*Pterocarpus macrocarpus*	40.00	25.00	65.00	65.00	130.00
6	*Afzelia xylocarpa*	70.00	40.00	110.00	50.00	160.00
7	*Afzelia xylocarpa*	90.00	30.00	120.00	90.00	210.00
8	*Sindora siamensis*	40.00	120.00	160.00	dead	dead
9	*Afzelia xylocarpa*	70.00	20.00	90.00	60.00	150.00
10	*Sindora siamensis*	35.00	15.00	50.00	25.00	75.00
11	*Pterocarpus macrocarpus*	80.00	20.00	100.00	40.00	140.00
12	*Pterocarpus macrocarpus*	90.00	30.00	120.00	85.00	205.00
13	*Sindora siamensis*	65.00	15.00	80.00	50.00	130.00
14	*Pterocarpus macrocarpus*	60.00	25.00	85.00	95.00	180.00
15	*Sindora siamensis*	55.00	50.00	105.00	100.00	205.00
16	*Sindora siamensis*	45.00	35.00	80.00	40.00	120.00
17	*Sindora siamensis*	40.00	20.00	60.00	5.00	65.00
18	*Pterocarpus macrocarpus*	50.00	115.00	165.00	80.00	245.00
19	*Sindora siamensis*	55.00	30.00	85.00	45.00	130.00
20	*Sindora siamensis*	40.00	60.00	100.00	20.00	120.00
21	*Sindora siamensis*	35.00	5.00	40.00	80.00	120.00
22	*Pterocarpus macrocarpus*	40.00	65.00	105.00	130.00	235.00
23	*Sindora siamensis*	30.00	25.00	55.00	65.00	120.00
24	*Sindora siamensis*	30.00	6.00	36.00	12.00	48.00
25	*Pterocarpus macrocarpus*	35.00	80.00	115.00	75.00	190.00
26	*Sindora siamensis*	40.00	30.00	70.00	30.00	100.00
27	*Sindora siamensis*	60.00	35.00	95.00	35.00	130.00
28	*Sindora siamensis*	10.00	30.00	40.00	40.00	80.00
29	*Pterocarpus macrocarpus*	35.00	85.00	120.00	50.00	170.00
30	*Sindora siamensis*	50.00	20.00	70.00	45.00	115.00
31	*Sindora siamensis*	30.00	10.00	40.00	75.00	115.00
32	*Sindora siamensis*	40.00	10.00	50.00	50.00	100.00
33	*Sindora siamensis*	45.00	35.00	80.00	45.00	125.00
34	*Sindora siamensis*	50.00	15.00	65.00	35.00	100.00
35	*Sindora siamensis*	51.00	34.00	85.00	55.00	140.00
	Average	50.03	37.71	87.74	56.29	141.91

Table 14. Diameter growth and increments (cm) of plot PQ 1 - 3 at 1, 2, and 3 years.

No.	Botanical Name	1 year	increment	2 years	increment	3 years
1	*Pterocarpus macrocarpus*	1.60	1.40	3.00	1.58	4.58
2	*Sindora siamensis*	0.70	0.80	1.50	1.00	2.50
3	*Sindora siamensis*	0.80	0.20	1.00	1.14	2.14
4	*Pterocarpus macrocarpus*	1.20	0.30	1.50	1.60	3.10
5	*Pterocarpus macrocarpus*	0.80	0.70	1.50	0.12	1.62
6	*Afzelia xylocarpa*	1.20	0.30	1.50	1.42	2.92
7	*Afzelia xylocarpa*	1.30	1.20	2.50	1.41	3.91
8	*Sindora siamensis*	0.50	1.50	2.00	dead	dead
9	*Afzelia xylocarpa*	1.00	0.50	1.50	0.73	2.23
10	*Sindora siamensis*	0.60	0.15	0.75	0.54	1.29
11	*Pterocarpus macrocarpus*	1.10	0.40	1.50	0.10	1.60
12	*Pterocarpus macrocarpus*	1.40	0.40	1.80	1.12	2.92
13	*Sindora siamensis*	0.80	0.40	1.20	0.86	2.06
14	*Pterocarpus macrocarpus*	0.90	1.10	2.00	1.20	3.20
15	*Sindora siamensis*	0.80	1.20	2.00	0.90	2.90
16	*Sindora siamensis*	0.60	0.90	1.50	2.22	3.72
17	*Sindora siamensis*	0.50	0.50	1.00	0.10	1.10
18	*Pterocarpus macrocarpus*	0.70	1.80	2.50	1.32	3.82
19	*Sindora siamensis*	0.70	0.80	1.50	0.70	2.20
20	*Sindora siamensis*	0.60	0.90	1.50	0.40	1.90
21	*Sindora siamensis*	0.50	0.50	1.00	0.44	1.44
22	*Pterocarpus macrocarpus*	0.40	1.60	2.00	0.90	2.90
23	*Sindora siamensis*	0.60	0.50	1.10	0.60	1.70
24	*Sindora siamensis*	0.60	0.20	0.80	0.32	1.12
25	*Pterocarpus macrocarpus*	0.60	1.10	1.70	1.26	2.96
26	*Sindora siamensis*	0.50	0.50	1.00	1.27	2.27
27	*Sindora siamensis*	0.60	0.90	1.50	0.70	2.20
28	*Sindora siamensis*	0.60	0.30	0.90	0.44	1.34
29	*Pterocarpus macrocarpus*	0.50	1.00	1.50	1.30	2.80
30	*Sindora siamensis*	0.80	1.20	2.00	1.09	3.09
31	*Sindora siamensis*	0.50	0.60	1.10	0.60	1.70
32	*Sindora siamensis*	0.60	0.90	1.50	0.59	2.09
33	*Sindora siamensis*	0.60	0.90	1.50	0.99	2.49
34	*Sindora siamensis*	0.60	1.00	1.60	0.36	1.96
35	*Sindora siamensis*	0.90	1.10	2.00	0.44	2.44
	Average	0.76	0.79	1.56	0.88	2.42

Table 15. Height growth (cm) of plot PQ 1 at Chitralada Palace site, Bangkok (planted in June 1994).

No.	Botanical Name	1.5 months	5 months
1	*Hopea odorata*	50.00	52.00
2	*Hopea odorata*	50.00	63.00
3	*Calophyllum inophyllum*	39.00	63.00
4	*Syzygium cumini*	40.00	65.00
5	*Calophyllum inophyllum*	42.00	45.00
6	*Afzelia xylocarpa*	41.00	42.00
7	*Dipterocarpus alatus*	74.00	80.00
8	*Afzelia xylocarpa*	41.00	43.00
9	*Dipterocarpus alatus*	80.00	110.00
10	*Hopea odorata*	44.00	65.00
11	*Syzygium cumini*	30.00	65.00
12	*Afzelia xylocarpa*	44.00	50.00
13	*Tectona grandis*	14.00	80.00
14	*Pterocarpus macrocarpus*	30.00	32.00
15	*Calophyllum inophyllum*	29.00	50.00
16	*Dipterocarpus alatus*	83.00	85.00
17	*Afzelia xylocarpa*	43.00	45.00
18	*Hopea odorata*	46.00	50.00
19	*Tectona grandis*	29.00	50.00
20	*Hopea odorata*	45.00	61.00
21	*Hopea odorata*	49.00	65.00
22	*Syzygium cumini*	46.00	90.00
23	*Hopea odorata*	55.00	60.00
24	*Hopea odorata*	50.00	52.00
25	*Lagerstroemia calyculata*	33.00	68.00
26	*Afzelia xylocarpa*	68.00	70.00
27	*Hopea odorata*	67.00	70.00
28	*Calophyllum inophyllum*	28.00	30.00
29	*Afzelia xylocarpa*	50.00	65.00
30	*Dipterocarpus alatus*	90.00	100.00
31	*Afzelia xylocarpa*	50.00	52.00
32	*Hopea odorata*	49.00	55.00
33	*Hopea odorata*	66.00	75.00
34	*Afzelia xylocarpa*	52.00	53.00
35	*Hopea odorata*	50.00	55.00
36	*Syzygium cumini*	47.00	54.00
	Average	48.44	61.39

Table 16. Diameter growth (cm) of plot PQ 1 at Chitralada Palace site, Bangkok (planted in June 1994).

No.	Botanical Name	1.5 months	5 months
1	*Hopea odorata*	0.60	0.90
2	*Hopea odorata*	0.65	1.05
3	*Calophyllum inophyllum*	0.60	1.00
4	*Syzygium cumini*	0.60	1.00
5	*Calophyllum inophyllum*	0.65	0.80
6	*Afzelia xylocarpa*	0.65	0.85
7	*Dipterocarpus alatus*	0.90	1.30
8	*Afzelia xylocarpa*	0.90	1.05
9	*Dipterocarpus alatus*	1.00	1.75
10	*Hopea odorata*	0.65	0.95
11	*Syzygium cumini*	0.55	1.10
12	*Afzelia xylocarpa*	0.55	0.90
13	*Tectona grandis*	0.40	1.80
14	*Pterocarpus macrocarpus*	0.40	0.80
15	*Calophyllum inophyllum*	0.55	0.85
16	*Dipterocarpus alatus*	0.70	1.10
17	*Afzelia xylocarpa*	0.60	0.80
18	*Hopea odorata*	0.80	1.00
19	*Tectona grandis*	0.70	1.80
20	*Hopea odorata*	0.70	0.90
21	*Hopea odorata*	0.70	1.20
22	*Syzygium cumini*	0.65	1.40
23	*Hopea odorata*	0.70	1.05
24	*Hopea odorata*	0.65	1.00
25	*Lagerstroemia calyculata*	0.50	1.30
26	*Afzelia xylocarpa*	0.80	0.90
27	*Hopea odorata*	0.65	1.00
28	*Calophyllum inophyllum*	0.50	0.80
29	*Afzelia xylocarpa*	0.70	1.30
30	*Dipterocarpus alatus*	1.30	1.65
31	*Afzelia xylocarpa*	1.00	1.05
32	*Hopea odorata*	0.70	1.40
33	*Hopea odorata*	0.70	0.95
34	*Afzelia xylocarpa*	0.60	0.75
35	*Hopea odorata*	0.65	1.10
36	*Syzygium cumini*	0.40	0.65
	Average	0.68	1.09