NATURAL REGENERATION OF THE DECIDUOUS FORESTS IN THAILAND

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Introduction

The deciduous forests are those in which some or all trees shed their leaves during the dry season. However, in these forest types there may be some evergreen trees mixed with the deciduous, and some trees will form new leaves before the old ones are shed. Along the dry belt of the country, where precipitation is low (less than 1,000 mm) the climate is more seasonal, and the soil is either made of sand or gravel loam or sometimes lateritic. The vegetation of these regions is classified as deciduous formation and the trees are seldom found at an altitude of over 1,000 m. The deciduous forests are sometimes called monsoon forests because they are influenced by the shift of direction of the prevailing winds which control the time when the dry and rainy seasons are expected to start. Since the phenophases e.g. leaf production, leaf shedding, flowering and fruiting are definite seasonal phenomena, these forests are also called seasonal forests (Sukwong, 1974).

Characteristics of deciduous forests in Thailand

Mungkorndin and Eadkeo (1978) divided the deciduous forests into three main categories: the Mixed Deciduous, the Dry Deciduous Dipterocarp and the Savanna forests.

1 Mixed deciduous forest

The composition of this type of forest consists of all deciduous species distributed in harmonious proportions but in certain localities a species may become predominant such as teak *(Tectona grandis)* and the forest is generally called a teak forest for convenience. The Mixed Deciduous forest can be further classified into three subtypes: the lower mixed deciduous, dry upper mixed deciduous and moist upper mixed deciduous forests. Lower mixed deciduous forest occurs at an elevation of 50 - 300 m. in the dry zone of the country where the soil is of sandy loam or lateritic. The absence of teak is a distinct characteristic of this sub-type. Characteristic trees include *Milletia* spp., *Lagerstroemia* spp., *Bombax* spp., *Albizzia lebbek, Dalbergia* spp. etc. The species of dry deciduous dipterocarp forest sometimes are also mixed in this sub-type. Bamboo especially *Thyrsostachys siamensis and Bambusa arundinacea* are frequently present. The dry upper mixed deciduous forest is usually found along the ridge at the elevation of 300 - 500m. The soil is made of sandy loam or of gravel. The dominant and characteristic tree is teak. Tree species commonly associated with teak are *Afzelia xylocarpa, Terminalia tomentosa, Pterocarpus macrocarpus, Xylia kerrii, Dalbergia* spp. and *Diospyros* spp. The undergrowth consists of bamboo such as *Bambusa arundinacea* and *Dendrocalamus strictus*. Species of dry deciduous dipterocarp forest are also found scattered in this sub-type. The canopy is often uneven and not dense. It should be noted that teak may not be present in every stand of this forest. The moist upper mixed deciduous forest occurs in well watered areas between elevations of 300 - 500 m. This forest is fairly dense and tall, and the soil is usually loamy, either calcareous or granitic. The tree species of the dry upper mixed deciduous forest are also present. Bamboos are present and usually attain larger dimensions than in the former sub-type.

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2 Dry deciduous dipterocarp forest

This type of forest occupies large stretches of the forest areas in Northern, Central, and Northeastern Thailand, whilst in Eastern Thailand it is found only in small patches. This type of forest occurs on the undulating peneplain and ridges, where the soil is either sandy or lateritic, and subject to extensive leaching, erosion, and annual burning. Its general appearance is of open nature with prevailing grass undergrowth.

Royal Forest Department (1962) described that in Northern and Central Thailand, this type of forest occurs both on the level plains and on the hills up to an elevation of about 1,000 m. The general appearance is open, grassy, often approaching the savanna type; the trees are scattered and as a general rule of medium or small size, both in height and girth. Undergrowth consists of long grass or scattered bushes. The forests are burnt over regularly every year, nevertheless natural regeneration is fairly plentiful and often luxuriant. The seedlings are burnt back every year but owing to the accumulation of food reserve in their root-stocks, they are able to develop more vigorous and bigger shoots each year. When the shoots are finally free from the danger of fire, the seedlings are able to establish themselves and become part of the forest crop.

The most common trees in this forest are *Dipterocarpus tuberculatus, D. obtusifolius, Shorea obtusa, Pentacme siamensis, Terminalia alata, Melanorrhoea usitata, Buchanania latifolia, Terminalia mucronata, Strychnos nux-blanda* and *nux-vomica, Phyllanthus emblica, Morinda tinctoria,* many species of Dillenia, Quercus and Castanopsis. The undergrowth consists of many species of grass, *Cycas siamensia, Phoenix acualis* and shrubs of the species Indigofera, Flemingia, Desmodium, etc.

In Northeastern Thailand, the deciduous dipterocarp forests have many features in common with forests of this type in Northern and Central Thailand except for local variations.

Wherever the soil forms a deep loam, these forests are present and fine crops of this type can be found in the whole of Thailand. Wherever the soil is dry and shallow with rocky outcrops of laterite, the growth and quality decrease accordingly.

The principal trees are *Dipterocarpus tuberculatus, D. obtusifolius, D. intricatus, Shorea obtusa, Pentacme siamensis, Adina cordifolia, Sindora siamensis, Xylia kerrii, Pterocarpus macrocarpus.*

The most important auxiliary species are *Garuga pinnata, Albizzia lebbek, Schleichera oleosa, Lagerstroemia floribunda, Odina wodier, Terminalia alata, T. chebula, T. bellerica, Phyllanthus emblica, Vitex limonifolia, Cassia garrettiana,* and *Careya arborea.*

The predominant undergrowth is the grass-like bamboo, *Arundinaria ciliata.*

In Eastern Thailand, the deciduous dipterocarp forests are similar in character and composition to those of the Northeastern part but rather poorly developed and covering just a small portion of the total forest area.

Sukwong (1974) identified the Pine-Dipterocarp forest as another association of the dry deciduous dipterocarp forest. This association occurs on ridges and mountains over 750 m. It occurs extensively at an altitude of 1,100 m. which seems to be the upper limit of the Dipterocarp species in Thailand. At this altitude, trees are covered with usnea mosses. *Pinus merkusii* is usually mixed with *Dipterocarpus obtusifolius, D. tuberculatus, Shorea obtusa, Melanorrhoea usitata,* and *Wendlandia tinctoria.* Quercus, Castanopsis, and Lithocarpus are also common. At high altitudes *Pinus merkusii* forms an emergent with crown above the canopy of accompanying species. This association is also found at lower altitudes between 100 - 400 m. on old river terraces and on the plains or gently undulating lowlands underlaid by fine sandy loam which is flooded in the rainy season. At lower altitudes *Pinus merkusii* does not form an emergent; its crown occurs at the same level as its associate species.

3 The savanna forest

Savanna can be regarded as the extreme form of deciduous types, and has been originated by subsequent burning. It is more frequent in the Northeastern region where cultivation has been practised from time immemorial. Precipitation is relatively low (50-500 mm). The savanna forest is, in essence, a grassland where trees of medium height sparsely grow, forming a very open stand where some thorny shrubs, and *Bambusa arundinacea* are interspersed.

It should be noted that savanna forest which Ogawa *et al* (1961) outlined in their study is equivalent to the dry deciduous dipterocarp forest as adopted by the Royal Forest Department of Thailand.

Structure and diversity

Sukwong (1974) defined that the structure of the ecosystem is related to species diversity. The more complex the structure, the greater is the diversity of species. Diversity here refers to the different kinds of species and the variations in number of individuals of different kinds.

Generally the flora tends to become less diverse toward higher latitudes and altitudes. The species diversity is greatest in the humid tropical rainforest, and becomes less through tropical deciduous forest, warm temperate evergreen forest and boreal forest. According to Ogawa *et al* (1961) the floristic diversity of dry deciduous dipterocarp forest and hill evergreen forest is essentially the same, while the evergreen gallery forest is considerably richer in species. At Sakaerat forest, the dry deciduous dipterocarp forest (Shorea-Pentacme association) had 18 tree species, 12 shrub species, 4 climber species, 6 herbaceous species, and 1 grass species in a 245 m^2 sample area. According to the results of the survey conducted by the Military Research and Development Center team throughout Thailand, among 51 sample plots of 10 × 40 m^2 located in the dry deciduous dipterocarp forest, 79 species were identified including 24 identified by genera while 22 trees were left unidentified. These figures apply to trees with a diameter larger than 5 cm. In the pine-dipterocarp forest, the results from 8 sample plots of the same size showed that 20 species were identified of which 2 were identified by genera only. In addition, among 71 sample plots in the mixed deciduous forest, 157 species were identified of which 42 were identified by genera while 45 trees were left unidentified.

The profile of the deciduous forests shows 2 - 3 stories, and usually there appears no continuous crown layer especially in the dry type. The canopy stratum reaches 20 - 37 m in height. In general, trees of the dry deciduous dipterocarp forest are vaguely stratified into 3 layers. The number of stems decreases from the third layer up to the uppermost layer. The sum of the stems in the basal area of the mid-layer is greater than that of the stems of the first layer as well as that of the stems of the third layer under more or less undisturbed conditions and the total coverage is about 70%. In the dry deciduous dipterocarp forest sunlight reaching the forest floor ranges from 60 to 80%.

Trees in the deciduous forests vary in dimensions, according to soil and site conditions. The trunks are not heavily buttressed, usually of moderate taper and good form. In the dry sites, trees may become stunted and crooked. The crowns are irregular in shape to rounded. The bark is usually thick and deeply furrowed. The wood of some trees shows concentric growth rings. The forest floor is usually sparsely covered by grasses and seedlings, but in some locations the ground floor is almost bare.

Phenology of the deciduous forests

There are at present limited data on the phenology of the deciduous forests in Thailand. Sukwong *et al* (1975a) studied the leaf fall, flushing, flowering and fruiting periodicities of forest trees in undisturbed dry deciduous dipterocarp forest at Sakaerat in 1975 and found that trees in this type of forest began to shed their leaves in January and the most intense leaf fall occurred from late February to March. After the heavy leaf fall in March the number of species losing leaves declined sharply. The lowest activity was recorded from July to November as the amount of rainfall increased. The most intense leaf flushing occurred in late March before the onset of the rainy season. A large number of species still produced a few new leaves until May, then the number slightly declined. A minor peak was also observed in late September. After November the production of new leaves in all species declined sharply with decreasing monthly rainfall which was lowest in December and January.

A high percentage of species bloomed during the months of the hot dry season (late March-

April) and after this period the total number of flowering species declined. Then the number slightly increased again in late July and the cessation of flowering occurred from September to mid-November when the monthly rainfall was highest. The flowering activity increased noticeably from late November to January coinciding with the beginning of the dry season. It was noted that the peak of leaf fall (late February to March) was followed immediately by the peaks of flushing and flowering. Some species e.g. *Vitex peduncularis* and *Xylia kerrii* appeared to be synchronized in leaf flushing and flowering.

Fruit-bearing trees could be found in all months, but the number of fruiting species was lowest in mid-March. When all species are considered together, fruiting peaks occurred in June and late August. After September the number of fruiting species was relatively constant.

From observations on seasonal variation of the whole community it was found that in February leaves of *Arundinaria pusilla* became yellow and withered. There occurred a patchy ground fire in the study area and during this month some canopy trees *(Shorea talura, Dipterocarpus intricatus, Mangifera duperiania,* etc.) still carried their foliage while some *(Pentacme sauvis, Phyllanthus emblica, Antidesma diandrum, Xylia kerrii, Cratoxylon formosum, Careya arborea, Albizzia odoratissima, Dalbergia dongnaiensis,* etc.) became leafless. On the burned area *Arundinaria pusilla* and *Cycas siamensis* produced new leaves within two weeks after burning. In March close observations revealed that seedlings of various tree species including herbaceous species were flushing. During the hot dry period of April epiphytic plants e.g. *Hoya kerrii* and orchids *(Aerides falcatum, Dendrobium draconis)* were seen in flower.

The mixed deciduous forest can be roughly divided into two strata, namely: teak-bearing and non-teak-bearing. Nearly all the species in the teak-bearing forests (with the exception of teak) are also found in the non-teak-bearing forests (Loetsch, 1958). Teak is the most valuable tree species in the mixed deciduous forest. The main teak area in Thailand is found between 97° 30′ and 101° 20′ East longitude and 16° to 20° 30′ North latitude. Among the factors which influence the establishment and natural distribution of teak and its survival are light, rainfall, soil aeration, soil type, soil moisture, topography, temperature, biotic factors, and forest fires (Kadambi, 1956; Banijbhatana, 1957).

Loetsch (1958) found that in Northern Thailand, Mai Rai *(Oxytenanthera albociliata)* usually occupies the open areas and often follows shifting cultivation as a pre-forest before teak unless the imperata grass *(Imperata cylindrica)* or *Eupatorium ordoratum* comes to the area first. Mai Sang *(Dendrocalamus strictus)* is closely associated with teak. Where Mai Sang occurs, it is a safe indication that the area can be replaced by teak plantation. Where Mai Sang occurs but without teak it is an indication that teak has been removed by human activities. Mai Bong *(Bambusa tulda)* generally grows in the mixed deciduous forest and usually occupies moist sites.

In the moist upper mixed deciduous forest, the prevailing bamboos vary with the area but the most typical species are *Bambusa polymorpha, Cephalostachyum pergracile* and *Dendrocalamus* spp. On sandy soil, *Oxytenanthera albociliata* is common.

In the lower mixed deciduous forest, teak avoids the badly drained areas. Wherever the drainage is adequate teak becomes plentiful and may reach large dimensions.

In Thailand, teak usually has a dominant crown and is taller than other species because it requires strong light. The associated species must tolerate shade more than teak. In dense vegetation, teak does not grow well, and is usually absent.

Teak flowers freely, with large, erect terminal panicles 30.7 to 92 cm long bearing small white flowers produced during the rainy season from June to September. During the rainy season teak trees are conspicuous by the presence of terminal inflorescences (Takle and Mujumdar, 1957). Light has a marked effect on flowering behavior of teak and inflorescences are confined to the upper most branches and protrude above the leafy crown so that they are exposed to full sunlight (Siripatanadilox, 1974). Inflorescences are conspicuously absent on the lower part of the crown and also on trees which grow under a thick canopy. The fruit ripens from November to January and falls during the cold season and up to the hot season in April. A fair crop of seed is set almost every year.

Fertile seeds are produced at an early age, usually when trees are ten to twenty years old (Haig *et al*, 1958). Years with low seed production do occur but are infrequent. The fruit is a drupaceous nut which is usually accepted as the seed. It consists of a hard, irregular globose nut covered with a spongy tissue. The fruit contains one to three, and rarely four, seeds. About 900 to 1,400 fruits (containing 1,000 - 3,000 seeds) weigh one pound (Takle and Mujumdar, 1957). The bladder-like calyx that encloses the mature fruits acts like a parachute carrying the seeds some distance from the mother trees (Kadambi, 1957).

Germination is greatly stimulated if seeds lie in open sun during the hot season and undergo alternate soaking and drying (Kadambi, 1957). Seeds germinate with difficulty in a cool, shady place and may lie viable for more than a year, germinating only when the forest canopy is opened up or undergrowth is cleared away.

Teak needs full sunlight for its optimum development but it can subsist for years in the shade of forest, either as seedling coppice or as suppressed, usually misshaped, trees of the understory. It can recover after years of suppression when given the chance, and it will respond with rapid growth (Kermode, 1954). In early stages of growth after germination, teak seedlings are likely to be smothered by weeds. Presence of smothering bamboos, weeds, and drips always accelerate the suppression (Korlhalli, 1956). Teak in the second canopy also faces similar problems of drips, shade, and side suppression or congestion and often overtopping by bamboos. In the uppermost canopy, wolf trees and some species such as *Lagerstroemia lanceolata, Adina cordifolia, Salmalia malabarica* and *Dalbergia* spp. are likely to overtop teak and suppress it. In the dry deciduous forest all these problems are not so acute.

Natural regeneration

The natural regeneration of the deciduous forests takes place both by seeds and coppices. Under natural forest conditions seed germination is often uncertain due to the variation of many environmental factors and also the viability of the seeds. Most of the dipterocarp seeds are sensitive to insect attack. Kittinant (1963) stated that more than half of the fruits of teak which fall before the forest fires occur are burned and lose their viability. The rest mixed with those falling from the trees, after fire ravage, maintain their viability and play an important role in the natural regeneration of teak. When germination takes place, some seedlings may be repeatedly killed by drought over several years, while the root systems continue to develop until eventually they attain sufficient size and vigor to maintain the shoots against the adverse effect of drought.

Teak as a seedling can survive the usual type of surface fire. The roots persist for years although the top is burned back annually (Kermode, 1954). Teak has a greater capacity to resist the effects of fire than any of its associates but fires are a cause of much of the unsoundness in the timber.

1 Natural regeneration of the mixed deciduous forests

Kittinant (1963) studied the natural regeneration of teak at Lampang Province and found that the rate of germination in the natural condition is very low, about 0.2% of the total seed production. Some of the emerged seedlings will be covered by undergrowth and will later die. The rest continue to grow slowly and will be only around 5 cm high at the end of the growing season. During the dry season, all of these seedlings may be burned by forest fire. Some of them are wiped out completely. Some with surviving root systems, however, will send off their new shoots in the next growing season and may again be burned during the dry season. This phenomenon occurs year after year. During this period, the root system gradually develops until it can send off the vigorous roots which survive. These findings revealed that the potential of the root system increases year after year with the consequence that the shoot produced could become in a specific year 11 cm higher on average than in the preceding year. It takes about 8 to 20 years to develop a root system capable of sending off a shoot that can attain the height of 125 cm which is the size considered as the requirement for survival and uninterrupted growth irrespective of drought and forest fire. It is also noted that the shoot will grow very fast in the beginning of the growing season; some reach the height of 60 cm within two weeks, and thereafter the growth rate will decrease.

Another interesting study on the establishment period of teak was made by Sono (1964) at Phang, Chiengmai Province, who found that teak grows undisturbed at ages ranging from 7 to 29 years. The average diameter of the stump that can send off a vigorous shoot for continuous growth is 18.4 cm (at a point 2.5 cm below ground level). He also noted that 4-year-old seedlings may die if exposed to severe fire.

Kaewla-iad (1973) studied root growth and development of teak seedlings during the establishment period at Ngao, Lampang Province and found that the establishment period of teak ranged from 4 to 30 years. Taproot penetration tended to increase with stump age until about 12-14 years. Beyond this age the penetration stopped. He also found that heights of both live and dead shoots will increase with stump age until reaching a maximum when 18-year-old. The surviving teak seedlings may safely be assumed to become established from stumps 12-to 18-year-old. The results of this study show that fire protection in the teak-bearing mixed deciduous forests is necessary. The time wasted during the establishment period causes great economic losses, since the harvest of the merchantable teak is delayed for about 15 years.

Yarwudhi *et al* (1977) found that the fuel consumed by fire on the annually burned plot in natural teak forest at Lampang Province amounts to about 10 ton/ha and fire intensity is 52 BTU/sec/ft. Root mortality caused by soil heating is confined to 6 cm of surface soil. Growth of small regeneration including teak is significantly retarded by fire. However stems of teak generation more than 2 m high can withstand a fire. Observations also indicated that the difference of growth rate between the burned and unburned teak trees is of little significance.

Teak coppices are vigorous and sometimes retain the power of coppicing to a considerable size, but do not produce any root suckers (Takle and Mujumdar, 1957). The growth of coppices in early years is very rapid and an average height of six to eight feet in one year is not unusual. The best period for coppicing teak is March and September.

Sukwong *et al* (1975b) studied the suitability of clear felling system for the management of dry teak forests at Lampang Province and found that one-year interval after fellings indicated that natural regeneration from seed origin is rather poor, but teak and other species sprout prolifically. Teak stump height has remarkable effect on the height of coppice shoot but not on the number of shoots per stool. The maximum stump height should not exceed 60 cm. Teak also shows a strong tendency for the number and maximum height of coppice shoots to vary with diameter at breast height. They found that dbh of 10 to 30 cm gives the highest number of coppice shoots. They also suggest that the suitable period for coppicing teak is from January up to early May depending on the time when the dry season starts in each area. The best time should be before the start of the growing season.

When exposed to full sunlight during the first year, the seedlings reach a height of one foot, while in shade, only an average of a few inches. In full light second year growth may be vigorous and exceptional and plants may grow to six or eight feet. Third year growth is rapid and the lateral branches begin to develop (Kermode, 1959). The growth of coppice is faster than the growth from seed (Royal Forest Department, 1964). From their study Sukwong *et al* (1975b) found that the highest coppice shoot was 6-5 m after the first year.

The growth rate of teak is rapid in the early stages if kept free of overhead domination and given ample side space (Haig *et al,* 1958). Teak does not usually form a clear bole until it has attained a girth of 1.2 m at breast height. Large trees with girth ranging from 4.5 to 6 m and a clear bole of up to 30 m to the first branch have been recorded in Thailand, Burma and India; but trees with 1.8 to 2.5 m in girth and 25 to 30 m in height seem average for good moist teak sites.

According to Banijbhatana (1957), the length of time required by teak growing on different types of soils in Thailand to reach a girth of 2.13 m was as follows:

On alluvial soil, 85 years
On soil derived from limestone, 113 years

On soil derived from shale and sandstone, 160 years

On soil derived from metamorphic rocks, 170 years

In the dry deciduous teak forest, Sukwong *et al* (1975b) found that regeneration from seeds of most valuable species is very rare. Most of the regeneration originates from coppice shoots. Results obtained from a quadrat 4 × 4 m among 100 quadrats show that 1 year after clear felling the coppice shoots of important species can be described as follows:

Species	No. of sapling from stump	Frequency %
Tectona grandis	39	29
Xylia kerrii	5	5
Hesperethusa crenulata	2	2
Cassia garrettiana	1	1
Cassia fistula	1	1
Lagerstroemia calyculata	1	1
Millettia brandisiana	1	1
Croton oblongifolius	1	1
Alangium chinensis	1	1
Morinda coreia	1	1
Terminalia alata	1	1
Premna tomentosa	1	1
Lagerstroemia tomentosa	1	1
Hymenodictyon excelsum	1	1

2 Natural regeneration of the dry deciduous dipterocarp forests

The dry deciduous dipterocarp forests are usually dominated by *Shorea obtusa, Shorea talura, Pentacme sauvis, Xylia kerrii, Dipterocarpus obtusifolius, D. intricatus, D. tuberculatus, Pterocarpus parrifolius, Dalbergia nigrescens, Morinda coreia, Albizzia odoratissima,* etc. The forest floor is covered with *Arundinaria pusilla.* Other undergrowth species consist of *Cycas siamensis,* tree and shrub seedlings, small climbers and herbaceous species.

Sukwong *et al* (1977) stated that fire season at Sakaerat usually begins in January with peak found in January - February normally, coinciding with intense leaf fall. Grasses are inflammable during this time of the year. The burning is almost entirely caused by man either accidentally or deliberately.

Sprouting of plants began immediately after burning in February and the grass, *Arundinaria pusilla,* was seen to sprout in 14 days. In March, about 26 days after burning, seedlings of tree and herbaceous species sprouted vigorously. New sucker shoots from old rootstocks attained considerable heights nearly equal to those in the previous year by the end of April before the onset of the rainy season, while during the rainy season the rate of shoot elongation was rather low though conditions for growth were ideal.

Sukwong *et al* (1977) on the basis of a sample area of 320 m^2 in each site, found that plant species of sapling size increased from 10 to 35 species after 10 years of fire protection. Number of saplings in the unburned community (290 stems) was larger than in the burned (34 stems) one. Saplings of *Shorea obtusa, Pterocarpus parvifolius,* and *Xylia kerrii* were more abundant in the unburned area. This suggests that seedlings of these important tree species grow better if they are not damaged by fire. Judging by 10-year growth response of tree reproduction in the unburned area it could be stated that a poor development of shrub layer under natural conditions was due to fire. As in areas burned every year some young saplings are killed and the regeneration dies back, plant species belonging to the shrub layer are thus rather sparse, making the stand open in physiognomy.

By contrast, in fire protected areas the shrub layer is well developed and dense.

The number of plant species excluding grasses is slightly higher in the burned (223 individuals, 30 spp. identified) that in the unburned (181 individuals, 25 spp. identified) areas. Number of seedlings of some important tree species e.g. *Shorea obtusa, Pterocarpus parvifolius*, and *Xylia kerrii*, are not so much different in both sites. This suggests that germination of some dry dipterocarp plants is not much hampered by fire. At Sakaerat, extensive fires usually occur from January to February and as during this time of the year the moisture content of undergrowth is lower than 35% it becomes inflammable (Nalamphun et al, 1974). A heavy fruit fall in this area occurred during February and March (Sukwong et al, 1975a), and seeds which fell on the burned area could germinate in the coming rainy season. In the unburned area studied, the reduced number of total seedlings found may be due to a decrease in light intensity on the floor and/or to more intense competition beneath dense sapling layer.

Fire protection results in increasing seedling growth of forest tree species and number of stems per unit area. Under natural conditions where fires occur frequently every year, small seedlings are generally present but plants of sapling size are sparse. A poor development of the shrub layer is essentially due to fire. Repeated fires cause considerable damage to small regeneration because the emergent shoots are killed and it takes some time to build up rootstock to send up more vigorous shoots until they get permanently established. During this process of regeneration, some root systems deteriorate and eventually die. Fire protection aimed at accelerating height growth of small regeneration until the trees can withstand a fire is possible and justified. A long-term fire protection policy, however, may not be wise if this forest type is to be maintained since it is possible to displace this fire community towards less deciduous forest. This phenomenon is consecutive to the change in soil properties and in the microenvironment on the forest floor due to denser canopy on top (Sukwong et al, 1977).

As for the effect of fire on plant survival the authors found that the total litter amounted to 4.67 ton/ha and the maximum temperature at ground level was 316°C. Temperatures over 200°C were recorded within a range of 50 cm above the soil surface. Soil temperatures over 52°C (125°F) were seldom observed below 2.5 cm. Normally plant tissue is damaged or killed when exposed for several minutes to temperatures ranging from 125° to 130°F (Hare, 1961). Thus, under the dry dipterocarp forest conditions plant roots are well protected from destruction by fire.

High fire intensity killed 95% *Shorea obtusa* saplings less than 1 m high, but only 7% of the saplings 1.5 to 2.5 m. high.

Wacharakitti *et al* (1971) studied the coppicing power and growth of some valuable tree species in dry dipterocarp forest at Lampang Province and found that each tree species bears different quantity of coppice shoots; *Dipterocarpus obtusifolius* contributes the maximum number, *Pentacme sauvis, D. tuberculatus,* and *Shorea obtusa* produce smaller numbers, respectively. The optimum sizes of tree for coppicing are those under 60 cm in girth. *Pentacme sauvis* and *Dipterocarpus obtusifolius* showed better growth in both diameter and height. It was suggested that the coppice system is not suitable for big timber in this type of forest, but is suitable for small wood.

Silvicultural practices for increasing natural regeneration

1 Mixed deciduous forests

Teak has been paid more attention to in this type of forests because of its high value. The teak-bearing areas of Thailand have been managed by the selection cum management system. The inherent structure is, therefore, uneven-aged and the composition is heterogeneous. Kutintra (1970) suggested that the items that must be considered in selecting the method to be used for increasing teak regeneration are:

(1) The number of mature teak trees over the sapling stage which can supply seeds to the area.

(2) The amount of saplings, seedlings, coppices, and current year's seedlings that are present in the area.

(3) The composition of the forest, the ratio of both young and mature teak trees to other species and the density of stand.
(4) The density of the undergrowth, climbers, and bamboos.
(5) Environmental factors determining the suitability for teak regeneration.

The silvicultural practices proposed by the encouragement program are as follows:
(1) Selection of trees for cutting.
(2) Girdling
(3) Bamboo and climber cutting
(4) Cleaning and weeding
(5) Light burning
(6) Improvement felling
(7) Thinning

A schedule of silvicultural practices suggested for an area operated under the encouragement program is outlined. After the program is completed and before the beginning of the next felling cycle, an assessment of the results must be made.

Time Schedule of Silvicultural Practices for Encouragement of Teak

	Year	Type of Work
Post Felling Cycle	26	Selection, Climbers and Bamboos Cutting
	27	
	28	Girdling, Climbers and Bamboos Cutting, Tending
	29	
	30	
Present Felling Cycle 30 Years	1	Exploitation, Improvement Felling, Thinning, Climbers and Bamboos Cutting
	2	
	3	Weeding, Cleaning, Coppice Cutting
	4	
	5	
	6	
	7	
	8	
	9	Light Burning
	10	
	11	
	12	
	13	
	14	
	15	Improvement Felling, Thinning, Climbers and Bamboos Cutting
	16	
	17	
	18	Weeding, Cleaning, Coppice Cutting
	19	
	20	
	21	
	22	
	23	Light Burning
	24	
	25	Assessment for Results
	26	Selection, Climbers and Bamboos Cutting
	27	
	28	Girdling, Climbers and Bamboos Cutting, Tending
	29	
	30	
Next Felling Cycle	1	Exploitation, Improvement Felling, Thinning, Climbers and Bamboos Cutting
	2	
	3	Weeding, Cleaning, Coppice Cutting
	4	
	5	

Kutintra (1970) also suggested that in areas of sparse distribution of teak or where teak is absent other species should be associated while in the case where soils and other factors are suitable for teak, the enrichment program should be carried out. It is possible to induce natural regeneration of teak in these areas if seed trees are available, and other species are eliminated. The general practices are similar to the encouragement plan except that the selection of trees to be cut or treated must be concentrated only on species other than teak. Teak is left even after it reaches the exploitable size in order to supply seeds to the area. Malformed teak can serve as suitable seed tree if the poor quality is not due to its genetic constitution.

Besides the silvicultural practices listed in the encouragement program, artificial regeneration is often used when it is deemed necessary to change the composition of the forest so as to make teak the dominant species. This will permit to establish the next generation of teak completely by natural regeneration.

Chantanaparb (1969) found that natural regeneration in teak-bearing forest was rather poor as the number of seedlings was only 1 in 37.91 m^2 in 1963 and increased to only 1 seedling per 32.13 m^2 in 1969. He also found that improvement felling practised at the same period increased the number of seedlings from 1 per 44.69 m^2 to 1 per 11.87 m^2. It is evident that improvement felling is necessary for promoting natural regeneration in this type of forest.

2 The dry deciduous dipterocarp forests

The coppice with standard system has been used in Thailand because most of the trees are of small size and have a vigorous coppicing power. Regeneration takes place both from seeds and coppices. Kutintra (1975) suggests that improvement felling should be aimed at favoring the component species of the community type. For example, sites at high elevations with deep soils and gentle slopes should be managed to favor pine and *Dipterocarpus obtusifolius*. It is also possible to obtain high production from *Shorea obtusa* in these sites. On the medium slopes at middle elevations with a deep C-horizon and lateritic soils one should favor *D. tuberculatus* or pine. Sites on steep slopes at low elevations with shallow soils are suitable for *Pentacme sauvis* or *Shorea obtusa*. Management for the species not included in the natural composition of the community type will be difficult.

Kutintra (1975) also found that the *Shorea obtusa - Pentacme sauvis* community is composed of scruby trees with high density and frequency but low basal area cover. The average number of trees per quadrat (10 × 20 m) is 11.3 on poor sites and 9.5 on the better sites and basal area covers are about 0.35 m^2 and 0.5 m^2 respectively. The *D. tuberculatus - S. obtusa* community type occurs as either a scruby or moderately tall community with low basal area cover. The *D. tuberculatus - Pinus merkusii* community type consists of medium to very tall trees. Stands are of medium density with an average of 10.54 trees and basal area of 0.84 m^2 per quadrat (10 × 20 m). The *D. tuberculatus - D. obtusifolius* community type is composed of medium to very tall trees. Stands are of medium density with an average of 10 trees and basal area of 0.64 m^2 per quadrat. The *D. obtusifolius - S. obtusa* community type is composed of medium tall trees with an occasional very tall individual. Stands are rich in species. Density averages 9.6 trees and basal area 0.54 m^2 per quadrat. The *D. obtusifolius - Pinus merkusii* community type has many characteristics similar to those of the *D. obtusifolius - S. obtusa* commanity type. The difference is that the pine species forms the uppermost layer above the continuous crown cover of *D. obtusifolius* and *S. obtusa*. Stands are of high density with an average of 9 trees and a basal area of 0.9 m^2 per quadrat.

It is noted that the vegetation in this forest type at Masanaam District, Chiengmai Province, is composed of seventy-seven tree species, fifty-four species of shrubs and small trees, forty-five species of climbers, sixty-one species of forbs and fifty-three species of grasses.

Generally, the height of the crown cover above ground is about 10 m in poor sites and 35 m in good sites with the exception that the two pine species may reach 40 m. Ground cover averages about 30 cm in height, but in moist deep soils the plants may grow to over 1 m in height and completely cover the ground.

Natural enemies

Damage to forests caused by man is recognized as being the most destructive activity. Shifting cultivation is the primary cause of forest destruction in the country. Timber stealing, illegal harvesting, charcoal and fuelwood production, and turpentine production are commonly practised by many kinds of people. All of these human disturbances have caused many changes in species composition, structure, and other features of vegetation in the deciduous forests.

Sukwong (1974) found that trees in the deciduous forests are generally resistant to pests. Some larvae of insects belonging to Lepidoptera were reported to feed on leaves of *D. tuberculatus, S. obtusa, Pentacme sauvis* and *Terminalia* spp. Some Coleopterous insects also attack bark, sapwood and sometimes heartwood of trees in dry deciduous dipterocarp forest. The most serious insect pest of teak is the larva of *Duotimus ceramicus* which bores holes in standing trees. The defoliators and skeletonizers which are caterpillars of several insect species also attack teak forest in many countries. In recent years some Coleopterous insects have been reported to attack teak flowers causing tremendous decrease in seed production. No detailed study of fungus pest has been made in the deciduous forests in Thailand. Some surveys of tree species attacked by fungi in the dry deciduous dipterocarp forest at Sakaerat revealed that only 1.5% of the trees are attacked by fungi mostly of *Fomes* spp.

However, about 10% of tree species were attacked by mistletoes. *Pentacme sauvis* is most heavily infested.

Fire is recognized as one of the important enemies in the deciduous forests. Numerous seedlings of tree species are destroyed by fire annually. Big trees are also more or less injured by fire due to many factors.

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Discussion

Yunus K. (Indonesia): 1) How many years do you need to develop teak root system to support an even coppice stand of teak? 2) Could you compare natural regeneration of teak with artificial regeneration, from the economic point of view.

Answer: 1) Research carried out in Thailand enabled to demonstrate that it takes 4 to 30 years (average 15 years) for teak stump in natural forest to have enough coppicing power to send up coppices which will survive fire, for example. 2) Economic comparison between artificial and natural regeneration of teak is difficult. Natural regeneration is cheaper provided that there is no land pressure or destruction by fire. On the other hand, artificial planting is preferable from the angle of management.

Tan C.H. (Malaysia): Please comment on the establishment of Dipterocarp species through clear cutting method as compared with planting under canopy.

Answer: Our experiments on *Dipterocarpus alatus* led to the conclusion that planting under canopy or controlled shade gave better results in the first 2—3 years. It should be emphasized that there is a marked difference between dry deciduous versus moist or tropical rain forest as the coppicing power is better in the former than in the latter.

Wawan K. (Indonesia): Would you comment on the problems relating to seed storage in Dipterocarp species?

Answer: Seed storage remains difficult as most seeds lose their viability within 1 or 2 weeks after ripening. More research is needed in this respect.

Sasaki, S. (Japan): 1) In your report you mentioned the existence of die-back in Dipterocarps. It appears that die-back which is caused by a fungus will not develop if the seeds are free from the disease. 2) Stump sprouting may be one of the effective methods for plantation. However did you check heart-rot in this case?

Answer: 1) I referred in my presentation to the die-back caused by fire which is one of the most serious hazards in natural regeneration in the deciduous forests. 2) I used to observe heart-rot symptoms in the young sprouts but dit not find any in the dry deciduous Dipterocarp species.