CHAPTER FOUR

Vegetation and forest types

The location and extent of forest types described in the following chapters correspond with the surface areas inventoried on the map. The descriptions which follow refer arbitrarily to environments ranging from coastal zones to mountain tops in much the same way as the first explorers approached the island. The vegetation of the Central regions is described first in detail, and the main differences encountered in the Southern and Northern areas are then specified.

A short cartographical analysis of the main plant formations of Sumatra

In the 1980s, Sumatra's forest coverage was estimated at 50% of island's total surface area (Anonymous-Directorate of Forestry Planning 1981, 257 890 km^2, i.e. 54% of land surface, Anon. -FAO 1981, 222 400 km^2, Anon. – Land Resources Department – Bina Program 1988, 233 200 km^2). During a study period spent in Indonesia (1979–1986), the author was able to make use of the cartographic facilities existing in BIOTROP and I.C.I.V. to map the island's vegetation on three 1/1,000,000 scale sheets (Laumonier 1983, Laumonier et al. 1986–87). When analyzed, these cartographic documents reveal that, in 1985, forest coverage was 228,000 km^2, i.e. 46% of the total surface area split into 33% for undisturbed forest coverage, and 13% for logging forest. The remaining vegetation, consisting of secondary formations and agricultural land use, respectively covers 30% and 24% of the island's total surface area. Considering that the figures put forward by the forestry department reflect data collected in the 1970s, the deforestation rate over a fifteen year period can be estimated at under one per cent per annum. The International Institute for the Environment and Development and the Institute of World Resources (1986) report a rate of 0.5% for all Indonesia for the period from 1981 to 1985. The latest Food and Agricultural Organization estimation of forest coverage for Sumatra is 203 800 km^2 in 1990 (Anon. -FAO 1990c), which would also mean a deforestation rate of under 1% per annum between 1969 and 1990. Using a combination of GIS and NOAA satellite AVHR data, Gastellu-Etchegorry et al. (1993) estimated the deforestation rate at 1.5% per year for the period 1982–1988.

Studying the distribution of plant formations according to forest categories is an extremely informative task (Fig. 29). As we have just seen, primary forests occupy 33% of the island's total surface area (Rupat, Bengkalis, Padang and Tebingtinggi islands included), i.e. about 163,000 km^2, but could be further divided up into the following types: mangroves (0.47%), fresh water swamp forests (9.75%), forests at altitudes above 1000 m (9.25%), and forests at altitudes below 1000 m (13.85%). It seems erroneous to consider only the 1000 m limit for characterizing lowland forests, which unfortunately is the practice of forestry departments and nature conservation organizations. The 13.85% are divided into 3.3% for lowland forests below 150 m, 3.9% for forests on low altitude hills (150–500 m), and 6.6% for forests on hills at altitudes between 500 and 1000 m. Out of the 33% of primary forest coverage, the lowland forests on drained land represent only 3.5% at most of Sumatra's total surface area, a figure which should be taken into account for genetic erosion issues and reserve delimitation.

Y. Laumonier, *The Vegetation and Physiography of Sumatra*

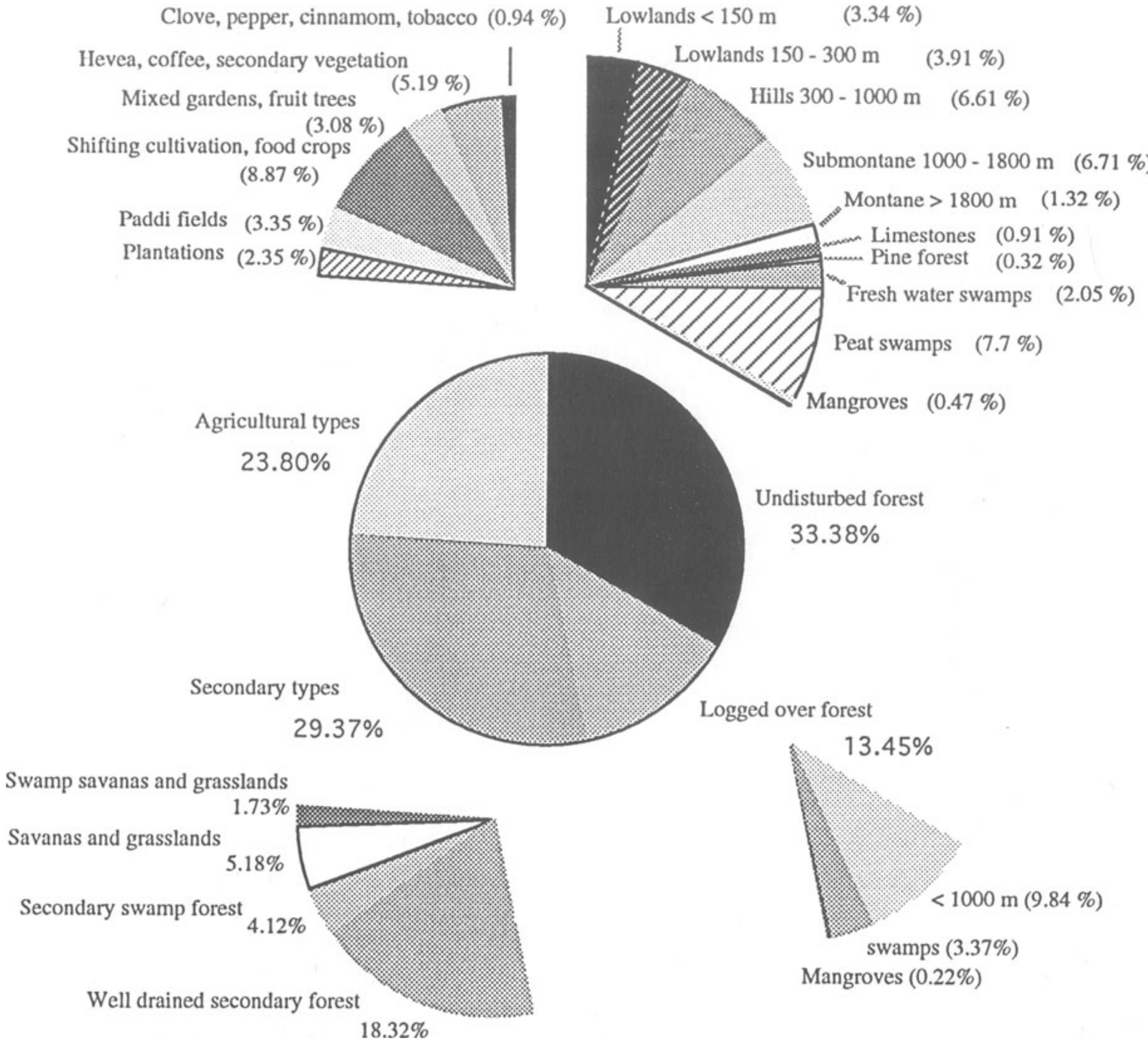


Fig. 29. Forest and land-use cover in Sumatra around 1985 (after Laumonier, 1983, Laumonier et al. 1986–87).

Plant formations in lowland swamp areas (alt. < 15 m)

Brackish or salty water environments

Most mangrove swamps throughout the tropical world have been well studied (Rollet 1981). In the Malesian region, where the most floristically interesting and, without a doubt, the most luxuriant mangroves are found, ecological studies (Watson 1928, Van Steenis 1958b, MacNae 1968) were carried out on the zonation of communities and evaluation of their productivity. International programmes aimed at the inventory and monitoring of these coastal environments have also been implemented for the entire region (Knox & Miyabara 1984; Silvius 1986). As a source of firewood, charcoal, tannin, poles for scaffolding and foundations, the economic importance of mangrove swamps soon became obvious and they were amongst the first forest communities of the region to receive silvicultural treatment (Danhof 1946).

Interdisciplinary research has been conducted on the functioning of parts of the ecosystem, mainly involving biomass, leaf litter production and productivity studies. For instance, Ong et al. (1982) calculated net productivity at Matang in Malaysia as being 23 to 28 tons/ha/year for *Rhizo-*

Photo 1. Mangrove stands at the mouth of Lalang river in the Musi-Banyuasin delta: such robust *Rhizophora apiculata* and *Sonneratia alba* mangrove communities are characteristic of the delta type zonation of the vegetation. The economic importance of these forests for forestry and fisheries activities has long been recognised.

phora apiculata stands 10 to 25 years after clear cutting. According to Whitmore (1975), these figures are similar to those observed for a mature lowland dipterocarp forest.

In Sumatra, a large number of specialists in all disciplines related to agricultural development have worked on the Musi delta north of Palembang (Hanson & Koesobiono 1978, Sobur et al. 1977, Hadi et al. 1977, Chambers & Manan 1978, Collier 1979, Tsubouchi et al. 1980), and the mangroves themselves were described and studied by Soekardjo & Kartawinata (1979), Yamada & Soekardjo (1980), and Soekardjo & Yamada (1984).

Location, extent and forest status

The mangroves of Sumatra occupy large areas on the east coast, being best developed at the Musi-Banyuasin delta in the South, between the Kampar and the Siak river mouths, on the string of swampy islands situated in the Malacca Straits opposite Singapore, and at the Besitang delta north of Medan. Sandy coastal strips with *Casuarina* trees alternate with small communities of mangroves in all other areas.

Mangrove surface area estimations vary greatly from source to source (400 000 ha for Wiroatmodjo and Judi 1979, a value maintained by the FAO in 1990, 500 000 ha for Knox and Miyabara 1984, 1,470,000 ha, for Whitten et al. 1984). While we could quote 400 000 ha as the surface area of potentially viable habitat for mangroves in Sumatra, our own cartographical results, which have recently been supplemented by SPOT satellite imageries, only reveal 200 000 ha of practically intact mangrove swamps and 100 000 to 150 000 ha of depleted or secondary mangroves, often in a very degraded state.

At Aceh and along the Malacca Straits in the Langsa-Temiang regions, the potential mangrove swamp surface area, estimated at 40 000 ha, has been subjected to considerable reduction over a very long period (Luytjes 1923). The majority has been transformed into shrimp farming ponds and the existing mangroves are in a very poor state, suffering from an excessive anthropogenic pressure. Further south, in the Medan region, forests have been exploited since early times, mainly for timber and charcoal export. Massive defoliation caused by caterpillars has also been observed (Whitten & Damanik 1986). These extremely depleted mangroves (*Excoecaria agallocha* dominant in back mangrove swamp) are disappearing. Today, the most extensive area is located between the Besitang and Belawan rivers north of Medan (60 000 ha), with 12 000 ha at most remaining intact.

Mangroves in the Riau region have also been exploited for a very long time, mainly because they are close to Singapore. In 1929, Van Bodegom estimated the mangrove surface areas of the Bengkalis, Tebingtinggi, Rupat and Padang islands at 50 000 ha and those of the mainland in Riau province at 126 000 ha (between Indragiri and Kateman). At the time, these mangroves were exploited for charcoal and firewood (*Rhizophora* spp), mainly for export to Singapore. Contrary to their use at Aceh, they also constitute the main source of poles and piles for the Sumatra market. Felling of young trees is particularly bad for the regeneration of the ecosystem, and this over-exploitation of the Riau mangroves and the illegal exportation to Singapore of young *Rhizophora* stems sold as scaffolding poles and beams has resulted, for what the author has seen during the survey, in an extremely depleted mangrove landscape.

As early as 1951, Versteegh expressed concern over intensive exploitation of *Rhizophora*, and recommended 64 mother tree individuals be conserved per hectare and opposed clear felling as practised at the time.

His advice was not followed until 1978, prior to which clear felling with a rotation cycle of 20 years was the system in force. This was slightly modified afterwards, although non-officially, with the introduction of the 'strip cutting system' brought in by operators who had already used these methods in Sarawak (Burbridge & Koesobiono 1980).

A new official system was created in 1978 including a mandatory inventory at the concessionaire's cost and the parameters recommended by Versteegh, slightly modified, such as maintaining 40 mother tree individuals, or 2500 seedlings per hectare.

The Musi-Banyuasin delta, further out of reach, remained relatively undisturbed and the most luxuriant mangroves in Sumatra – indeed in the entire region – are still to be found there today (Bungin river – Sembilang river, approx. 110 000 ha). Nevertheless, the delta has undergone serious change in recent years due to ambitious transmigration programmes implemented upstream from the mangroves in the swamp forest zone. Purnadjaja (1980) for instance, estimated the decrease in forest coverage inside a sector allotted to transmigration between 1969 and 1978: approximately 100 000 ha of swamp formations were converted into agricultural use (mangroves, *Nypa* formations, swamp forests). Satellite images acquired between 1978 and 1986 (Landsat MSS & SPOT) highlight increased deforestation of the delta with about 425 000 ha cleared during the above eight year period.

The physical environment

Several factors must be considered when studying this environment, especially tides and currents. The tide amplitude along the immense string of islands and archipelagos of Sumatra's east coast can reach 3 m, but the flooding regime varies according to the complexity of the estuary and the direction of the coastline. The texture of the substratum, its salinity, oxygenation and mineral composition are the parameters most often considered. Measurements of these parameters for the region have been summarized by Whitten et al. (1984), but very few were actually made in Sumatra. Surface salinity varies from 17.5 to 23 per thousand (Anon. BIOTROP 1990a), with the strongest concentration located in the Riau – Palembang portion. The dissolved oxygen content has been estimated to be approximately 4,3 ml/l at sea and to drop as low as 1,5 at 100 m from the coast.

Mangroves soil types in Sumatra show dark brown clayey surface horizons. Accumulations of organic matter ($<$ 30 cm) can sometimes be observed above a light grey acidic horizon where pyrite can develop. If the medium becomes aerobic again, jarosite may form which, when hydrolyzed, liberates sulfuric acid. The presence of these acid sulfate soils (Thionic Fluvisols), their pedogenesis and their limitation for agricultural activities have been dealt with by Dorst (1972) from a general point of view and by Ismangun and Driessen (1974) for Indonesia. Seawater sulfates are first reduced to hydrogen sulfide by bacteria. The hydrogen sulfide reacts with iron to produce FeS and then pyrite FeS_2 at greater depths. If the terrain is drained, i.e. oxygenation takes place, ferric sulfate and sulfuric acid are formed. Hydrolyzed ferric sulfate produces jarosite and even more sulfuric acid. The acids thus formed exceed the quantity of iron hydroxide and the pH drops to a particularly low level. Physical processes are often combined with these chemical processes, especially in regions where the dry season is relatively long or in aged mangrove soils out of the reach of today's tidal influence zone. These soils are chemically poor and naturally infertile, while the opposite is true under the natural forest. Moreover, they can have highly toxic levels of alumina, iron and manganese, preventing normal development of crops such as rice.

The primary forest

The author did not record structural measurements in the mangroves. Studies were limited to physiognomic and floristic reconnaissances for the vegetation map or for evaluating the usefulness of remote sensing images in this type of environment (Laumonier & Djailany 1989).

A distinction should be made between forests specific to the large estuaries and those which consist only of a narrow band of *Avicennia marina*. They have been described by, amongst others, Soekardjo (1978) on the east coast of Lampung and by Silvius et al. (1984) at Jambi. Often set back from a coastal strip of *Casuarina equisetifolia*, this mangrove flora has colonized areas which had once been lagoons.

For estuaries, two zonation models for community and mangrove species can be found:

When the coastline is straight and watered by short perpendicular rivers, zonation is parallel to the coastline. By general rule, the coast is colonized by *Avicennia alba*, followed by *Rhizophora apiculata* sometimes combined with *Sonneratia alba*. Further inland, communities dominated by *Rhizophora apiculata*, *Bruguiera gymnorrhiza* and *B. parviflora* develop. Deeper into the forest, communities of *Bruguiera* mixed with *Nypa fruticans* are encountered, finally giving way to the species which announce the end of the mangrove such as *Heritiera littoralis*, *Ficus microcarpa* and *Oncosperma tigillarium*. This is the pattern most frequently encountered at Riau, and it also corresponds to the type of mangroves described by Soekardjo and Kartawinata (1979) and Soekardjo and Yamada (1984) for Musi delta, whose species are shown in Table 8.

Delta type zonation is a more complex model as the network of small creeks, islands and channels gives rise to a wide range of variations in the texture of the substratum, flooding intensity and salinity. In Sumatra, zonation corresponds with the classic pattern described by Watson (1928) and Van Steenis (1958b). A fine example of this model can be found at the Sembilang river mouth. Two distinct environments are revealed on satellite imagery, enabling to distinguish between communities dominated by *Rhizophora apiculata* and *Sonneratia alba* from those dominated by *Bruguiera*. The back mangrove where *Nypa fruticans* is more abundant is also clearly differentiated as are the formations of *Oncosperma tigillarium*, often highly developed in this region. Dransfield (1974) mentions *Calamus aquatilis* and the *Livistona saribus* palm in the Berbak mangroves in Jambi.

Secondary types

The author travelled through the overexploited mangroves at Riau, the Bengkalis and Tebingtinggi islands. As all the large trees have been cut down, these mangroves show an impoverished physiognomy. The floristic composition has been considerably modified and although practically all the species specific to mangroves are still found, those without any commercial value dominate. In this way, *Bruguiera parviflora* has become the dominant species at Riau near the coast, while *Bruguiera gymnorrhiza*, *B. sexangula* and *Xylocarpus granatum* are characteristic of the communities found further inland in association with *Excœcaria agallocha*, *Ficus retusa*, *Suregada glomerulata*, *Lumnitzera racemosa* and *Allophylus cobbe*.

In the undergrowth, a Rubiaceae shrub, *Scyphiphora hydrophyllacea* is extremely abundant and grows in association with *Acanthus ilicifolius* and *Acrostichum aureum*. These last two species become particularly invasive as degradation gets worse. Silvius et al. (1984) also mention *Acanthus ebracteatus* at Jambi.

Nypa fruticans formations and the back mangroves

These forest formations have been described by Wyatt-Smith (1963) in peninsular Malaysia and are similar to those of Sumatra. The back man-

Table 8. Mangrove and back mangrove species found in the Musi delta (adapted from Sukardjo et al., 1984 and Silvius, 1986).

Rhizophoraceae	Euphorbiaceae
Rhizophora mucronata	*Excœcaria agallocha*
Rhizophora apiculata	Rubiaceae
Bruguiera gymnorrhiza	*Scyphiphora hydrophyllacea*
B. sexangula	Fabaceae
B. parviflora	*Derris trifoliata*
Ceriops tagal	*Intsia bijuga*
C. decandra	Rutaceae
Kandelia candel	*Paramignya angulata*
Sonneratiaceae	Acanthaceae
Sonneratia alba	*Acanthus ilicifolius*
S. caseolaris	*A. ebracteatus*
Avicenniaceae	Sterculiaceae
Avicennia alba	*Heritiera littoralis*
A. marina	Arecaceae
A. officinalis	*Nypa fruticans*
Combretaceae	*Oncosperma tigillarium*
Lumnitzera racemosa	Pandanaceae
Myrsinaceae	*Pandanus furcatus*
Aegiceras corniculatum	Pteridaceae
Ardisia humilis	*Acrostichum aureum*
Meliaceae	
Xylocarpus moluccensis	
X. granatum	

grove forest, i.e. the ecotone corresponding to the upper limit of tidal influence, has a specific flora which differs from that of the mangrove. Its most widely known representative is the stemless palm *Nypa fruticans*, which often forms pure stands alongside the rivers. It may also be observed delineating circular areas inland of the mangrove or colonizing brackish swamps, the remains of former lagoons trapped by sandy strips colonized by *Casuarina equisetifolia*.

Brownlowia argentata, *Heritiera littoralis*, *Intsia bijuga*, *Cerbera odollam*, *Excoecaria agallocha*, *Ficus retusa* and *Ardisia humilis* are often encountered in this type of formation as is *Sonneratia caseolaris*, sometimes found very far upstream from the river mouth (near Palembang city for instance).

In Sumatra, particularly in the Riau region, this back mangrove area is often a very characteristic narrow strip (10–100 m) which very clearly announces the end of the mangrove and the beginning of the fresh water swamp forest. This formation, most often dominated by the 'Nibung' palm (*Oncosperma tigillarium*), is clearly visible on satellite imagery in such places. Hillocks are formed by the action of tunneling crayfish (*Thalassina anomala*), and are often colonized by the fern *Acrostichum aureum*.

Further south, *Oncosperma tigillarium* grows very densely (1000 trees/ha in the Musi delta), and the areas covered by this economically viable species are vast. These formations are characteristic of swamp forests on alluvial deposits. Other dominant species include *Glochidion littorale*, *Pittosporum ferrugineum*, *Harpullia cupanioides*, *Allophylus cobbe*, *Ganophyllum falcatum*, *Erioglossum rubiginosum*, and *Scolopia macrophylla*.

Fresh water swamp formations on alluvium.

Riparian formations (periodically flooded for short periods of time)

Location, extent and forest status. These formations occupy small areas on our map (1000 km^2), and could not be systematically represented at the scale used as they are not always distinguishable from bordering forests on remote sensing documents. In all events, they have been much damaged by Man and have practically disappeared from the banks of the main rivers and streams, having been converted into orchards, coconut and bamboo plantations. Corner (1978) has meticulously described the natural plant succession observed as one travels upstream from the river mouth. Some of the plant formations we observed along the river banks in Sumatra resemble those described for the Malaysian peninsula, while others did not. These riparian types are in fact highly diversified and are floristically divergent depending on where they are located along the river, as well as on the river's width and flood regime.

The physical environment. The area concerned (0.1 to 1 km wide) may undergo temporary flooding during heavy rain. The soils developed on this recent alluvium are grey colored with an upper brown horizon with a low organic content (0.2–0.5 m). This often developed above successive deposits, witnesses of previous floods. Although these soils can sometimes be saturated with water causing gleying, drainage is generally good. These relatively fertile soils have been put to agricultural use nearly everywhere, mainly as fruit orchards.

Structure and floristics. Downstream, the disappearance of *Nypa fruticans* formations indicates the outer limits of the effects salinity has on the environment. Other species begin to appear, colonizing the submerged part of river banks, which soon form dense thickets of *Gluta velutina* (Anacardiaceae), *Barringtonia conoidea* (Lecythidaceae), and *Pandanus helicopus* (Pandanaceae). This zone is still affected by tidal movements. In Southern Sumatra, *Quassia indica* (Simaroubaceae), *Elaeocarpus odontopetalus* (Elaeocarpaceae), *Ochthocharis paniculata* (Melastomataceae), *Vitex negundo* (Verbenaceae), *Garcinia celebica* (Clusiaceae), *Canthium dicoccum* (Rubiaceae), *Clerodendrum inerme* (Verbenaceae) and several varieties of *Eugenia* (*E. garcinifolia*, Myrtaceae) are associated with this environment whose physiognomy is similar to that of secondary formations, including a tree canopy at a height of 10 to 20 meters covering a dense undergrowth of shrubs and lianas.

These lianas and epiphytes include numerous varieties of *Ficus* (*F. deltoidea*, *F. globosa*), *Poikilospermum suaveolens* (Urticaceae), *Hoya macrophylla*, *Sarcolobus globosus* (Asclepiadaceae), *Spatholobus ferrugineus* and *Dalbergia candenatensis* (Fabaceae), particularly common. At ground level, Araliaceae (*Schefflera subavenis*), Araceae (*Rhaphidophora*) and *Hanguana malayana* (Flagellariaceae) complete the list.

Upstream, this environment is gradually replaced, especially on large rivers, by the formation known as 'rapak' in Malay, whose most characteristic genera and species are *Lagerstroemia speciosa* (Lythraceae), *Alstonia spathulata* (Apocynaceae), *Ficus retusa* (Moraceae), *Mangifera gedebe*, *Gluta renghas* (Anacardiaceae), and numerous species of Euphorbiaceae. The stature of these formations is higher, giving the impression of a mature forest topped mainly by emerging Anacardiaceae and Fabaceae. In the Southern part of the island along the river Lalang we collected *Intsia bijuga*, *Koompassia excelsa* (Caesalpiniaceae), *Dillenia excelsa* (Dilleniaceae), *Neesia malayana* (Bombacaceae), *Vatica pauciflora*, *V. venulosa*, *Shorea sumatrana* (Dipterocarpacae), *Kayea ferruginea* (Clusiaceae), *Myristica elliptica*, *Horsfieldia iriya* (Myristicaceae), *Ficus crassiramea* (Moraceae). Two species of Rubiaceae (*Canthium dicoccum*, *Tarenna fragrans*) and a Rhamnaceae (*Ziziphus* cf. *calophylla*), are the most characteristic species of the undergrowth.

Vegetation types dominated by *Mimosa aspera* and *Gluta renghas*, often observed along the banks, indicate the ultimate stages of degradation of that particular forest type.

'Gallery' forests form along small affluents in the swamp flats. They are mainly dominated by *Gluta renghas*, *Shorea palembanica*, *S. sumatrana*, various species of mango associated with *Allophylus cobbe*, several species of *Calophyllum*, *Dysoxylum alliaceum*, *Koompassia excelsa*, *Lagerstroemia speciosa* and *Shorea teijsmanniana*.

Photo 2. The natural habit of the "gelam" tree (*Melaleuca cajuputih*) is the swampy banks of small rivers or lakes such as the "lebaks" often encountered near Palembang (South Sumatra).

Palms such as *Licuala spinosa* and *Oncosperma tigillarium*, and numerous species of rattan (*Korthalsia*, *Daemonorops*, *Calamus*) are always abundant. As the observer travels up these small rivers to reach the peat forest zone, the flora also changes significantly: *Anisoptera marginata*, *Shorea hemsleyana*, *S. platycarpa*, *Dillenia reticulata* become the main components of the canopy, while the rattans disappear.

Riparian forests on the west coast, however, are quite different: trees are sparser and plant diversity is lower. Enormous *Canarium pseudodecumanum* (50 m high) dominate a low forest (canopy between 20 and 25 m) of *Santiria apiculata*, *Blumeodendron kurzii*, *Neoscortechinia sumatrensis*, *Antiaris toxicaria*, *Pometia pinnata*, *Turpinia sphaerocarpa*, *Pterospermum javanicum* and *Dracontomelon dao* (Fig. 30).

The lower strata consist mainly of a thorny Rutaceae (*Burkillanthus malaccensis*), while at ground level, *Lasia spinosa* (Araceae) colonizes the swamp. Levees are narrow and the water depth increases rapidly as one penetrates further into the swamp lands. It is sometimes necessary to resort to swimming when crossing wide areas with no tree cover.

Alluvial formations (periodically flooded for long periods of time)

Location, extent and forest status. Available remote sensing imagery did not always enable us to distinguish alluvial forests from peat forests. The former occupy smaller surface areas in comparison to the immensity of the peatlands. In a similar way to the riparian forests, the alluvial forests were soon converted by man since they are located near the ancient travelling rivers on relatively fertile soil. In the majority of cases, these forests have been transformed into paddi fields or sometimes into sago palm (*Metroxylon sagu*) plantations.

Alluvial forests only represent about 9000 km^2 on the map, i.e. 1.85% of the island's total surface area and extend 2 to 5 km inland from the mangroves or on either side of the rivers running through the swamp plains. They colonize depressions located behind the banks. The ecology of these formations is not very well known and the only descriptions for Sumatra are those of Franken and Ross (1981), Silvius et al. (1984), and Bihari and Lal (1989).

The physical environment. The ground is periodically flooded for relatively long periods of time (two to four months or more). The soil is generally characterized by a brown horizon of a finer texture than that of the banks, with high C/N and organic matter content. Slight accumulation of peat (< 0.5 m) can sometimes be observed.

Structure and floristics. The wide physiognomical and structural diversity observed for these forests depends on variation in the frequency and duration of the flood period. Structure varies considerably from that of comparable forests on drained ground or peat forests to that of more open formations developed in deep water.

In east Sumatra (Figs. 31 and 32a), emergent trees (further up the canopy and sparser than in drained forests) are typically large Apocynaceae as *Alstonia pneumatophora* easily reaching a height of 50 m. Near the Lalang river in the Musi delta, the latter are associated with dipterocarps such as *Dipterocarpus apterus*, *Shorea sumatrana*, *S. balangeran* and *S. palembanica*, the last two species only growing in the South of the island.

The species habitually observed in the canopy located at a height of twenty to twenty–five meters above the ground are mainly Anacardiaceae, *Campnosperma auriculatum*, *Mangifera paludosa*, Moraceae, *Artocarpus kemando*, *Parartocarpus venenosus*, and Euphorbiaceae, *Baccaurea bracteata*, *Neoscortechinia kingii*, *Blumeodendron tokbrai*.

The palm tree *Oncosperma tigillarium*, characteristic of the back mangrove swamps, is often encountered, but less frequently than the 'serdang' (*Pholidocarpus* cf. *macrocarpus*), 'salak' (*Eleiodoxa conferta*), and several species of *Licuala* (including the very common *L. spinosa*).

Besides *Stenochlaena palustris*, the climbing Pteridophyte whose shoots are edible, other ferns representative of this environment are *Vittaria elongata*, *Pyrrosia lanceolata*, *Paragramma longifolia*, and the particularly abundant *Mesophlebion chlamydophorum* and *Microsorum musifolium*.

Franken and Ross (1981) describe similar types in the Berbak reserve further North in the Jambi province where Dransfield (1974) notes palms in great abundance, especially rattans (mainly *Daemonorops geniculata*, *Korthalsia flagellaris*, *K. robusta*, *Calamus caesius*).

Alluvial forests also exist on the west coast. Although they are not very well documented, a number of them have been described (Ahmad 1976, Laumonier 1981). Their floristic composition and their structure are similar to east coast forests, but here the swamps have developed relatively recently in the subsidence formed between the islands of the west coast and Sumatra. The kind of peat vegetation found in this area confirms this relative youth.

The same physiognomy with sparse *Alstonia pneumatophora* emerging above *Campnosperma auriculatum*, *Xylopia fusca* and very large *Gluta* or *Melanochyla* (which we were not able to identify), is observed in the Indrapura plain west of Kerinci, Fig. 32b. Compared with the east coast, the canopy is less dense and the abundance of light at ground level causes a proliferation of rattans which strain towards the canopy. The most common species is *Daemonorops melanochaetes*, which, however has no economic value. Practically every trunk is covered until mid-height by the same climbing fern *Stenochlaena palustris*, an excellent indicator of these environment. On ground level, Cyperaceae such as *Thoracostachyum bancanum* and *Mapania* sp. are extremely abundant. The same palms as those of the east coast are encountered here, and *Hanguana malayana* (Flagellariaceae) indicates the environment is not peaty. In the openings, the presence of a tree fern (*Cyathea* cf. *contaminans*) and a bamboo (*Bambusa* sp.) is noteworthy.

Table 9 provides a list of the main species occurring in such swamp environment on alluvial soil or thin layers of peat (< 50 cm).

Secondary formations. The secondary formations corresponding with these environment have not been adequately investigated, simply because they generally consist of an inextricable mesh of rattans. In areas where the habitat has not been overly disturbed, recolonization at forest edges is similar to the serial stages observed in the drained lowlands, e.g. dominated by *Macaranga* species. On the west coast one encounters *Macaranga tanarius*, *M.* cf. *hosei* and *M.* cf. *triloba*, and the very common *Trema orientalis* and *Commersonia bartramia*. *Alstonia pneumatophora* (a successful pioneer species), *Dyera lowii*, the palms *Eleiodoxa conferta*, *Licuala spinosa*, and numerous ferns are often associated with the above species.

Another type of secondary vegetation attracts the traveller's attention because it covers con-

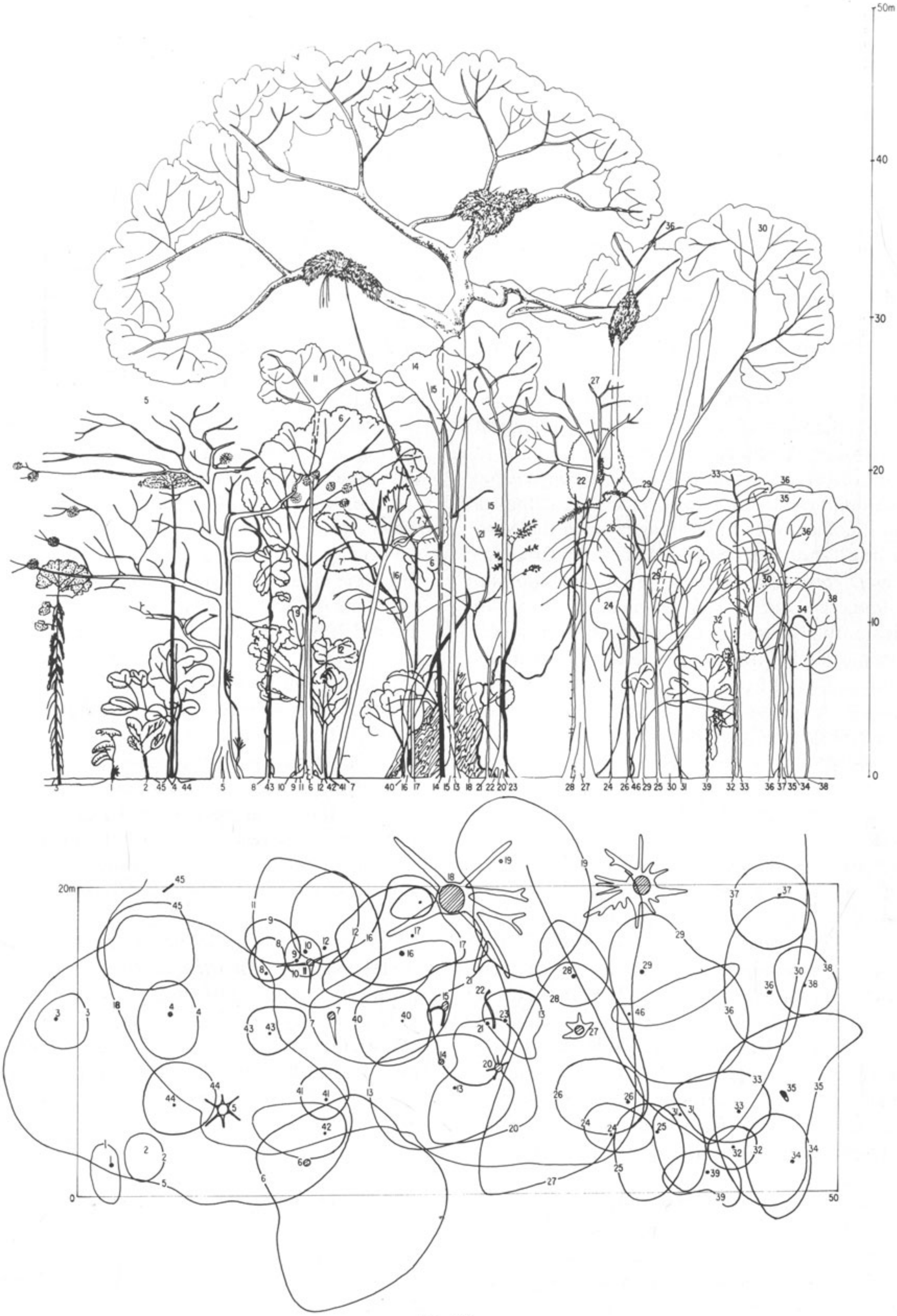


Fig. 30.

Antiaris toxicaria (15), *Artocarpus elasticus* (27), *Baccaurea sumatrana* (2,3,12,16,21,36), *Blumeodendron kurzii* (34), *Burkillanthus malaccensis* (13), *Canarium denticulatum* (18b), *C. pseudodecumamum* (18), *Dracontomelon dao* (11), *Eugenia sp.* (24), *Ficus sp.* (30), *Ganua sp.* (2), *Glochidion glomerulatum* (33), *Knema intermedia* (23), *Macaranga sp.* (31), *Neonauclea sp.* (4,8,26), *Neoscortechinia sumatrensis* (14), *Pometia pinnata* (4b,5,9,17), *Pterospermum javanicum* (29b), *Ryparosa* (29), *Santiria apiculata* (20), *Stelechocarpus cf. cauliflorus* (10,28), *Turpinia sphaerocarpa* (7), unidentified (19,22,25,32,35,37,38).

Crown planimetry (m2)				**Relative cover**	
				% tot al surf.	% cover surf.
Trees of the Present					
	Structural ensemble IV	0		0	0
	Structural ensemble III	756		76	80
	Structural ensemble II	321		32	34
	Structural ensemble I	106		11	11
		Total	**1183**	118	126
Trees of the Future			322	32	34
Trees of the Past			50	5	5
		Total	**1555**	156	165
Plot surface			1000	100	
Gaps			60	6	
Covered surface			940		100
Crown overlapping on			615		65

Fig. 30. Riparian forest type of the West Coast: The dense canopy layer, sometimes dominated by huge *Canarium pseudodecumanum* and *Ficus* spp., gives way to more open forest when the water level is higher. In such areas, *Lasia spinosa* colonises the forest undergrowth.

siderably large areas (slightly less than 5000 km^2 in the Palembang region). These 'Gelam' formations (*Melaleuca cajuputi*, Myrtaceae), particularly well developed in the Palembang region, represent a serial stage of alluvial forests and not of peat forests, as is so often written. The natural habitat of the Gelam is the banks of little rivers and lakes or 'lebaks' frequently encountered near Palembang.

This fire-resistant species sometimes forms almost pure stands after clearing and frequent burning. In areas where fires occur less often, it is associated with *Alstonia* cf. *pneumatophora*, *Campnosperma auriculatum*, *Ilex cymosa*, *Ploiarium alternifolium* and *Dyera lowii*. Undergrowth is mainly composed of Cyperaceae of the genus *Scleria* such as *Scleria sumatrensis* and the most degraded stage of these formations are savanna type areas of Cyperaceae, *Eleiodoxa* and *Melaleuca*. Kostermans (1958) has described the ultimate degraded state with *Leptonychia heteroclita*, *Scleria lithosperma*, *S. bancana*, *Cyperus haspan*, *Digitaria pertenuis* and *Lepturus repens*.

Peat swamp environments

The genesis of the large peat swamps on the west coast has not yet been elucidated. According to the Chinese chroniclers of the Sriwijaya kingdom (Vth century), a narrow coastal plain existed east of Palembang, which at the time was a harbour

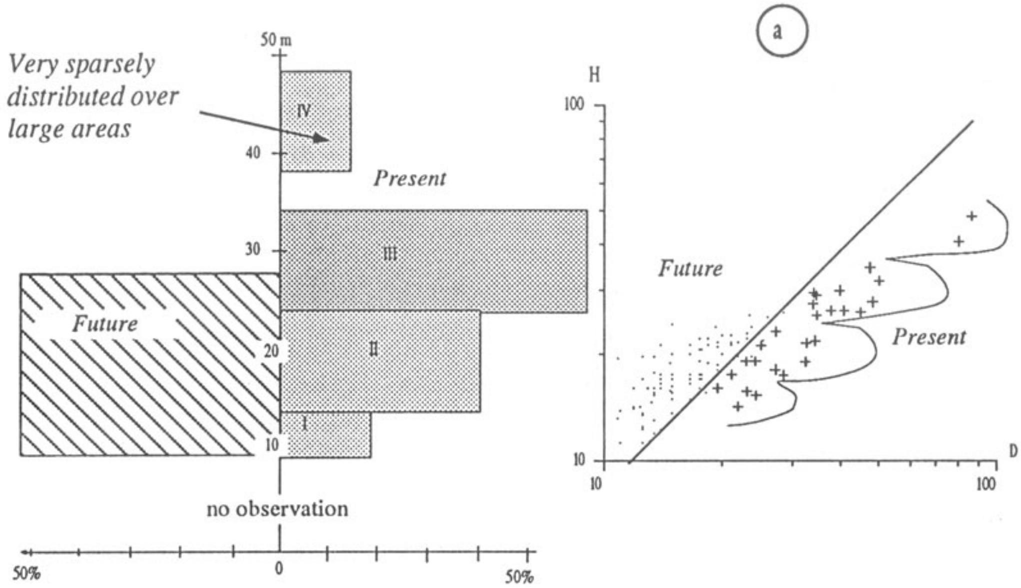
133 Alangium sp., 30 Alstonia pneumatophora, 23,22,101,147 Artocarpus kemando, 66,81,99 Baccaurea bracteata, 29,128 Baccaurea sp., 31 Calophyllum sp., 47 Calophyllum venulosum, 21 Campnosperma auriculatum, 117 Canarium cf. asperum, 134 Carallia brachiata, 112 Diospyros areolata, 48 Diospyros cf. confertiflora, 51 Diospyros sp., 13,20 Eugenia cf. antiseptica, 14,15,32,54,49,100,148 Eugenia sp., 10 Eugenia sp. 2,18 Eugenia sp. 2,83 Ficus sp., 11,19,56,144 Ganua motleyana, 53 Glochidion cf. borneense, 146,115 Gonystylys bancanus, 52 Horsfieldia sp., 85 Kayea sp., 55 Knema laurina, 111 Knema sp., 84 Lithocarpus sp., 68 Macaranga conifera, 67,86 Mangifera quadrifida, 110 Myristica iners, 16 Neesia glabra, 50,82,97,98,118,116,130,17 Parastemon urophyllum, 79,80 Pholidocarpus macrocarpus, 12 Polyalthia sumatrana, 113 Pometia pinnata, 109,132 Pternandra galeata, 145 Ptychopyxis costata, 131,135,143 Santiria rubiginosa, 87,114,129 Stemonurus secundiflorus.

Crown planimetry (m2)			**Relative cover**	
			% total surf.	% cover. surf.
Trees of the Present				
Structural ensemble IV	120		6	6
Structural ensemble III	1345		67	71
Structural ensemble II	751		38	40
Structural ensemble I	368		18	19
	Total	**2584**	**129**	**136**
Trees of the Future		1030	**52**	**54**
Trees of the Past		549	**27**	**29**
	Total	**4163**	**208**	219
Plot surface		2000	100	
Gaps		100	5	
Covered surface		1900		100
Crown overlapping on		2263		**119**

Fig. 31. Alluvial swamp forest, Berbak, Jambi (after Franken and Roos, 1981). Floristic composition and coverage of the various structural ensembles in a mature forest phase. Crown overlapping is typically very important in such a forest type. (Fold out.)

in the crux of a bay. Sobur et al. (1977) calculated the current sedimentation speed as approximately 30 m/year. If historical data were correct, this sedimentation rate would have to be 100 m/year. Manguin (1988) pointed out historical evidences that the Portuguese pilots of the 16^{th} century situated the island of Bangka and the part of the Sumatra coast opposite to it exactly at their present location. The swamps were probably less extensive at the time of the great Malaya kingdom, but Palembang was certainly not a sea harbour. According to the geologists, it is more likely that the withdrawal of the sea at the beginning of the Quarternary era caused a widening of this coastal area (Van Bemmelen 1949) rather than the accumulation of alluvial deposits, at least for the Palembang region. Diemont and Van Reuler (1984) have studied erosion phenomena of coastal peatland at Jambi, further North (Berbak) and use dating methods to show that this sector's coastline was not located any further inland than it is today.

Fig. 31. Alluvial swamp forest, Berkak, Jambi
(after Franken & Roos, 1981).



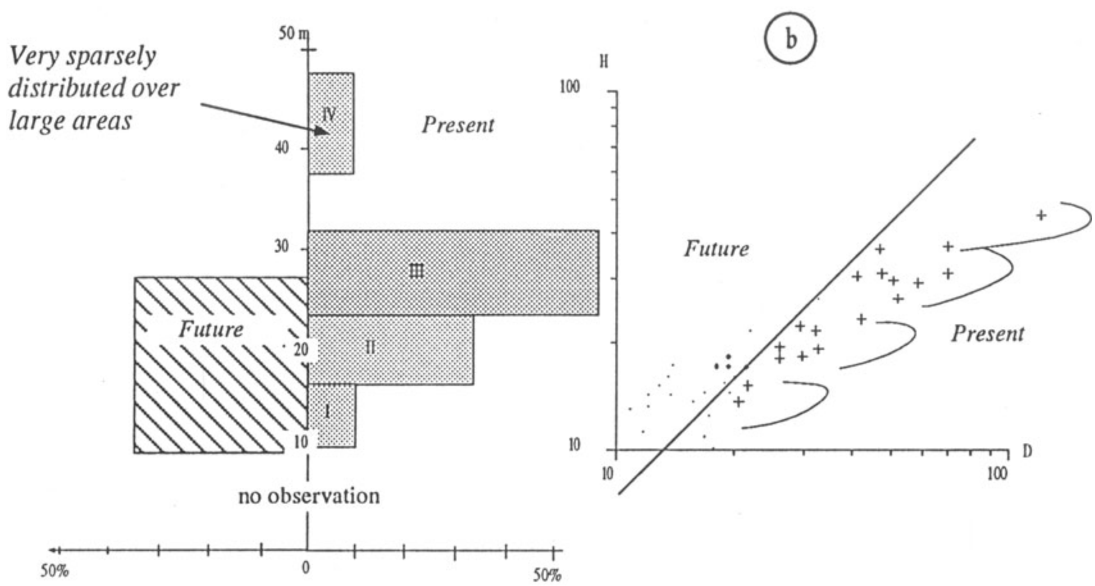


Fig. 32. Height-diameter relationship, stratification, number and cover of various architectural ensembles in alluvial swamp forest types (a: East coast; b: West coast). The emergent trees are always very sparsely distributed. Generally speaking, alluvial swamp forests of the west coast are less tall, less dense, with less crown overlapping, but overall structural organisation is very similar.

The low-lying peat swamps along the valleys described for Sarawak (Anderson 1964), or those of central Borneo which have developed on the podzols of terraces or badly drained plateaus (Brünig 1974 at Sarawak and Brunei, Sieffermann 1988 at Kalimantan) do not seem to exist in Sumatra. Here, peat swamps form in submerged basins of topographical origin.

While most existing peat swamps are situated on ancient mangrove soils, as proved by oil drilling at Riau and Jambi, one may reasonably believe that this is not the case for all these swamp

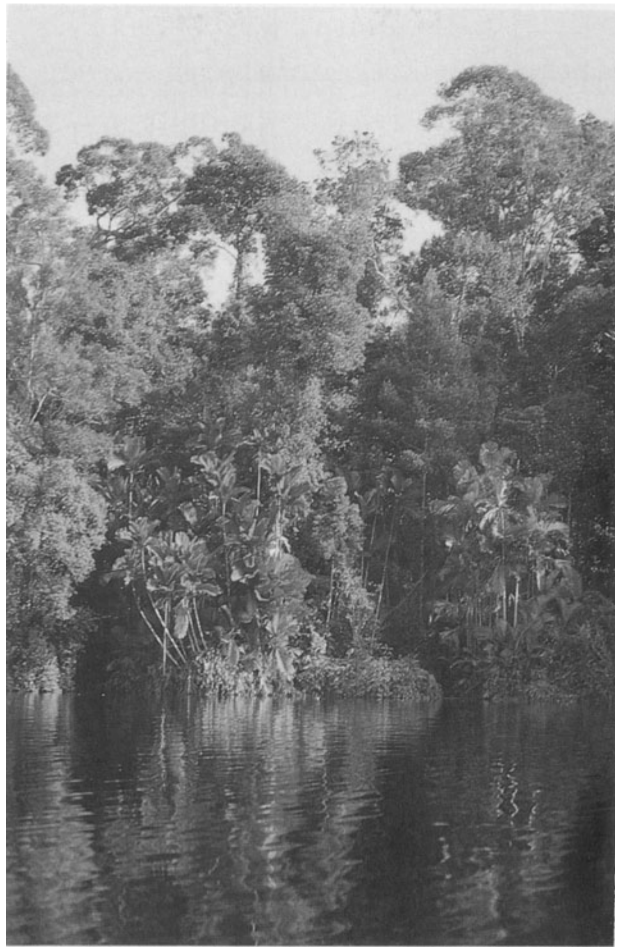


Photo 3. Mixed peat swamp forest on a moderate peat layer: *Shorea platycarpa*, *Anisoptera marginata*, and *Durio carinatus* are characteristic species of the forest canopy along the shore of Lake Pulau Besar, Riau. *Cyrtostachys lakka*, the "sealing wax palm" often occurs in clusters.

formations. According to Diemont and Supardi (1987), some swamps at Jambi and Riau have developed on marine sediment which have been raised above today's sea level (2–6 m at Riau 1–3 m at Jambi), and not on ancient mangrove soil. These authors estimate that this elevation occurred prior to formation of the peat swamp, thus confirming the pluvial origin of these bogs, dated at ± 4575 years.

Certain peat swamps may even have developed along the same lines as those described by Morley (1981) in South Kalimantan, i.e. by colonization of Poaceae swamps and 'floating islands' such as those found in the lebak areas near Palembang (Driessen & Soepraptohardjo 1977). The delta is still undergoing change, with mangroves colonizing new land and the ocean currents remodeling the estuaries.

Age differences exist between the peat formations at Riau and those of Palembang. This difference is noteworthy in the vegetation zonation. The former are the oldest, having developed during the Holocene after the last sea withdrawal phase (11 000 years ago). The level of the sea rose to its present level, where it stabilized approximately 5000 to 6000 years ago. Alluvial deposits began to form along the rivers and in the deltas. The depressions situated behind the mangroves and banks were gradually occupied by herbaceous vegetation and tree species characteristic of the plant formations described previously (fresh water swamp on alluvium).

Photo 4. Peat swamp forest on a deep peat layer: a few emergent trees, such as *Palaquium burckii*, *P. ridleyi*, and *Gluta aptera*, overtop an almost even canopy composed mainly of *Shorea* spp., *Calophyllum sundaicum*, *Cratoxylum arborescens*, *Tristaniopsis obovata*, and a large number of *Eugenia* species. (Lake Pulau Besar, Riau).

Photo 5. This "pole" forest ("padang") on a very deep peat layer is dominated by *Shorea teijsmanniana* and *Calophyllum sundaicum* in the Bengkalis mainland area. Here floristic diversity is higher than in similar vegetation types on Borneo (between Siak and Kampar, Bengkalis, Riau).

Table 9. Main species found in each structural ensembles in fresh water alluvial swamp forest.

Emergent trees	APOCYNACEAE	Lower Ensembles
	Alstonia pneumatophora	CELESTRACEAE
	ANACARDIACEAE	*Bhesa paniculata*
Canopy	*Gluta spp.*	EBENACEAE
	ANACARDIACEAE	*Diospyros cf. malabarica*
	Campnosperma auriculatum	EUPHORBIACEAE
	Mangifera paludosa	*Baccaurea bracteata*
	Mangifera griffithii	*Neoscortechinia kingii*
	Gluta spp.	*Blumeodendron tokbrai*
	ANNONACEAE	*Antidesma cf. montanum*
	Xylopia fusca	*Galearia fulva*
	BOMBACACEAE	FLACOURTIACEAE
	Coelostegia griffithii	*Scolopia macrophylla*
	BURSERACEAE	CLUSIACEAE
	Santiria rubiginosa	*Garcinia cf. rostrata*
	COMBRETACEAE	*Calophyllum spp.*
	Terminalia adenopoda	ICACINACEAE
	DIPTEROCARPACEAE	*Stemonurus secundiflorus*
	Dipterocarpus elongatus	*Platea latifolia*
	Shorea sumatrana	MELIACEAE
	Shorea palembanica	*Sandoricum emarginatum*
	ELAEOCARPACEAE	PALMAE
	Elaeocarpus macrocerus	*Caryota mitis*
	MORACEAE	*Eleiodoxa conferta*
	Artocarpus kemando	*Licuala spinosa*
	Parartocarpus venosus	RHIZOPHORACEAE
	Ficus spp.	*Gynotroches axillaris*
	PALMAE	
	Oncosperma tigillarium	
	Pholidocarpus cf. macrocarpus	Undergrowth
	ROSACEAE	
	Parastemon urophyllus	*Ficus sinuata*
	SAPINDACEAE	*Ilex sp.*
	Harpullia sp.	*Nenga pumila*
	Pometia pinnata	
	Ganophyllum sp.	*Stenochlaena palustris*
	THYMELAEACEAE	
	Gonystylus sp.	*Thoracostachyum bancanum*
	SAPOTACEAE	*Hanguana malayana*
	Ganua motleyana	

Organic accumulations due to vegetation debris caused dome-shaped peat deposits to form, due to a faster rate of decomposition around the periphery where the medium has a higher mineral content. Polak (1933) mentions peat depths of up to 15 m at Jambi or Riau, although the average maximum depth does not exceed 7–8 m (Cameron et al. 1987)

Location, extent and forest status
Peaty soils are most often defined as soils with at least 65% organic matter within a layer 50 cm thick (Driessen 1977). Andriesse (1974) estimated the surface area of organic soils at 7.3 to 9.7 million hectares in Sumatra. These figures, often quoted in literature (Soepraptohardjo & Driessen 1977, Anderson 1983), depend on the definition used for organic soils, but are probably overestimated. According to the vegetation studies undertaken the mapping survey, the surface area occupied by peat layers over 50 cm thick attains 6.3 Mha at the most.

Plant formations on peat swamps represent approximately 38 000 km^2, i.e. nearly 8% of Sumatra's total surface area. They mainly extend along the east coast at the central and south section of the island, and are particularly abundant from the Musi delta at Palembang to the Siak river. Several smaller formations exist on the west coast north of Bengkulu and in the Indrapura, Airbangis and Singkel plains.

Traditionally, the Malay populations of the Malacca Straits gathered wood from these forests (mainly 'Balam', several *Palaquium* species and other Sapotaceae). They also harvested latex and the 'Suntai' fruit (*Palaquium burckii*, *P. walsurifolium*) from which they extracted an edible oil. The peat forest comprises a large number of species, some of which are attractive for loggers such as the 'Balam' already mentioned, the 'Ramin' (*Gonystylus bancanus*) and several dipterocarps (three species of *Shorea*, one species of *Anisoptera*). Forestry practices generally involve the use of a lorry system for carriage. In most cases, the trunks are sawn into small logs on the spot and dragged or pushed by workers over rolling log paths to the main roads. Forest exploitation is limited to areas where peat depth is shallow and, due to high running costs, has not given rise to major operations except on the Musi delta. This is doubtlessly the reason why vast tracts of relatively undisturbed forests can still be found today even if large zones have been put to agricultural use. Coconut plantations were established as early as 1903 in the Kampar-Indragiri delta (Endert 1932), and in 1922 Tembilahan, the town located at the river mouth, became an important copra export center. In spite of a market slump in 1940 and serious losses due to subsidence of peatlands (Driessen & Sudewo 1977), this land use continues to develop, mainly southwards in Jambi province. This is a unique example of intensive agricultural use in such environment. In other locations, immense areas have been assigned for transmigration programs, such as at the Musi delta. Where the peat is less than 1 meter thick, many perennial crops can be cultivated (Driessen & Sudewo, op. cit.). It is thus important that peat thickness should be mapped.

Oil drilling operations should also be mentioned at this point as they contribute to the rapid transformation of the landscape, above all in Riau province.

The physical environment
The peat swamps occupy regions near the equator where average yearly rainfall is always high ($1500 < P < 2000$ mm/year) and relatively well distributed over the year. This distribution influences evapotranspiration and is therefore important in explaining the presence of the peat swamps. Dry periods may nevertheless occur, alcthough they are not repeated every year, (a typical instance would be Kuala Tungkal weather station, $P = 2129$ mm/year, average number of dry months, 2 to 3). Fires have often been recorded near Palembang. The impact of drought on swamp formations is difficult to evaluate as the driest areas have been farmed for a long time and the network of weather stations extremely inadequate.

The physical properties of organic soils such as peat depend primarily on the degree of decomposition of the organic matter. Peat formations in Sumatra are essentially hemic and only rarely fibric (Hardjowigeno & Abdullah 1987), consisting of a matrix of almost non decomposed material enclosing a semi-liquid filler. The bulk density, extremely variable, is obviously much lower than that of mineral soils and is evaluated at less than 0.1 gr/cm^3 for fibric peat, instead of 0.2 gr/cm^3 for highly decomposed sapric peats (Driessen & Rochimah 1977).

Irreversible changes can occur in the colloidal structure of peat after excessive drainage. The matrix shrinks, the water retention capacity decreases and, in extreme cases, the terrain subsides (Chambers & Sobur 1979). The peat becomes hydrophobic, and the forests it supports rapidly die (consequently subjected to drainage). We observed this phenomenon in the oil field exploitation and transmigration areas.

These peats are extremely acidic with pH levels of 3 to 4.5, and a high humic and fulvic acid content. Suhardjo & Wijaya-Adi (1977) measured pH values ranging from 3.5 to 4.2 in the Kampar region. These authors also confirmed that the phosphorus and potassium content were very low. Nitrogen is abundant in the form of nitrogenous organic compounds which are not easily freed into the environment and are therefore not available to the plants. The CEC is high, ranging from 114 to 137 meq/100 g, while base saturation rarely exceeds 10%. A significant drop in the phosphorus, potassium, calcium and magnesium amount is observed as one approaches the center of the peat dome, i.e. as the peat depth increases.

The water exuded by these peat formations is black and rich in phenolic compounds which can be toxic for both plant and animal life (Janzen 1974), an opinion not shared by Whitmore (1984) for plants.

Primary formations

Anderson (1963, 1964) was the first researcher to observe the way vegetation varies according to peat depth and described a forest zonation for Sarawak comprising up to 5 zones distinguished by structural and floristic criteria.

It is nevertheless difficult to generalize, and in 1977 Anderson observed relatively important differences between peat swamps in Sarawak, Kalimantan and Sumatra: 'Large tree species in mixed peat swamp forest are mainly common to both Kalimantan and Sumatra. Most of the dominant and most abundant species in the padang vegetation in Kalimantan are apparently absent from similar forest types in Sumatra. Floristic drift across the catena is more marked in Kalimantan'.

The above-mentioned author states that, unlike his observations in Borneo, the number of species counted along a transect perpendicular to the vegetation zonation remained almost constant in Sumatra, and that the floristic differences between each place visited were very conspicuous.

The flora that is genuinely specific to peat swamps is fairly limited. It is worth mentioning several species characterising this environment (Table 10).

Mixed peat swamp forests on shallow peat layer (< 2 *m*). The structure of these forests is similar to that of the drained lowland forests, with emerging trees attaining heights of 45 to 50 m and the canopy often situated thirty to thirty five meters above the ground.

In Southern Sumatra (Fig. 33 and 34a), the emergent tree species are *Shorea uliginosa*, *S. teijsmanniana* (Dipterocarpaceae), *Dyera lowii* (Apocynaceae), while those most representative of the canopy include additionally: *Tetramerista glabra* (Tetrameristaceae), *Campnosperma coriaceum* (Anacardiaceae), *Mezzettia leptopoda*, *Xylopia fusca* (Annonaceae), *Durio carinatus* (Bombacaceae) and *Santiria laevigata* f. *glabrifolia* (Burseraceae).

Among the smaller species, one has to mention *Gonystylus bancanus* (Thymeleaceae), *Tetractomia obovata* (Rutaceae), *Rothmania* cf. *malayana* (Rubiaceae), *Parastemon urophyllus* (Rosaceae), *Combretocarpus rotundatus* (Rhizophoraceae), *Stemonurus secundiflorus* and *S. scorpioides* (Icacinaceae), *Neoscortechinia sumatrensis*, *Blumeodendron tokbrai*, *Baccaurea bracteata* (Euphorbiaceae), and numerous species of *Diospyros* (Ebenaceae).

Shrubs of the undergrowth are mostly represented by *Goniothalamus malayanus* (Annonaceae), *Dacryodes rostrata* (Burseraceae), the latter being much smaller here than on drained ground, *Antidesma montanum* (Euphorbiaceae), *Memecylon oligoneurum*, *Pternandra coerulescens* (Melastomaceae), *Ixora malayana* (Rubiaceae) and *Eugenia setosa* (Myrtaceae).

Hanguana malayana (Flagellariaceae) remains abundant on the ground, and the peat layer is still fairly shallow (1–2 m) as further indicated by the presence of *Dyera lowii*(Apocynaceae), *Koompassia malaccensis* (Caesalpiniaceae) or *Coelostegia griffithii* (Bombacaceae).

In the region of lake Pulau Besar at Riau, (Fig. 34b and 35) the same species are generally encountered, although the undergrowth is composed differently, with *Pandanus atrocarpus* (Pandanaceae) dominating vigorously. The peat

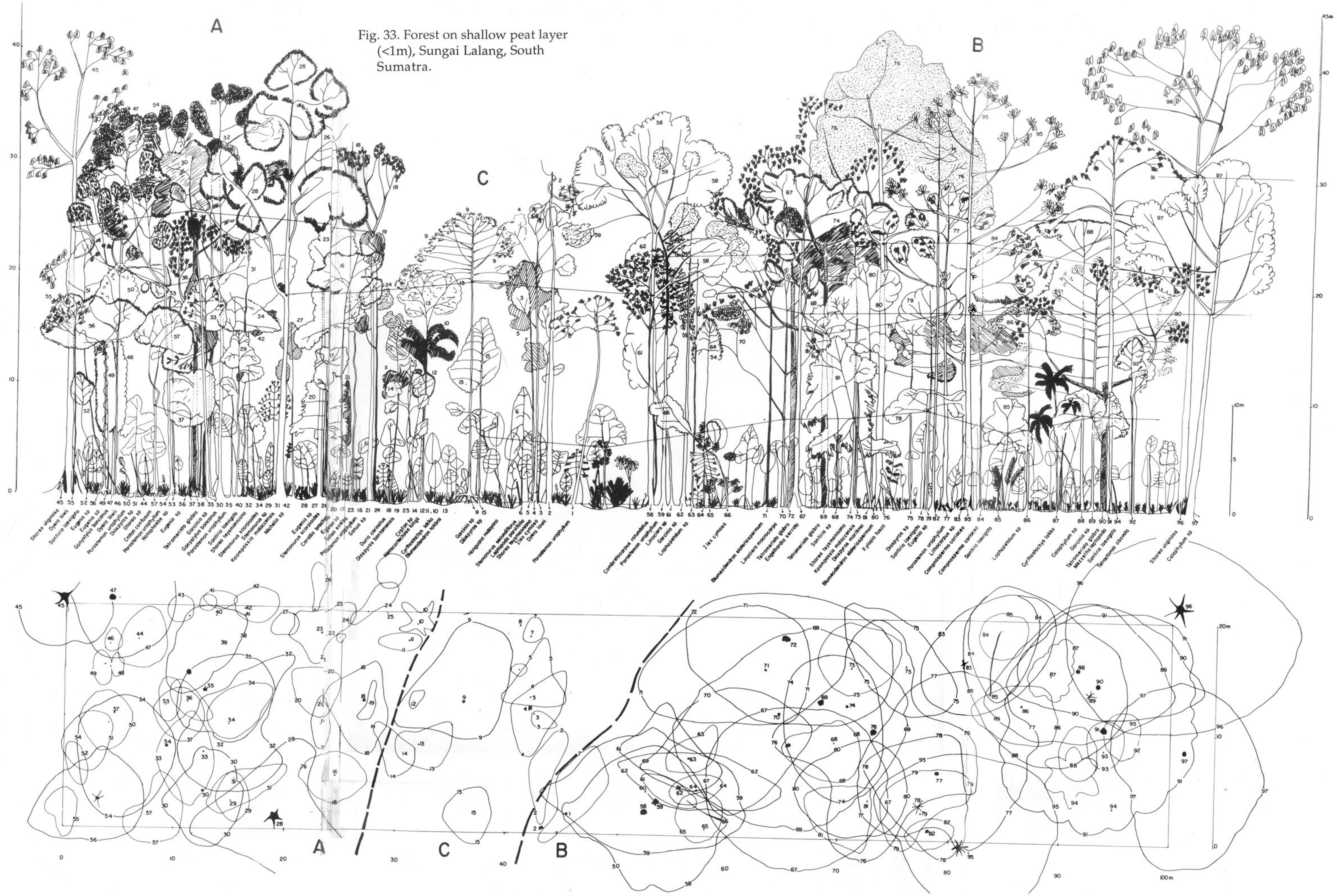


Fig. 33. Forest on shallow peat layer (<1m), Sungai Lalang, South Sumatra.

Crown planimetry (m2)			Relative cover	
			% total surf.	% cover surf.
Trees of the Present				
Structural ensemble IV	97		5	6
Structural ensemble III	1129		56	69
Structural ensemble II	690		35	42
Structural ensemble I	291		15	18
	Total	2207	110	134
Trees of the Future		897	45	55
Trees of the Past		259	13	16
	Total	3363	168	205
Plot surface		2000	100	
Gaps		358	18	
Covered surface		1642		100
Crown overlapping on		1721		105

Fig. 33. Mixed peat swamp forest on shallow (<1 m) layer, Sungai Lalang, South Sumatra (after Laumonier, 1980). The purpose of this forest profile was to illustrate forest dynamics in the Mixed Peat Swamp forest: part A = building phase, no proper "stratification"; part B = mature phase, several structural ensembles are visible; part C = tree-fall gap. (Fold out.)

layer here is just over two meters thick. Floristic diversity remains very high. As is the case in Palembang, the large emergent trees are dipterocarps such as *Shorea platycarpa*, *S. teijsmanniana*, *S. uliginosa* and, more rarely, *Anisoptera marginata*. An Anacardiaceae of the genus *Gluta* (*G.* cf *aptera* or *G. wallichii*) is also extremely abundant while in the canopy, reached by *Pandanus atrocarpus*, the most common species include *Calophyllum sundaicum*, *C. venulosum* (Clusiaceae), *Ganua coriacea*, *G. motleyana* (Sapotaceae), *Mangifera* cf. *parvifolia* (Anacardiaceae), *Ormosia* cf. *macrodisca* (Papilionaceae), *Aglaia ignea* (Meliaceae). *Pandanus atrocarpus* is sometimes extremely abundant and colonizes the clearings.

Formations on moderately thick peat layers (2–5 m). The height and physiognomy of the forest diminish rapidly as one penetrates further inland, diameters tend towards homogeneity and the stem density is higher. From the floristic standpoint, the extreme abundance of *Calophyllum sundaicum* is an excellent indication of this zone boundary, where floristic diversity diminishes also notably (Fig. 36). *Pandanus atrocarpus* becomes more rare, while *Ilex cymosa* starts to dominate the undergrowth.

On the outer regions of the dome (2–3 meters of peat), a few emergent trees with small crowns are still encountered (Fig. 37), mainly *Palaquium burckii* and *P. ridleyi*, *Tetramerista glabra*, *Combretocarpus rotundatus*, or *Gluta aptera*. The other species constitute an almost even canopy 20 to 25 meters above the ground composed mainly of *Mangifera parvifolia*, *Shorea uliginosa*, *S. teijsmanniana*, *Blumeodendron kurzii*, *Calophyllum sundaicum*, *Garcinia* cf. *rostrata*, *Cratoxylum arborescens*, *Horsfieldia crassifolia*, *Knema kunstleri*, *Tristaniopsis obovata*, and a large number of *Eugenia* species. *Ilex cymosa* remains the most common species of the undergrowth.

Architectural analysis is difficult here as most species do not reiterate. Trees of the Present are tall and slender with heights very much greater than 100 times the trunk diameter (Fig. 38).

The floristic composition of the next zone (peat thickness > 3–4 m) is almost identical except that the emergent trees disappear (Fig. 39).relatively uniform canopy at a height of 20 meters can be easily distinguished on aerial photographs. Anderson (1977) likens these forest types to pole forests ('padangs') and cites 'padang' forests dominated by *Campnosperma coriaceum*.

We spent a long time searching for these zones,

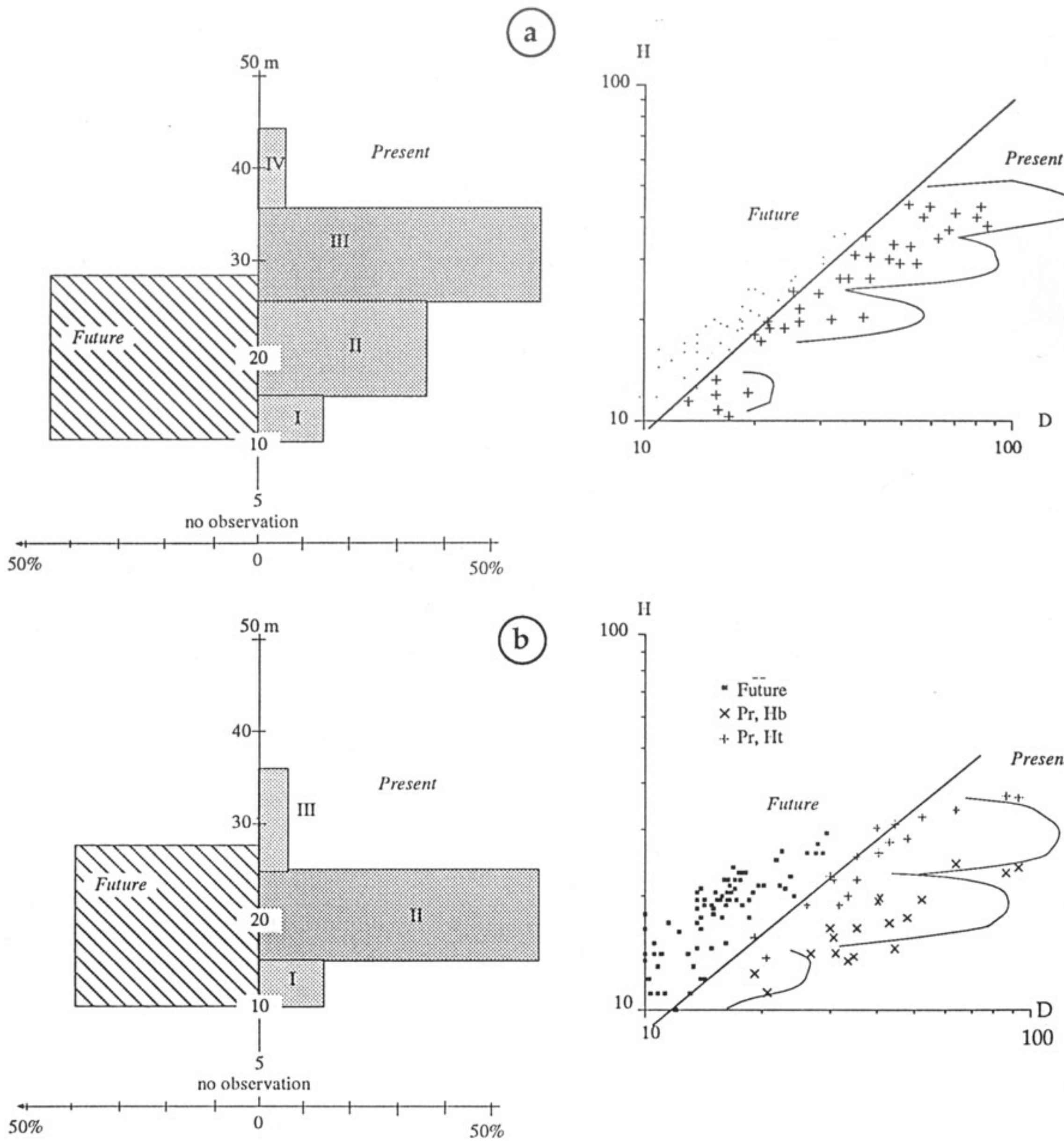


Fig. 34. Height-diameter relationship, stratification, number and cover of various architectural ensembles in mixed peat swamp forest types. a: South Sumatra, peat layer <1 m. Four structural ensembles are still visible in the tall mature forest phase, for a general canopy height around 30 m. b: Riau 1 m < peat depth <2 m. The forest is shorter, "stratification", when apparent, shows three layers only.

where the floristic diversity should supposedly diminish even further. They exist, but are difficult to inventorize accurately because they blend with the previous forest type, despite their much lower physiognomy, even on aerial photographs.

Low pole forests ('padangs') on deep peat layers ($>5\,m$). Endert (1920) and Polak (1933) mention 'padang' or pole forests dominated by *Tristaniopsis obovata* on the Paneh peninsula. Referring to the formations described previously, the *Pandanus* padang cited by Sewandono (1938) on Bengkalis island in Riau are more likely to correspond with a moderate peat depth zone where the depletion of the original formation by Man has encouraged dominance by *Pandanus*.

The 'padang' zones near lake Pulaubesar at

Shorea teijsmanniana (26,21,81,87,92,93), Palaquium ridleyi (61,67,68,76,77,84), Diospyros sp.2 (1,2,44,49,53), Calophyllum sundaicum (3,18,54,57), Polyalthia glauca (45,50,83,85), Knema kunstleri (46,51,88,97), Eugenia sp. 1 (9,6,16,60), Stemonurus secundiflorus (5,20,96), Ganua coriacea (8,65,99), Diospyros sp. 1 (22,53,49), Artabotrys maingayi (31,78,90), Ganua motleyana (95,94), Tetractomia (4), Garcinia cf. rostrata (7), Shorea uliginosa (17), Gluta cf. wallichii (74), Calophyllum venulosum (19), Parastemon urophyllum (28), Aglaia ignea (32, 41), Shorea platycarpa (59,62), Eugenia sp. 2 (66), Ormosia cf. macrodisca (100), Neoscortechinia sumatrensis (91), Campnosperma coriaceum (10), Pandanus atrocarpus (11,12,13,14,24,25,33 à 40,52,55,56,69 à 73,79,80,98), Gluta aptera (27,63), Quassia borneensis (58,86), Mangifera parvifolia (64,82), Ilex cf. macrophylla (89).

Fig. 35. Mixed peat swamp forest on medium peat depth (1–2 m): Floristic composition and main structural features. The main canopy at 20–25 m above the ground is characterized by rather small crown trees, over-topped by large emergent species, mainly *Shorea teijsmanniana* and *Palaquium ridleyi*. Gaps are common, usually colonized by *Cyrthostachys lakka* and *Pandanus acrocarpus*. Floristic diversity remains very high. Large climbers such as *Artabotrys maingayi* are noteworthy.

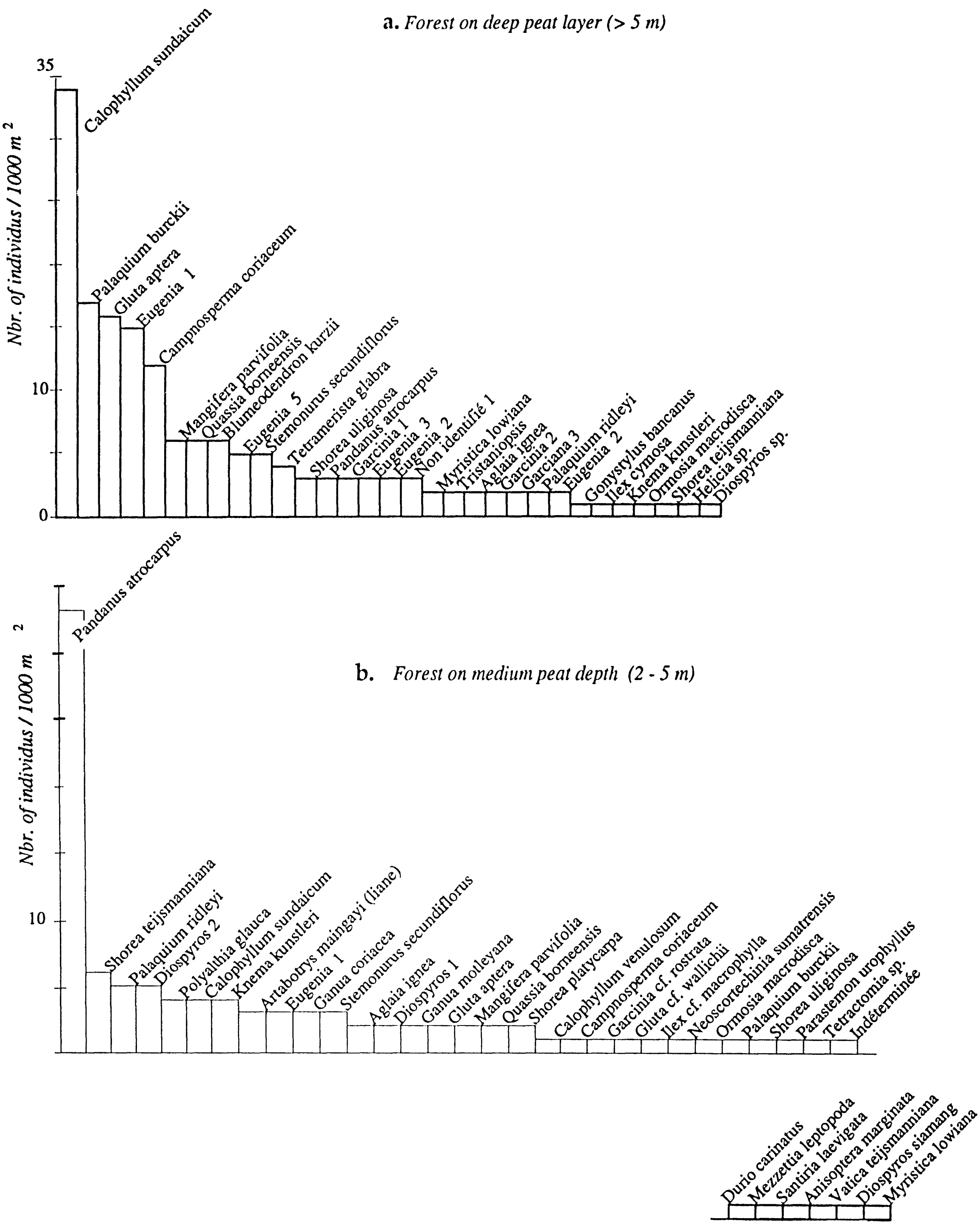


Fig. 36. Floristic diversity decreases with peat depth increase. For about the same number of species, the list of species only represented by one individual is much longer in b (peat depth between 2 and 5 m), than in a (peat depth >5 m).

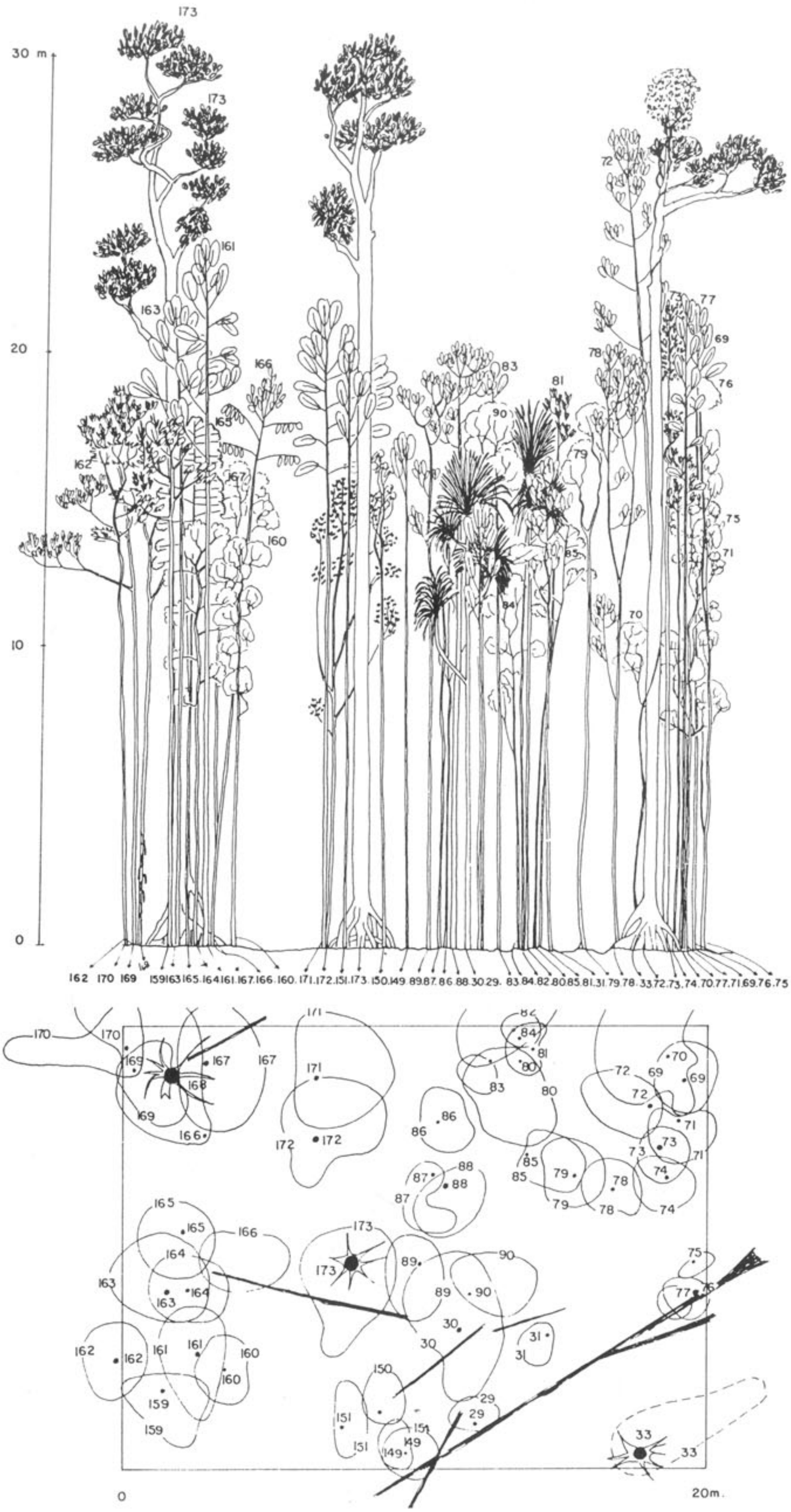


Fig. 37. Peat swamp forest on deep peat layer (±5 m). Lake Pulau Besar, Bengkalis main land, Riau. *Calophyllum sundaicum* (*69, 77, 83, 172, 163, 161, 149, 151, 29*), *Palaquium burckii* (*33, 173, 168*), *Gluta aptera* (*74, 81, 170, 150*), *Eugenia sp.* (*70, 84, 87, 167*), *Mangifera parvifolia* (*71*), *Stemonurus sp.* (*171*), *Blumeodendron kurzii* (*82, 164*), *Stemonurus secundiflorus* (*162*), *Eugenia sp. 2* (*160*), *Aglaia ignea* (*86*), *Eugenia sp. 3* (*79, 90*), *Garcinia* (*85*), *Tristaniopsis obovata* (*169*), *Garcinia cf. forbesii* (*165*), *Gonystylus bancanus* (*73*), *Parartocarpus venenosus* (*76*), *unidentified* (*30, 88, 89, 31, 75, 72, 166, 80, 78, 159*).

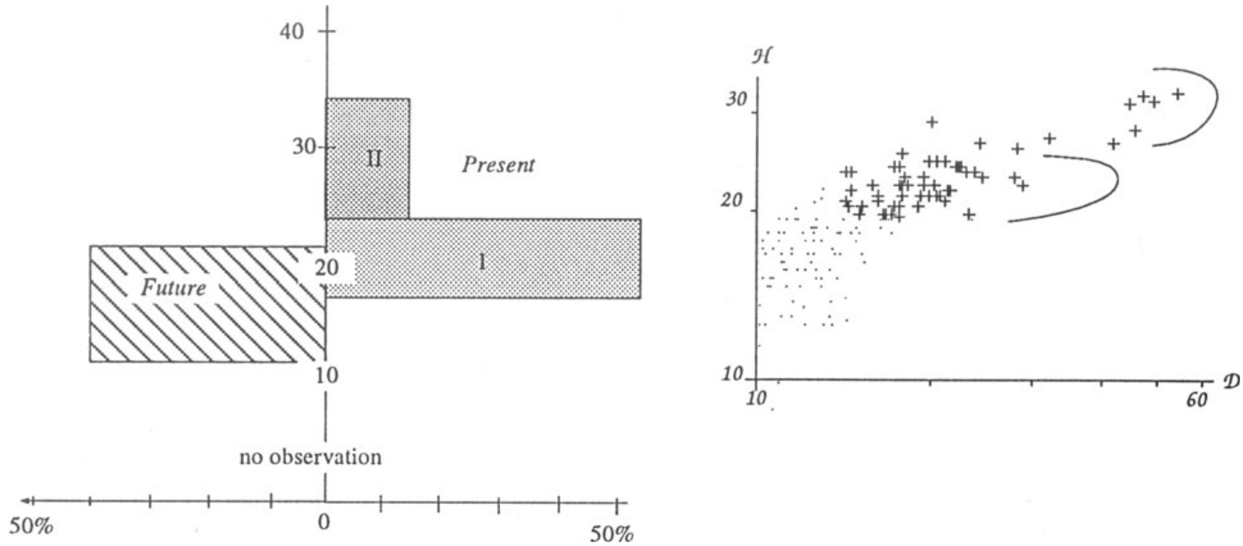


Fig. 38. Height-diameter relationship, stratification, number and cover of architectural ensembles in a swamp forest on deep peat layer. Architectural analysis is difficult as most species do not reiterate. The main canopy layer is at about 20 m above ground, with sparse small crown emergent trees, all represented by *Palaquium burckii*.

Riau are dominated by *Shorea teijsmanniana* and *Calophyllum sundaicum*. There, the very dense forest (10 000 stems/ha) has an even canopy 6–8 meters high (Fig. 40), and a physiognomy which often incites photo-interpreters to classify them as secondary formations. Floristic diversity remains higher than in Borneo with *Timonius flavescens*, *Antidesma* sp., *Tristaniopsis obovata*, *Ilex cymosa*, *Eugenia* cf. *elliptilimba*, *Aglaia ignea* and *Horsfieldia crassifolia* still present. *Nepenthes* species are abundant on the ground.

Secondary vegetation types

Secondary vegetation in peat swamp environment is not well documented. The author observed they are most often characterized, in areas where the peat layer is not too thick, by a shrubby vegetation composed of *Combretocarpus rotundatus*, *Lophopetalum* sp. and *Campnosperma coriaceum*. The latter is sometimes monodominant. On thick peat layer, *Calophyllum sundaicum*, *Ilex cymosa*, *Tristaniopsis obovata* and *Ploiarium alternifolium* dominate, while Cyperaceae remain abundant in the undergrowth.

Plant formations of the plains and piedmonts (drained soils at low elevation, <150 m)

Location, extent and forest status

Further upstream from the eastern swamp flats, primary forests have most suffered from logging and from the indirect consequences that these practices have had on human occupation and use of the local environment. On our map, intact forests now only cover 3.34% of the island's total area in comparison to 8.85% logged forests and 8% secondary vegetation.

Until the Second World War, the exploitation of Sumatra's forest resources in the lowlands mainly involved resin, gum or latex-producing species ('Gutta Percha' and the Jelutung, rubber substitutes extracted respectively from *Palaquium gutta*, various Sapotaceae and from *Dyera costulata*, an Apocynaceae), the 'Baros campher' (*Dryobalanops sumatrensis*[1], *Dipterocarpaceae*) *from the west coast, and the 'Garu' or 'Gaharu'* (*Aquilaria malaccensis*, Thymelaeaceae). As already mentioned, wood production was restricted to the 'panglong' regions of the Malacca Straits and, inland, further limited to the use of hard-

[1]formerly *D. aromatica* (Kostermans 1988).

woods such as the 'Bulian' (*Eusideroxylon zwageri*, Lauraceae), the 'Merbau' (*Intsia bijuga* and *I. palembanica*, Caesalpiniaceae), or the 'Tembesu' (*Fagraea gigantea*, Loganiaceae). 'Meranti' (*Shorea* spp.) utilization, still fairly localized, had just begun to interest the Dutch foresters (Endert 1920, 1925). The use of aerial photography for forestry inventories developed soon afterwards (Reerink 1932, Boon et al. 1950) and gave rise to the Hannibal (1953) classification system still in use today.

At the time, Sumatra was Indonesia's most important forest resource (Van de Koppel 1945) and continued to be so until the beginning of the 70's when the logging sector began to take an interest in Kalimantan, the Indonesian part of Borneo. New legislation appeared in 1967 expressing the State's will to maintain its control over the natural forestry resources, and to attract foreign investment. The wood market then began to favour timber varieties such as the dipterocarps and Philippino, American, Korean and Japanese investments became commonplace (Durand 1988). The Indonesian selective cutting system (Tebang Pilih Indonesia, or 'TPI') was then introduced, which involves cutting only individuals of commercial species whose diameter is greater or equal to 50 cm. The cutting cycle is circumscribed at 35 years and the forester has to spare at least 25 trees of commercial species with a diameter greater than 35 cm per hectare (Soerianegara 1970; Ministry of Forest Decree 1972). Cleaning around young commercial trees is recommended as well as replanting in areas disturbed by forestry operations. Longer rotation periods are stipulated for forest types where too few trees with a diameter greater than 50 cm exist (eg. if cutting is allowed as from 30 cm in diameter, the rotation period must be 55 years). These rotation cycles are based on the premise that the average growth rate of the species involved is 1 cm per annum. Our own results however show that this is far from the actual truth. Not enough research has been undertaken in Indonesia to evaluate this system (Alrasjid & Effendi 1979) which was suddenly challenged by the FAO[2] (Anon. 1990c). On the Sumatra lowlands, the low concentration of sound commercial tree species (many hollow individuals) means that operators only remove an average of 4 to 8 (10) trees per hectare, which favours regeneration but often calls for a second cutting before the 35-year rotation period is over. Timber production varies from 60 to 100 m^3 per hectare, and the extraction methods used are similar to those implemented everywhere.

Mechanization of forestry practices in the 70's resulted in a denser road network providing easier access to forest. Consequently, this caused deforestation to increase due to local populations shifting cultivation practices. This combination of intensive forestry exploitation and the further local depletion which unavoidably follows is often cited as the main cause of deforestation in tropical insular Asia (Anon. FAO 1981b, Lanly 1982, Kartawinata et al. 1989).

As from 1980, Indonesia implemented a plan to ban log production for export and, in 1985, became the world's second largest producer of plywood (Laurent 1985). Today, Indonesia's forests remain, together with Malaysia, one of the world's most important sources of timber, although its lowland forests are now seriously threatened. The last lowland forests in central Sumatra are the remainders of the past 15 years of exploitation. They are now criss-crossed with roads which provide easy access everywhere. These forests have a very uncertain future as proved by the facts observed in the South and in Lampung provinces. All our former plots in this region, which we illustrated by means of a structural profile diagram (Laumonier 1980, data collected in 1979–1980), have disappeared and been replaced by shrubby or grassy secondary vegetation.

The author was able to calculate the deforestation rate for south-west Sumatra using Landsat MSS satellite imagery. The entire region extending from Baturaja-Martapura to Lake Ranau-Krui and to the Sumatera Selatan II reserve has lost 210 000 ha of forests which disappeared during the period between 1978 to 1985 (Fig. 41), accounting for one of the highest rates on the island (1,6% par annum).

The rapid transformation of forest lands generally runs its course according to the following pattern: after logging, land is either allotted to transmigration (270 000 ha/year for Sumatra, Anon. – FAO 1990c), or to industrial oil palm or rubber plantations. These are the three all-powerful and somewhat 'spectacular' factors of deforestation. Most attempts at replanting had resulted in total failure and, faced with a situation

[2]from now on, a rotation of 60 to 70 years is advised

Calophyllum sundaicum (57, 56, 61, 68, 116, 144, 127, 140), *Palaquium burckii* (64, 113, 123, 139), *Gluta aptera* (120, 130), *Eugenia sp.* (126, 135), *Mangifera parvifolia* (62, 108), *Stemonurus sp.* (65, 129), *Blumeodendron kurzii* (117), *Stemonurus secundiflorus* (121), *Eugenia sp.* 5 (122,124,131,132,133), *Aglaia ignea* (110), *Eugenia sp.6* (125), *Garcinia* (134), *Tetramerista glabra* (118, 119, 141), *Eugenia cf. elliptilimba* (58), *Tristaniopsis obovata* (114), *Horsfieldia crassifolia* (67, 137), *Garcinia sp.* 2 (109), *Helicia sp.* (138), *Ilex cymosa* (115), unidentified (30, 88, 89, 31, 75, 72, 166, 80, 78, 159).

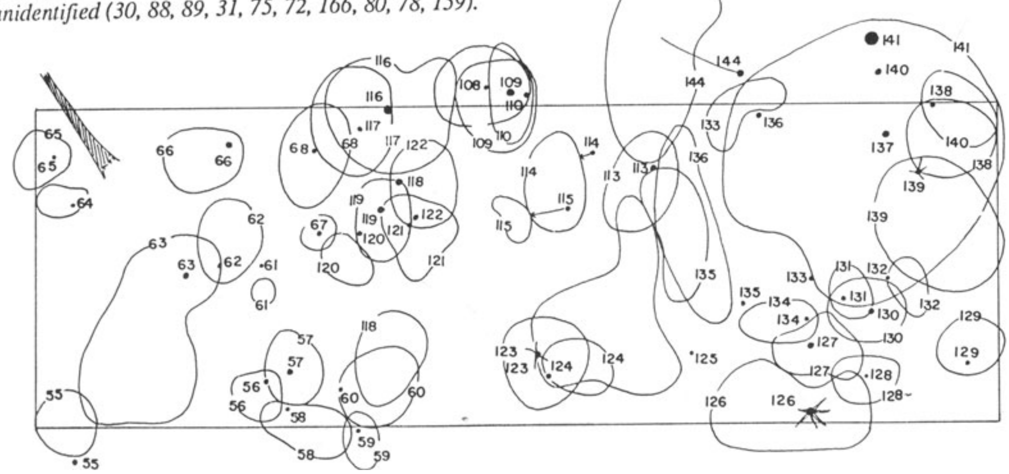


Fig. 39. Peat swamp forest on deep peat layer (>5 m). Lake Pulau Besar, Bengkalis mainland, Riau.

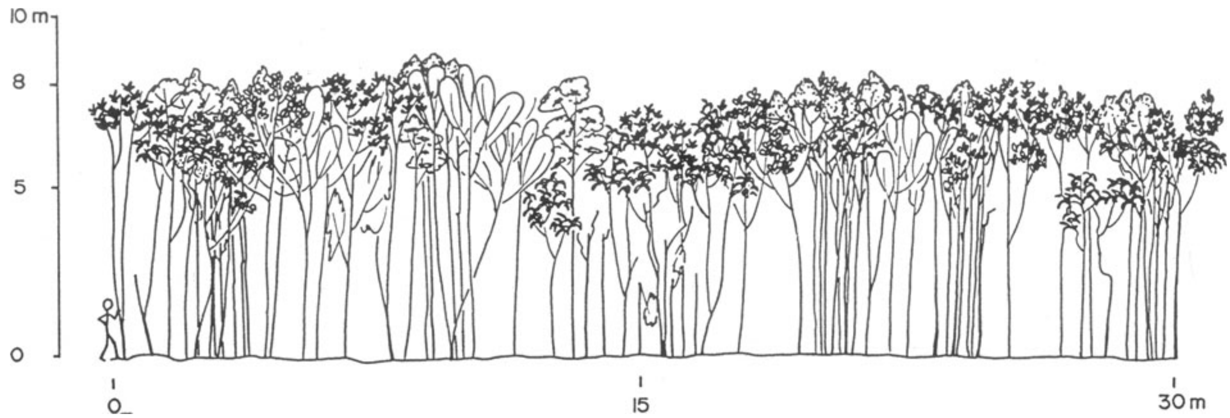


Fig. 40. "Pole" forest, low peat swamp forest dominated by *Callophyllum sundaicum* and *Shorea teijsmanniana*, Lake Pulaubesar, Bengkalis mainland, Riau.

which was obviously getting worse. The Ministry of Forests modified the forestry system in 1989 (TPI became TPTI, with T for 'planting'). An important amendment was added to the previous 1972 decree involving regeneration and replanting aspects under the responsibility of the forestry license holder.

The industrial deforestation issue is compounded by clearing due to local or migrant populations estimated at 0.5 to 2 ha/year /family. After two or three years of upland rice farming, the land is generally planted with *Hevea*. The young saplings are left to compete with natural regeneration and the plot is only cleaned according to requirements, or whims of the market. One family can thus possess from 5 to 20 ha of 'jungle rubber garden'[3].

The physical environment

Physiography, geomorphology and geology. To the east, plains and peneplains extend lengthwise along a strip approximately 1000 kilometers long and 100 kilometers wide running from the South of the island to the river Barumun at the borderline between Riau province and North Sumatra, which is delimited by the Padanglawas plain. Average altitude varies between 50 and 100 meters and the region's physiography is flat to undulating with slopes ranging from 2 to 8% for drops of 5 to 30 m. Geomorphologists distinguish three facies in this zone: fluviatile terraces, alluvial plains subject to flooding, and the higher lands which are constantly drained. The eastern limit approximately matches the 50 m contour, an altitude at which the large rivers start forming meanders and deposit great quantities of sediment.

Before one reaches the eastern hills, a piedmont zone stands out as a strip about 40 kilometers wide (sometimes much narrower) separating the mountain range from the eastern peneplains. The southern end of the strip meets the sea. According to Scholz (1983), the surface area occupied by the piedmonts (altitudes ranging from 100 to 200 m) represents 14% of Sumatra, i.e. approximately 64 000 km^2. The relief is undulating to hilly, crisscrossed by river tributaries and valleys for which a twin-terrace pattern is often observed.

The geology is that of vast tertiary deposition basins mainly formed in sedimentary rock or acid tuff, sometimes covered by more recent deposits in areas corresponding to the present valleys, a folded to various degrees in the piedmont zone. These geological formations often consist of layers several kilometers thick and mainly include sandstones, calcareous sandstone and marls.

Dominant soil types

Acrisols. Acrisols *sensu stricto* (sols ferrugineux désaturés – Ultisols) are rare in the plains of Sumatra and the surface area they occupy has doubtlessly been exaggerated on the world soil map (FAO, op.cit.). The soil types which most resemble acrisols have mainly developed on acidic sedimentary rock or very acidic volcanic tuffs

[3]Shifting cultivation *sensu stricto* no longer exists in Sumatra; it has been replaced by slash and burn agriculture aiming at permanent or semi-permanent use of the land.

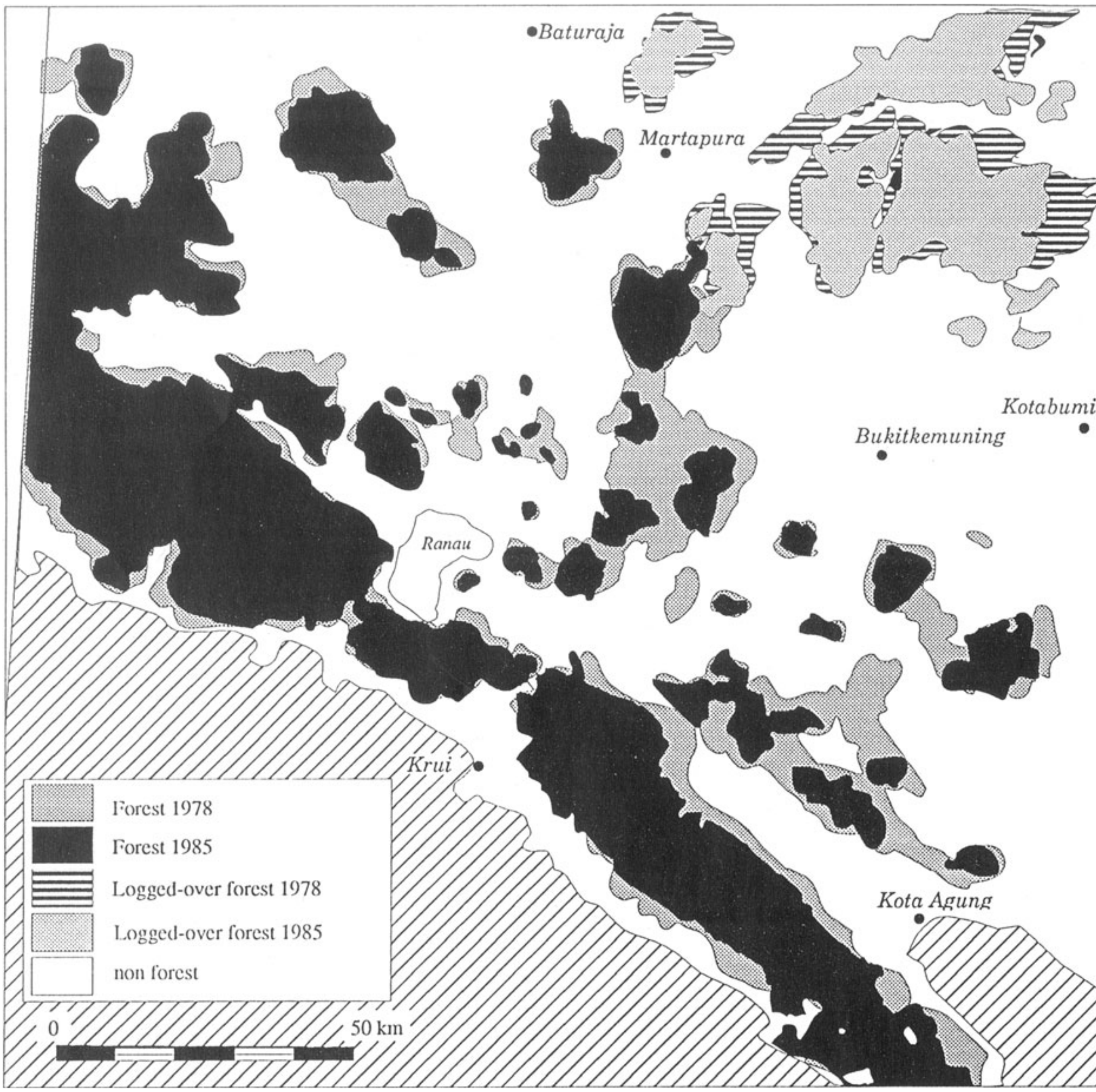


Fig. 41. Estimation of the deforestation rate between June 1978 and May 1985 in South West Sumatra using Landsat MSS data. 210,000 ha of forests have disappeared during that period, accounting for one of the highest rates on the island (1.6% per year).

in the Lampung region (Buurman & Dai 1976) and in the North-west section of Riau province. They are located in regions with a dryer climate, where natural forest has been cleared or where shifting cultivation has been practised for a long time. These soils are acid and marginally fertile, and the existing vegetation most often consists of vast zones of anthropogenic *Imperata cylindrica* savanna.

The examples we provide are profiles taken under shrub or grassland (Fig. 42). These soils are very porous at the surface, have typically a very small amount of litter and a 2 to 30 cm A horizon which is generally dark grey-brown with a granular structure and sandy-loamy texture. The C/N ratio varies from 10 to 15 and the cation exchange capacity from 15 to 25 meq/100 g of clay. The alluvial horizon is grey-brown or brown, sandy-clayey-loamy, and gradually changes into a B horizon which is brown-yellow, brown-red or

Table 10. Indicator species for deep peat layer.

Pandanaceae	Dipterocarpaceae
Pandanus atrocarpus	*Anisoptera marginata*
Clusiaceae	*S. platycarpa*
Calophyllum sundaicum	*S. teijsmanniana*
Garcinia cf. rostrata	*Shorea uliginosa*
Sapotaceae	*Vatica teijsmanniana*
Palaquium burckii	Simaroubaceae
P. ridleyi	*Quassia borneensis*
Arecaceae	Bombacaceae
Cyrthostachys lakka	*Durio carinatus*
Tetrameristaceae	Ebenaceae
Tetramerista glabra	*Diospyros siamang*
Rhizophoraceae	Meliaceae
Combretocarpus rotundatus	*Aglaia ignea*
Anacardiaceae	Myristicaceae
Mangifera parvifolia	*Horsfieldia crassifolia*
Gluta aptera	Rubiaceae
G. wallichii	*Timonius flavescens*

red, clayey with a lumpy structure. This horizon is generally at a depth of 30 to 80 cm on flat topography and 30 to 120 cm on slopes. Clay content is maximum in the B horizon, CEC approximately 10 to 15 meq, and base saturation 10 to 20%. The pH is relatively constant throughout the profile (≈ 5.5).

Ferralsols (*sols ferralitiques désaturés, oxisols*). The soil types more frequently encountered in forest plots are oxisols (Fig. 43) on the acidic tuffs which cover most of the peneplain. The difficulties in classifying these soil types in Sumatra have been described by Buurman and Sukardi (1980).

The litter layer in the plots was mostly very thin and covered a humus horizon 2 to 3 cm thick. One sometimes observed litter fifteen centimeters deep from place to place. These thicker layers are related to dominance of certain species like *Dipterocarpus crinitus* or *D. lowii* whose leaves apparently decompose very slowly. The humus horizon is extremely acid in these instances (pH 3.8 to 4).

The physical properties of these soils are good and large roots reaching down to a depth of one meter are frequently observed. The A horizon, located at a depth of 2 to 8 (10) cm, contains superficial hair roots and its low organic content is a characteristic feature (C/N from 8 to 15). Clay content increases with depth (A-B located between 10 and 40 cm), at any rate until the center of the profile. Kaolinite *sensu stricto* accounts for at least 80% of the clay fraction and the low loam-over-clay ratio is characteristic. In the brown or yellow-brown B horizon, soil acidity remains relatively constant (pH between 4 and 5). The cation exchange capacity is very low at less than 15 meq/100 g of clay. Calcium is the main cation and the absorbing complex is very desaturated with an SiO_2/Al_2O_3 ratio less than 2. Lack of silica is even greater than for Acrisols, and there is free alumina in the profile. These soils rank amongst the least bountiful in chemicals and are extremely fragile once forest has been cleared (erosion on slopes, compacting by heavy vehicles, insolation and rapid loss of surface minerals).

Few changes with respect to the lower slopes are observed at the top of the low ridges, the only remarkable feature being the additional presence of disorganized kaolinites at the upper part of the profile.

On the west coast (Fig. 43a), Oxisols under forest cover are often relatively more fertile de-

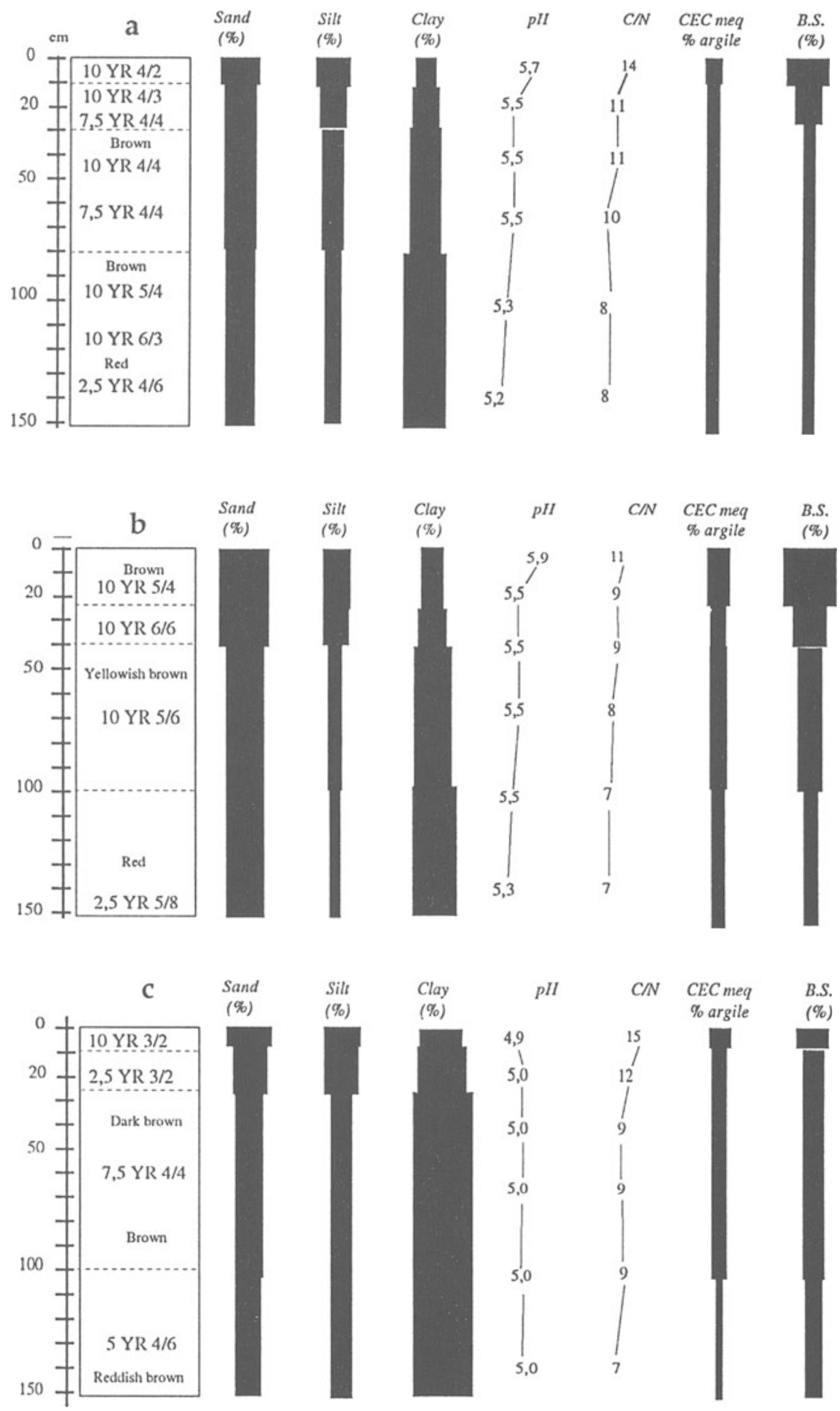


Fig. 42. Evolutionary trends of Acrisol properties under three major secondary vegetation types. a: under a secondary forest (North Riau province); b: under a shrubby environment (Lampung province); c: under an *Imperata clindrica* grass savanna (Lampung province).

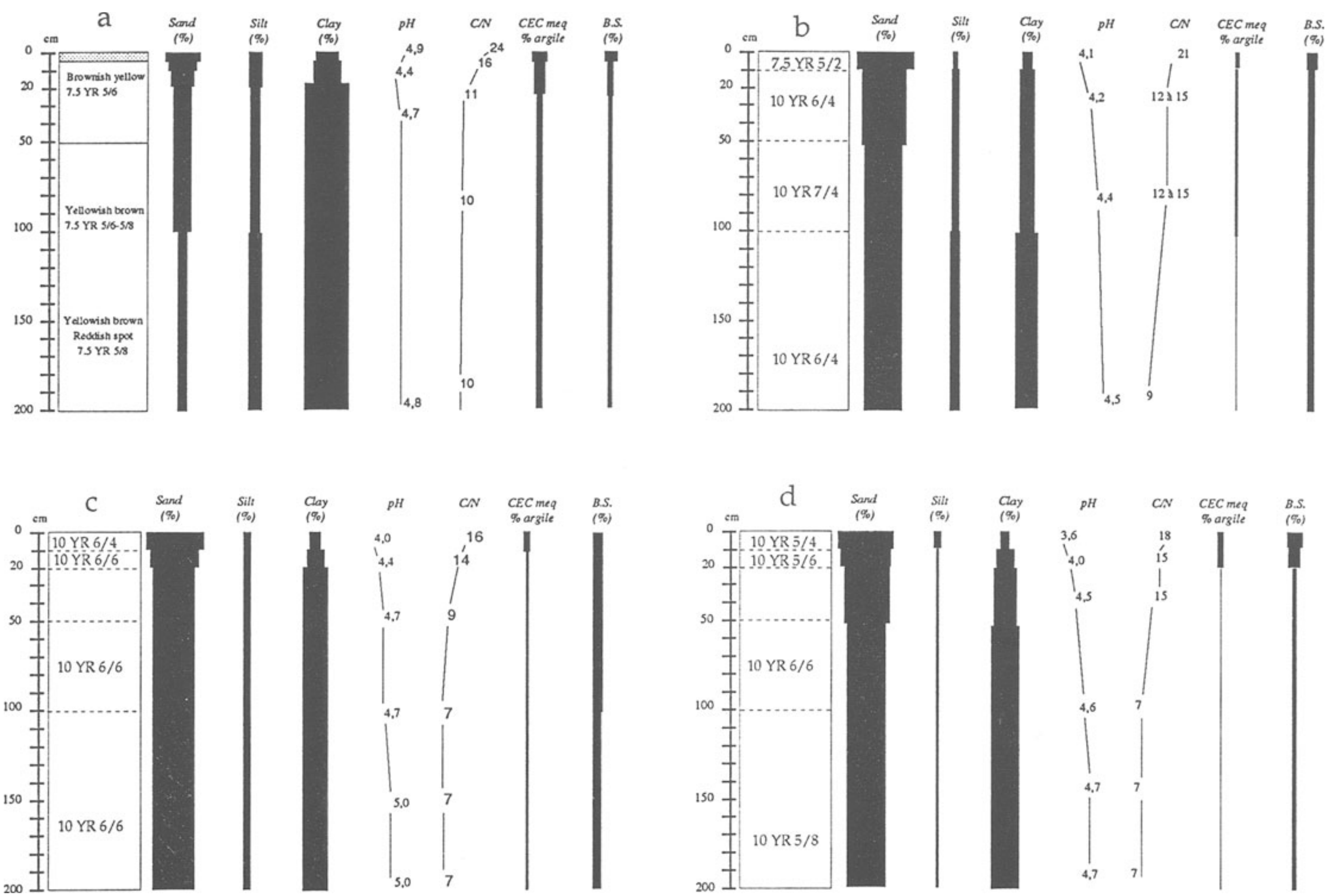


Fig. 43. General trends in Ferralsol under contrasted geological and topographical situations a: andesitic rocks; b: sedimentary rocks. They are slightly more fertile on andesitic materials. c and d: sedimentary rocks; c = lower slopes, d = upper slopes and ridges.

spite the very high rainfall. The substratum, frequently andesitic, could explain this apparent contradiction. Here the clays are metahalloysites at the base of the profile and a mixture of metahalloysites and disorganized kaolinites near the surface.

Bioclimate
Superhumid bioclimate ($2000 < P < 3000$ mm/year) is the most frequent type observed in these areas. Monthly mean rainfall can drop below 60 mm for one month at most, and the yearly average of rainy days varies from 120 to 150. The whole of the eastern edge of the peneplain, especially the South-east, has been known to undergo dry seasons which, although not yearly occurrences, can be fairly severe (≤ 60 mm for up 4 months). The dry season intensity gradient declines from Jambi to Lampung (Fig. 44).

On the other hand, the eastern piedmonts and even the entire west coast always receive over 3000 mm of rain each year. The average number of rainy days a year varied from 180 to 220, and the least humid season is very short (Fig. 45). The distribution of these superhumid bioclimates should draw the attention of forestry or development agencies in charge of planning for these regions. Formidable cloudbursts could be catastrophic once the forest, which regulates surface water and stabilizes the soil, is cut down. While rainfall in the east rarely exceeds 4000 mm, this is often the case on the west coast.

Primary formations

Physiognomy and structure

The dense evergreen rain forests of Sumatra's lowlands correspond to the 'Tropical rain forest' described by Richards (1952) or Whitmore (1975). The life form spectrum (in the sense of Raunkiaer 1937) typically shows dominance of phanerophytes, big lianas are fairly common, epiphytes occasional to frequent, and the bryophytes often abundant. Undergrowth is generally dense although herbaceous ground vegetation is sparse. Frequent buttresses, cauliflory or ramiflory and a majority of entire mesophylous leaves best characterise this forest type.

Horizontal structure. The horizontal structure of forest formations is traditionally represented by diameter class histograms. All our graphs show a classic 'L' distribution (Fig. 46), proof that our sample plots have not undergone major disturbances (Rollet 1974). Nevertheless, there are considerable variations in horizontal structure as one can easily observe by drawing up density maps (Fig. 47). The horizontal heterogeneity of the canopy is in itself remarkable. For diameters above 30 cm, grouping of large trees is often encountered and openings account for an average of 30 to 40% of the surface plot area (Fig. 48a). Below this value, the space occupied by openings is reduced to approximately 15%, if the 20 to 29 cm diameter class is introduced (Fig. 48b). The 25–30 cm diameter class represents the densest coverage, the canopy *sensu stricto*. Constants do, however, exist when mapping the average coverage of the various architectural classes in these forests (Fig. 49).

Vertical structure and representativeness of forest profiles. The height of the forest canopy varies from 30 to 40 m with emergent trees rising to heights of 45 to 55 (60) m. Mature parts of the forest may have up to four distinct structural ensembles whose foliage masses are respectively situated at the following heights: 5 to 10 (15), 15–20(25), 25–30(35), and 35–40(45) meters (Laumonier 1981, Torquebiau 1986, Limier 1988, Fig. 50). The shrub and the herbaceous 'layers' should be added to the general picture. This kind of stratification is only observed over limited surface areas, a fact easily verified by computer-assisted analysis of repetitive profiles drawn up every twenty meters (Fig. 51). Eco-units *sensu* Oldeman comprising all the various structural ensembles occupy little space. The heterogeneity of the vertical structure is also very high and poses the problem of profile diagram representativeness: ideally, profile locations should be chosen after mapping the forest mosaic, no matter how roughly.

Three-dimensional structure and forest function. Tropical forests are mosaics of various facies of different histories locked in a constant cycle of death and renewal by the process of gap formation due to tree fall events (Hallé *et al.*, 1978). Research on the forest dynamics has already provided a profusion of articles and books (eg. refer to Sutton et al. 1983, Pickett & White 1985,

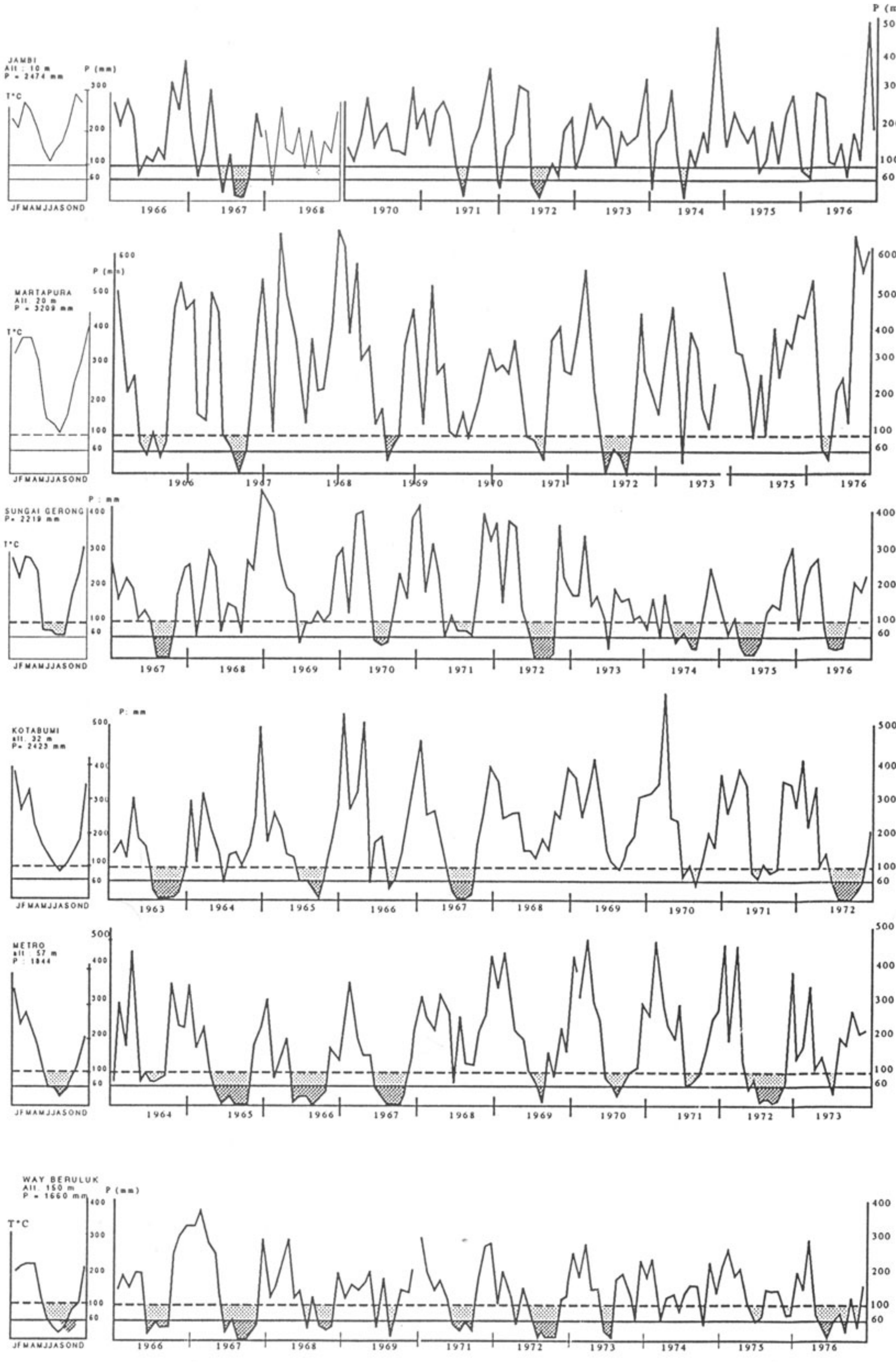


Fig. 44. Increasing trend of dry season intensity in the eastern lowlands, from Jambi to Lampung provinces.

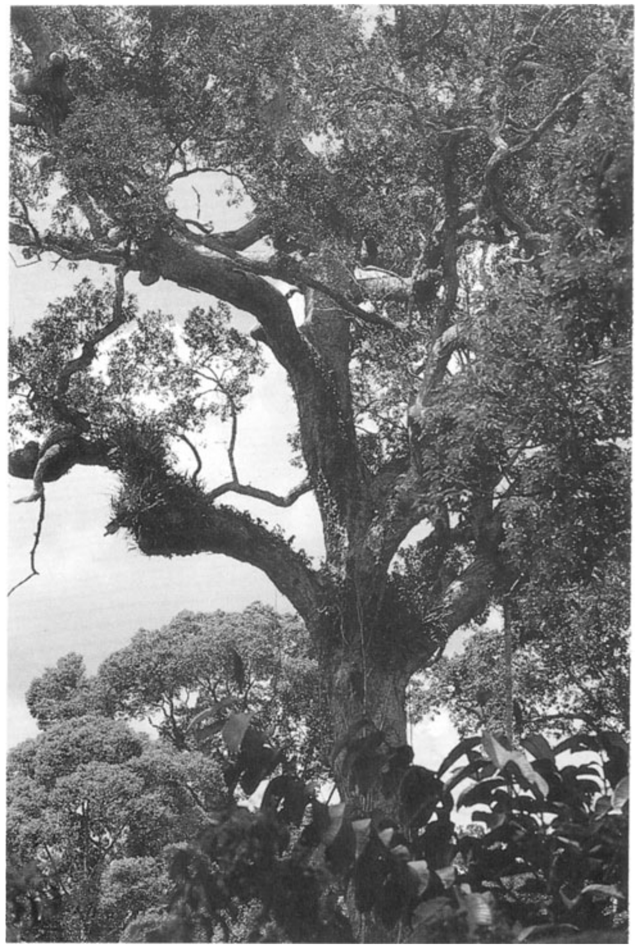


Photo 6. In the rain forests of the eastern Sumatra lowlands, the canopy varies from 30 to 40 m with emergent trees, such as *Anisoptera laevis*, rising to heights of 45 to 60 m.

Swaine et al. 1987). Dynamics of forest regeneration was observed and discussed for the first time by Aubréville (1938) in the forests of the Ivory Coast and by Watt (1947) for the temperate vegetation of the British Isles. Oldeman (1974) introduced architectural concepts to the subject and studied the spatial and temporal arrangement of the various phases. He referred to the 'sylvigenetic cycle' or the forest 'mosaic' (Hallé *et al.*, op.cit., Oldeman 1979, 1983, 1989, Torquebiau, 1984). Only tree fall gaps, the origin of sylvigenesis, have been intensively studied in the tropics (Whitmore 1978, Brokaw 1982 a and b, Denslow 1987, Hubbell & Foster 1986, Kapos et al. 1990, Brandani et al. 1988), and in Sumatra by Huc and Djailany (1981), but the number of 'phases' ('eco-units' in Oldeman's sense 1983) leading to the ultimate stage of forest structure maturation remains a controversy. Whitmore (1975) describes three phases, Mutoji-a-Kazadi (1977) four, and Torquebiau (1984) distinguishes seven in a detailed study on representation of this mosaic for the Indonesian lowland forests. For the latter analysis, gaps account for approximately 4% of the forest's surface area, the dynamic pioneering phase 10%, static phase 84%, and senescent phase 2%. Depending on canopy height and the location of the first reiteration with respect to half-height, Torquebiau differentiates homeostatic eco-units of different history which represent respectively 2, 12.5 and 11.5% of the forest matrix (Fig. 52). This representation is

Photo 7. There is considerable variation in the horizontal structure of the lowland dipterocarp rain forests. Clusters of large trees are often encountered but openings in the upper canopy account for an average of 30 to 40% of the plot surface area (for trees with d.b.h. ⩾30 cm). A lot of light reaches the undergrowth which is rather dense in such a forest type. This forest is mainly composed of *Licuala* spp. and *Fordia* cf. *johorensis*. There has been some cutting in this plot for phytomass sampling.

practically an aerial view of the forest. In the present study, the author also intended to study the variations under the canopy which should contribute to enhance forest mosaic representation and understanding. A detailed representation of forest mosaic is of importance also for the design of sampling strategy for subsequent measurement of ecological parameters.

Trial classification of mean volumes occupied by the trees was performed on 4, 5, and 6 classes. For a sampling elementary grid of 20 by 20 meters, the most satisfying classification was produced for 4 classes (higher F statistic for nearly all variables), which, taking into account the gap phase, will correspond to 5 'sylvigenetic' situations pertaining to the average volume and form of the trees. We provide a graphic illustration of it on 3 hectares which agrees fairly well with the dynamic status map of the plot (Fig. 53). The ecological interpretation of these results on the spot was complex and compared with Torquebiau's method they did not provide more information on possible distribution of any more elusive eco-units under the canopy.

In combination with the crown projection map, schematic profile diagrams showing contiguous 'slices' of forest were also used to analyze the mosaic in detail as well as the relief of the canopy in relationship to ground topography.

The epigeal (above ground) phytomass is another parameter which is closely linked to spatial structure. In eastern lowland forests it varies between (300) 320 and 400 (450) tons of dry matter per hectare, according to our evaluations based on formulae developed for the lowland forest in Borneo (Yamakura et al. 1986), and calculated for surface areas varying from 2 to 6 ha for trees and lianas with a diameter ⩾ 10cm. Undergrowth samples taken at Jambi provide a further estimate of 15 to 20 ton/ha for individuals with a diameter ranging from 3 to 10 cm. At Pasoh in Malaysia, Kato et al. (1978) and Kira (1978) estimated the root system to represent 10% of total epigeal phytomass which will mean a global estimate of 350 to 450 ton/ha for lowland forests of east Sumatra. The large variations recorded when dealing with sample plots which are too small (variations range from 280 to 400 tons per hectare) are, of course, dependent on the sylvigenesis of the forest as well as on the faculty

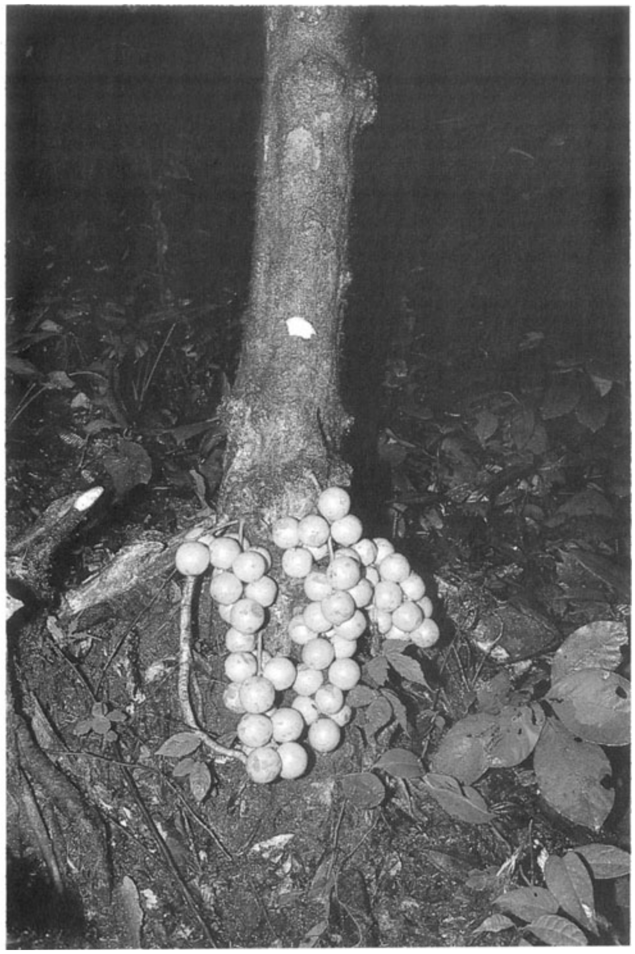


Photo 8. Cauliflory is a common feature of lowland as well as hill forest types: *Baccaurea sumatrana* (Euphorbiaceae), Muarasako, Tapan hill forest, Kerinci.

of dispersion, the competing power and the vigor of the various species. The composition and the density of the undergrowth are also extremely variable, and the ecological determinism governing this aspect is not well understood. A map of epigeal phytomass was drawn up (Fig. 54) in order to design a sampling strategy for future ecological parameter measurements and to try to correlate it with reflectance data obtained by satellite. At an average of 30 to 40 kg/m^2 (extremes being 0 to 80 kg/m^2), epigeal phytomass varies for instance from 2640 to 30 625 kg/400 m^2 for one pixel of a SPOT satellite image.

The functioning of these lowland forest types is unknown in Sumatra. No data whatsoever exists on litterfall, productivity or production, water or geochemical cycles. Few ecological parameters have been studied. Only solar radiation in relationship to forest architecture has been studied by Torquebiau and Walter (1987) and Torquebiau (1988). These authors calculated a leaf area index (LAI) ranging from 4 to 5 which is fairly low in comparison to the values normally attributed to tropical rain forests (7 to 8, Alexandre 1981, Whitmore 1984), but reflects well the high luminosity observed in the understorey in these forest. Research on the correlation between this index and forest mosaic would be worthwhile.

Work on regeneration, autoecology and population dynamics are either non-existent or fragmented. An important aspect of population dynamics is mortality. During the 1986–1990

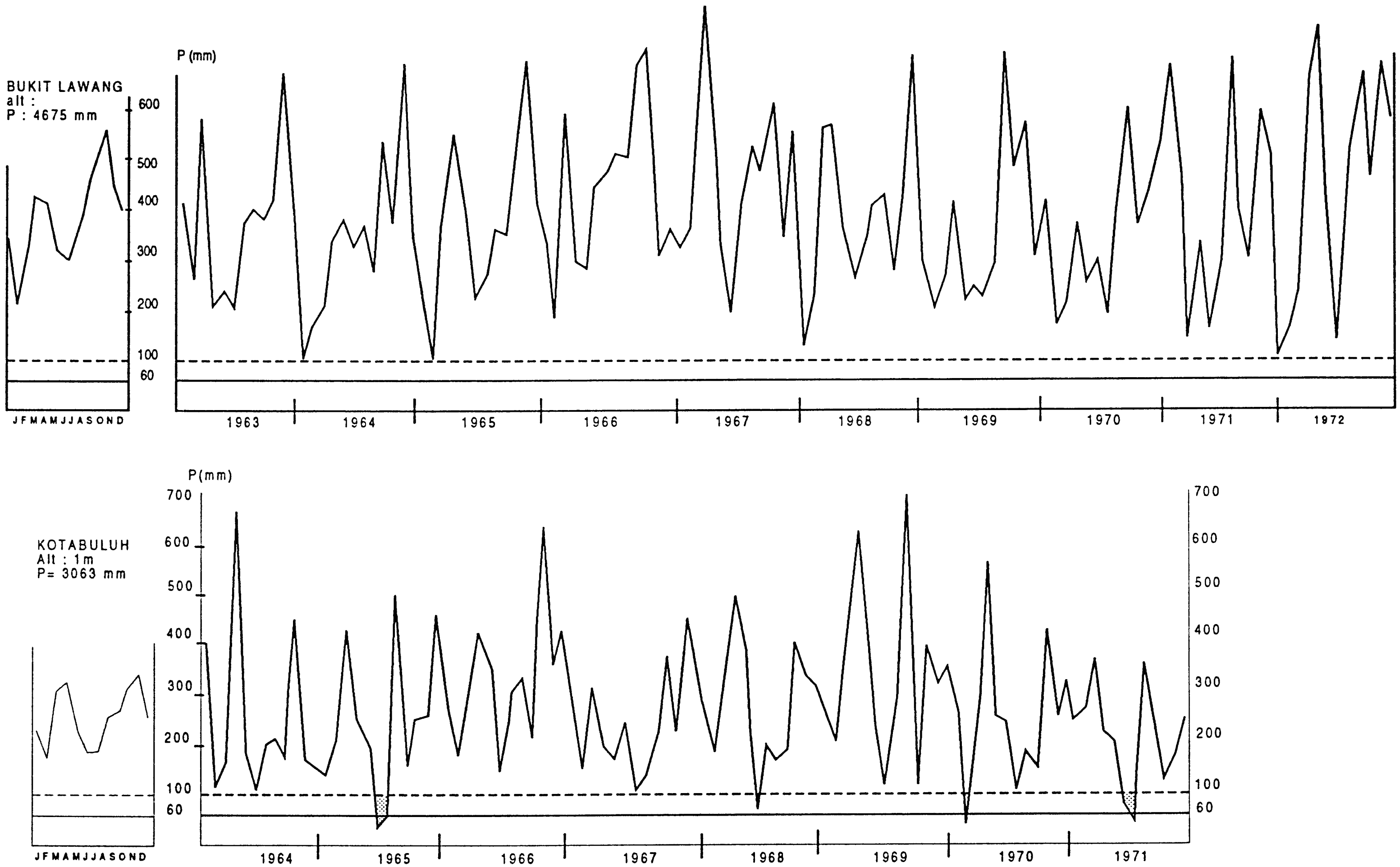


Fig. 45. Hyperhumid climatic regimes of the west coast and eastern piedmonts: the least humid season is very short and the rainfall rather evenly distributed from year to year.

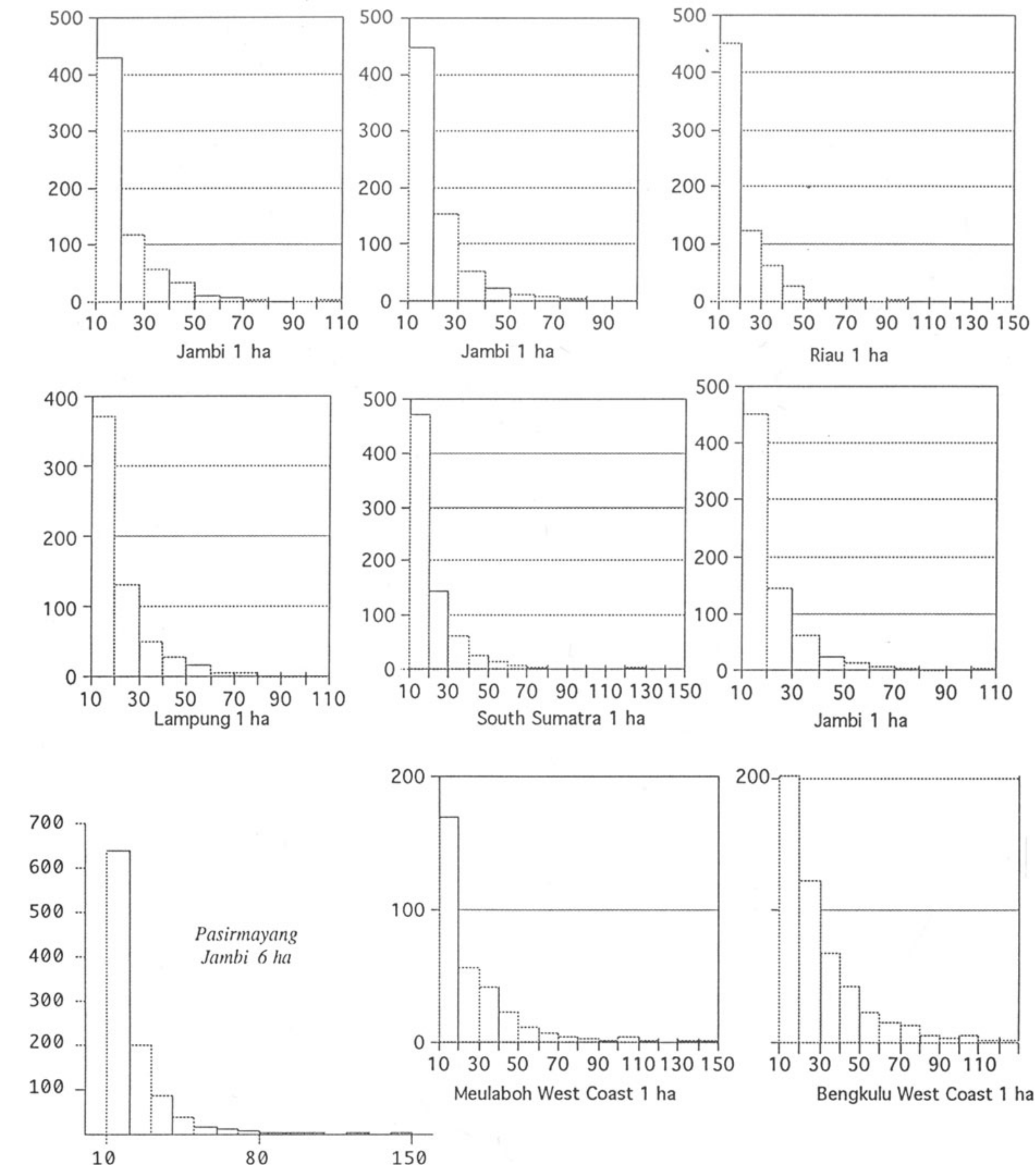


Fig. 46. Diameter class histogram for some lowland forest plots in Sumatra. Data are insufficient to compare forest types but an "L"-distribution certainly indicates that the plot is not disturbed.

period at Pasirmayang, an average of 4 to 5 trees with a diameter greater than 10 cm died per hectare per annum. Out of the total number of dead trees, 30% were trees of the past, 25% trees of the present, and 45% trees of the future which either died as they stood or were damaged by treefalls. It should be noted that during the same period of time and for the same surface area, an average of 5 to 6 trees a year enter the 10–19 cm diameter class. The global balance for this forest

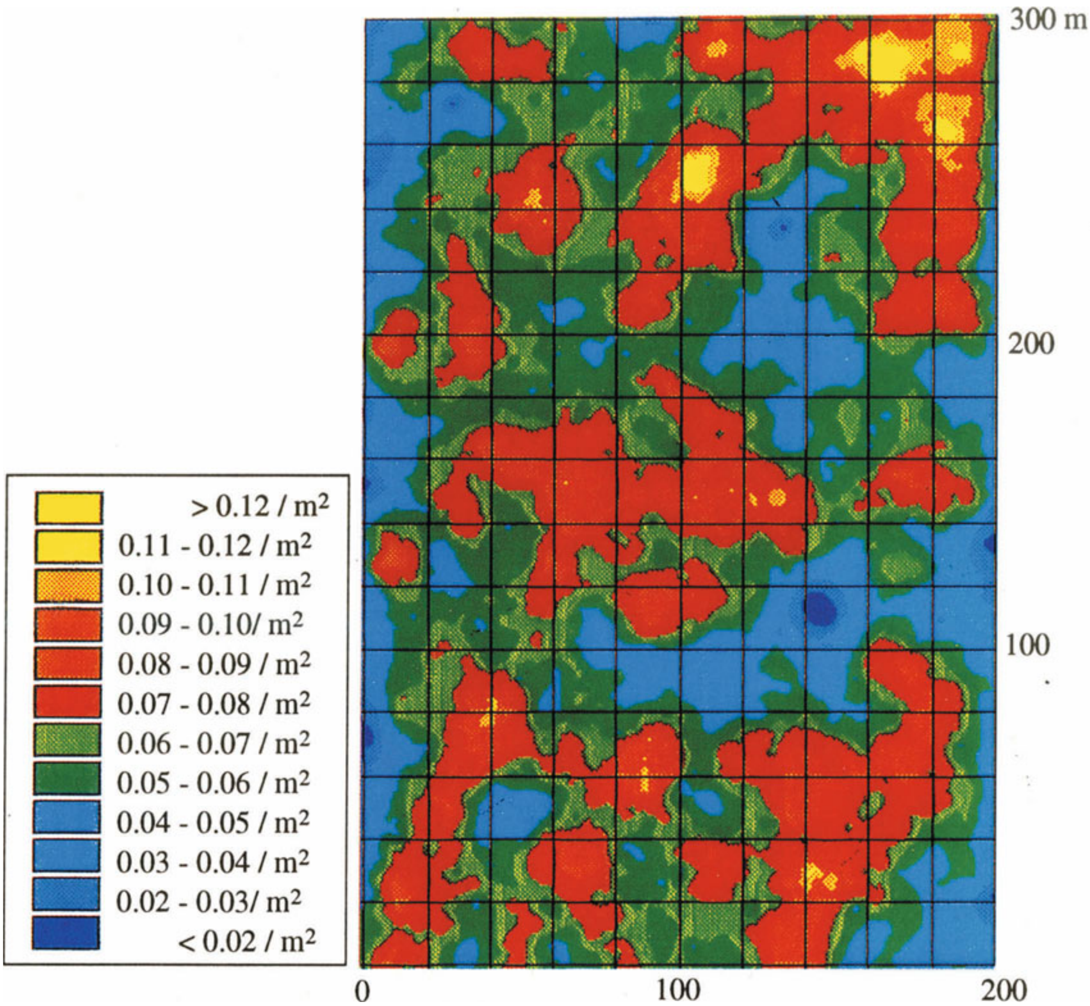


Fig. 47. Horizontal structure heterogeneity: tree density mapping in a lowland rain forest in Pasirmayang, Jambi.

is therefore positive. We could apply Hartshorn's (1978) formula based on this hypothesis to calculate a turn-over from chablis until mature forest. Huc and Djailany (1981) give values of 120 years for the sylvigenetic cycle.

Our first growth measurements for a 4-year period indicate that for canopy trees (with a diameter grater than 30 cm), mean growth is 3 mm/year with maxima of 8 mm/year for *Shorea macroptera*, *S. lumutensis* and *Dipterocarpus crinitus*. Dipterocarps often show the highest growth rate (5 to 8 mm/year). Growth rates for smaller trees are far more variable: between 1 and 5 mm / year on average with a maximum of 14.5 mm/year for a *Shorea acuminata* in a canopy opening. Growth rate was zero for a fair number of individuals which did not grow at all during the four years. The values obtained for a few of the most abundant species are given in Table 11. They agree with the results reported by Manokaran and Kochummen (1987) on the Malaysian peninsula.

Floristics

Richness and diversity. Lowland forests of insular South-East Asia are known as 'Mixed dipterocarp rain forests' after the dominance by this family. The importance given to dipterocarp family varies depending on the classification criteria adopted by the various authors, the size limits of individuals being, of course, a crucial factor. In most cases, dominance (and sometimes abundance) is determined in relation to commercial species or relatively to canopy or emergent species only (Sy-

Crown planimetry (m2) for tree diameter ≥ 30 cm			Relative cover: % total surf.	Relative cover: % cover surf.
Trees of the Present				
	Total	**12502**	63	105
Trees of the Future		703	4	6
Trees of the Past		4365	22	37
	Total	**17570**	88	148
Plot surface		20000	100	
Gaps		8138	41	
Covered surface		11862		100
Crown overlapping on		5708		48

Crown planimetry (m2) for diameter ≥ 10 cm			Relative cover: % total surf.	Relative cover: % cover surf.
Trees of the Present				
Structural ensemble IV	1379		28	33
Structural ensemble III	2205		44	53
Structural ensemble II	1448		29	35
Structural ensemble I	142		3	3
	Total	**5174**	103	124
Trees of the Future		2877	58	69
Trees of the Past		157	3	4
	Total	**8208**	164	197
Plot surface		5000	100	
Gaps		836	17	
Covered surface		4164		100
Crown overlapping on		4044		97

Dominance for trees of the present P			Dominance for trees fo the future F		
DIPT	*Dipterocarpus*	*crinitus*	DIPT	*Shorea*	*macroptera*
DIPT	*Shorea*	*macroptera*	CELA	*Kokoona*	*reflexa*
OLAC	*Scorodocarpus*	*borneensis*	EUPH	*Pimelodendron*	*macrocarpum*
STER	*Scaphium*	*macropodum*	OLAC	*Ochanostachys*	*amentacea*
MYRT	*Eugenia*		DIPT	*Parashorea*	*lucida*
DIPT	*Shorea*	*acuminata*	EUPH	*Neoscortechinia*	*kingii*
OLAC	*Ochanostachys*	*amentacea*	MYRI	*Knema*	*scortechinii*
BURS	*Santiria*	*griffithii*	ANNO	*Monocarpia*	*marginalis*
BURS	*Santiria*	*laevigata*	MYRI	*Gymnacranthera*	*bancana*
LEGU	*Koompassia*	*malaccensis*	LEGU	*Archidendron*	*bubalinum*
SAPO	*Burckella*		FAGA	*Lithocarpus*	*cf. wallichianus*
ANAC	*Swintonia*		MYRIS	*Myristica*	*beccarii*
DIPT	*Shorea*	*cf. dasyphylla*	LINA	*Ixonanthes*	*icosandra*
MYRI	*Horsfieldia*	*superba*	DIPT	*Shorea*	*cf. dasyphylla*

Fig. 48. Mixed Dipterocarp forest, Mahato lowlands, Riau province. Floristic composition and coverage of the structural ensembles. *Dipterocarpus crinitus* and *Shorea macroptera* are co-dominant, but only the latter is well represented in the regeneration stock.

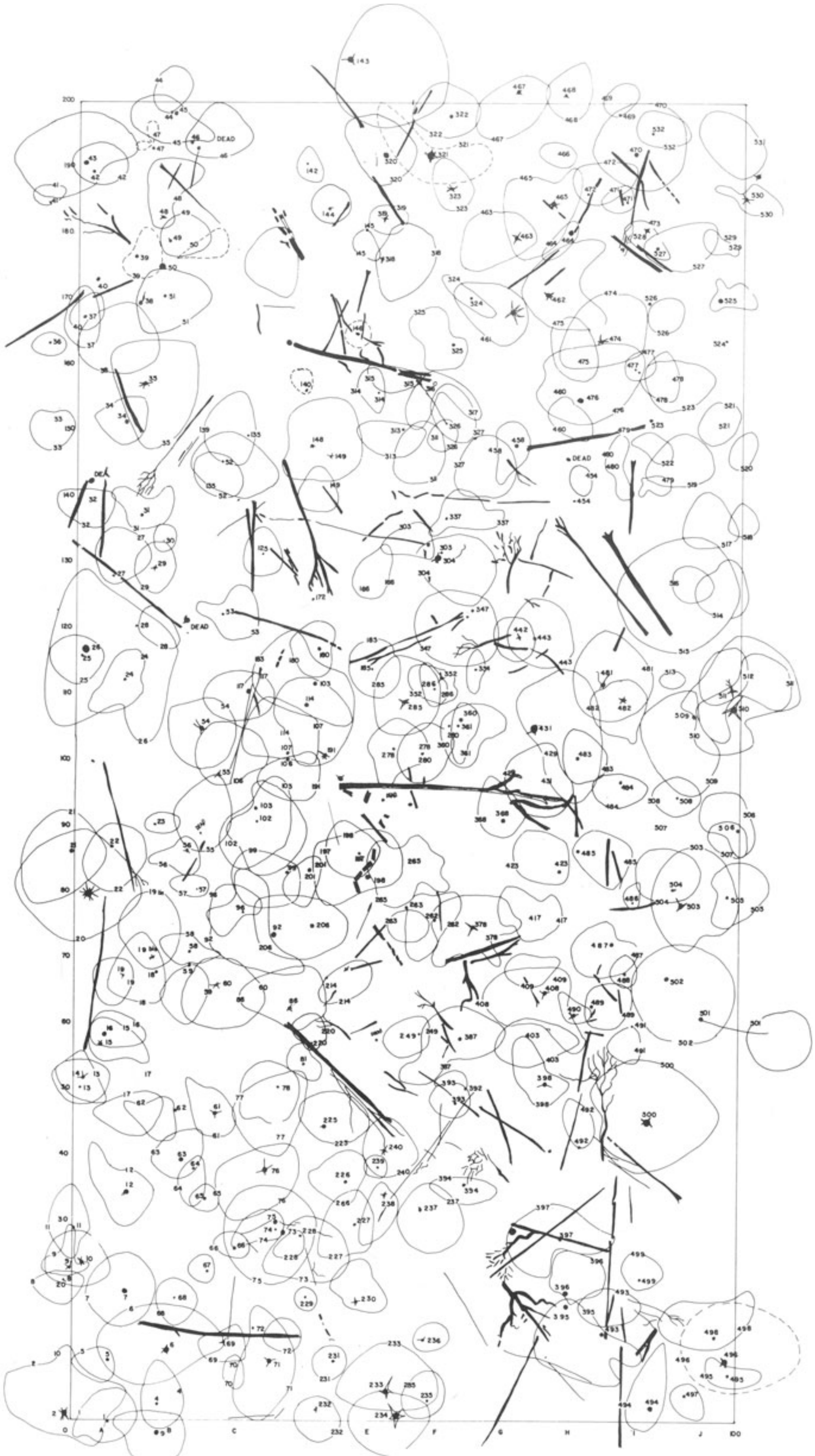


Fig. 48 Continued.

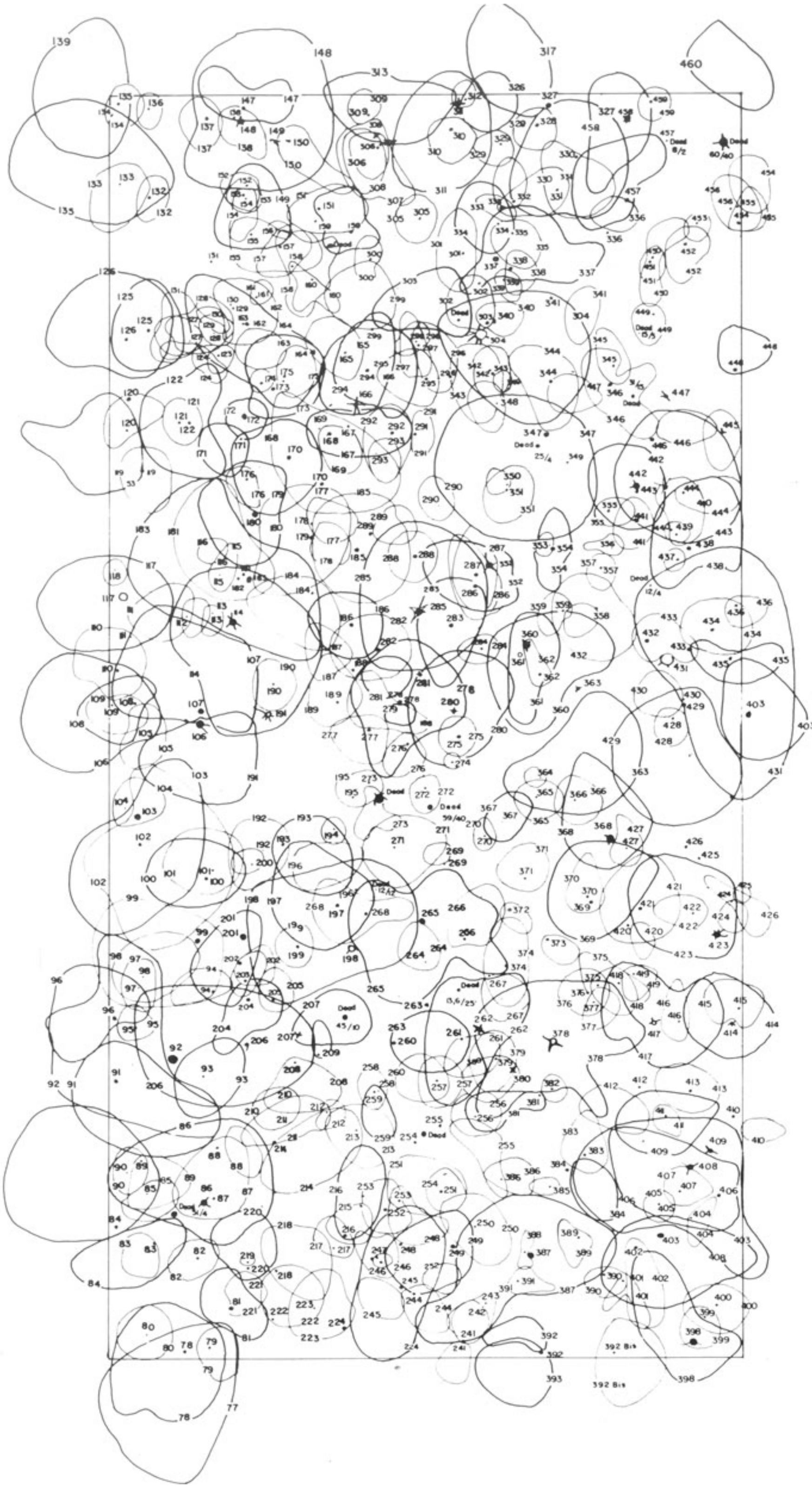


Fig. 48 Continued.

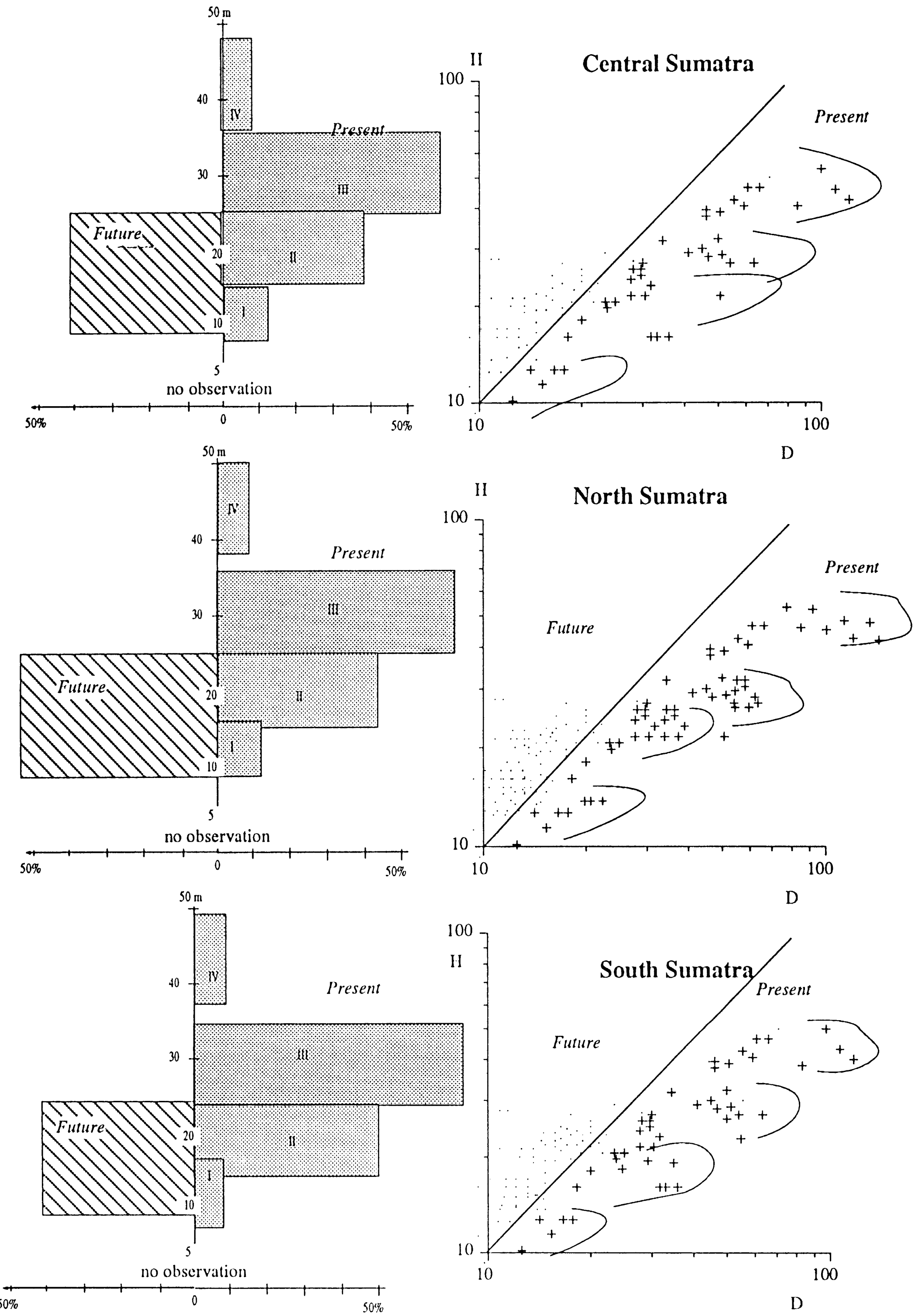


Fig. 49. Height-diameter relationship, stratification, number and cover of various architectural ensembles in the eastern lowland rain forest types (alt. <150 m). Structural constants do exist: four structural classes of the present with a main canopy layer between 25 and 35 m high and a general total cover of more than 100% of the total surface. Trees of the future represent always a further 40 to 55% of the plot area.

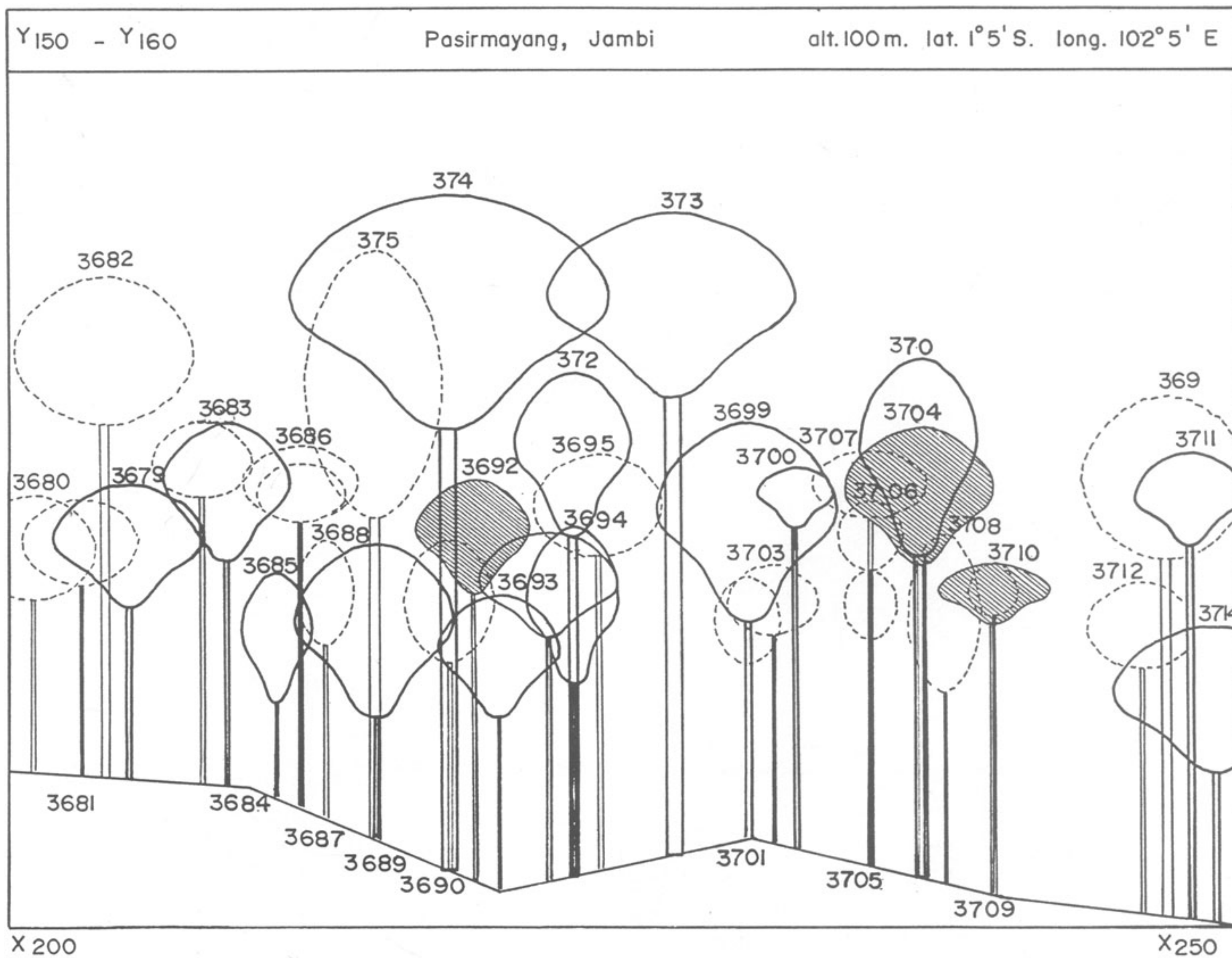


Fig. 50. A 50 × 20 m forest profile and topography diagram drawn by computer: (straight line = tree of the present; dotted line = tree of the future; hatched line = tree of the past). It allows a quick analysis of the architecture of the forest at any spot and in any direction within large permanent plots. In the example shown, "stratification" is only visible in the middle of the diagram, the rest being much more into a dynamic stage.

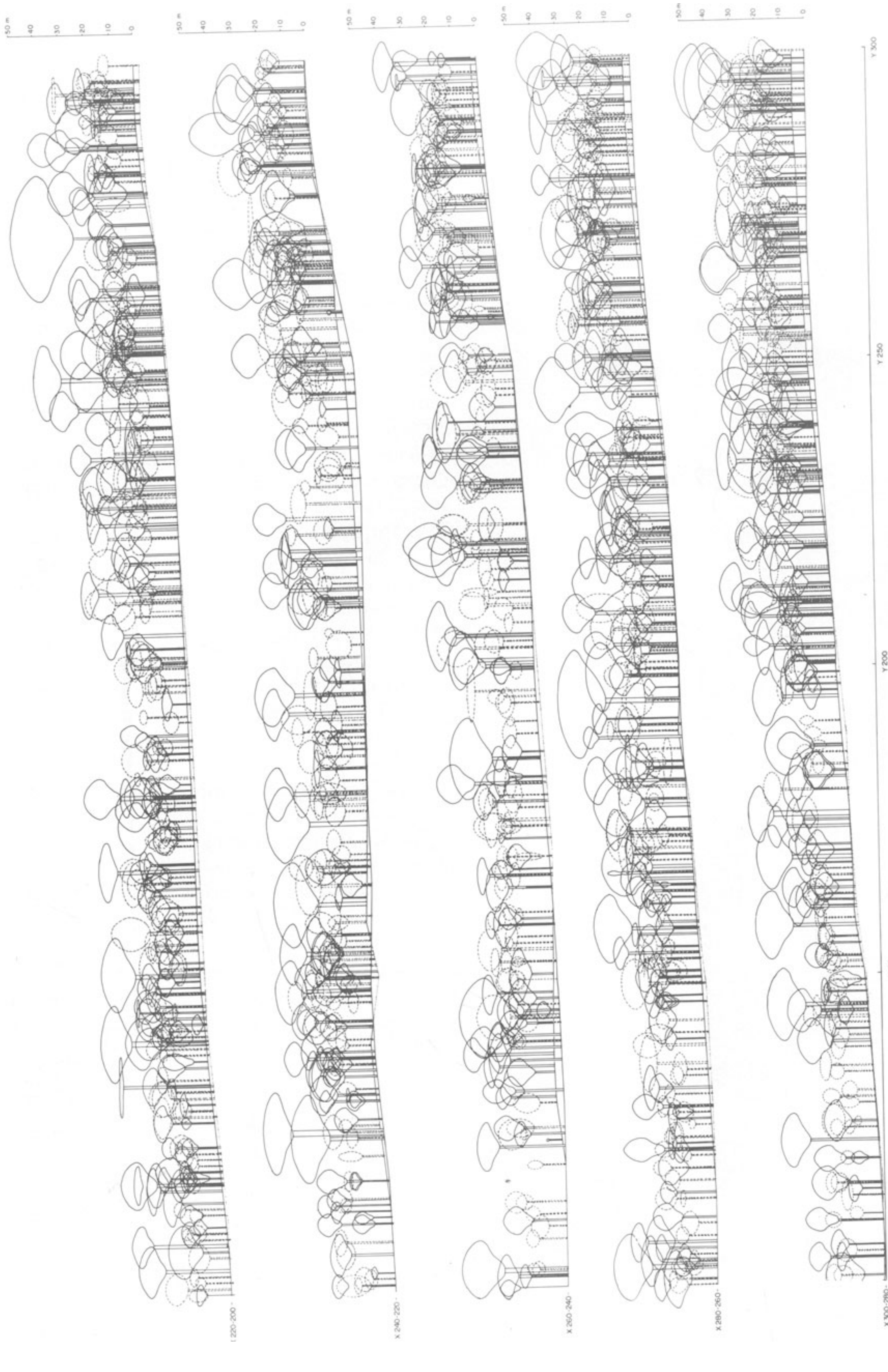


Fig. 51. Vertical structure heterogeneity: consecutive parallel transects in a lowland dipterocarp forest, Jambi.

mington 1943: 30% abundance and 55% wood volume).

For example, by considering only trees with diameters greater or equal to 50 cm (logging lower limit) will give a value of 50% for the abundance and 60% for the basal area dominance for the dipterocarps over a 10 hectare sampling plot in the eastern Sumatra lowlands. This corresponds with the figures given by Ashton (1964) for Brunei.

For diameters equal or greater than 30 cm, which includes the near majority of canopy trees, these figures become respectively 25 and 40% for the plot mentioned above. The lowest degree of dipterocarps' representativeness measured during our inventories stands at 20% for individuals and 30% for basal area.

When classes of smaller diameter are introduced into the calculations, different figures are still obtained, such as 9.5% for abundance and 25% for dominance (diameters greater or equal to 10 cm over 6 ha). As far as abundance and dominance are concerned, four families generally stand out in the lowlands: Dipterocarpaceae, Myrtaceae, Burseraceae and Euphorbiaceae. These latter account often for the majority of individuals but always account for a small amount of basal area (Table 12).

Strictly speaking, there are no dominant species, the floristic composition is extremèly diversified and it is difficult to apply any of the methods used to analyze temperate vegetation.

The significance of abundance and dominance measurements by species in these forest types, whether absolute or relative, is debatable given that the most abundant species over 6 hectares only represents 2% of the total area and the most 'dominant' 3%. These measurements are nevertheless constantly used by the Indonesian foresters and ecologists to classify species according to their 'Importance value' (Curtis & MacIntosh 1951), an index defined as being the sum of relative density, dominance and frequency. This index, whose ecological significance has often been criticized in temperate regions (Mueller-Dombois & Ellenberg 1974; Greig-Smith 1983),

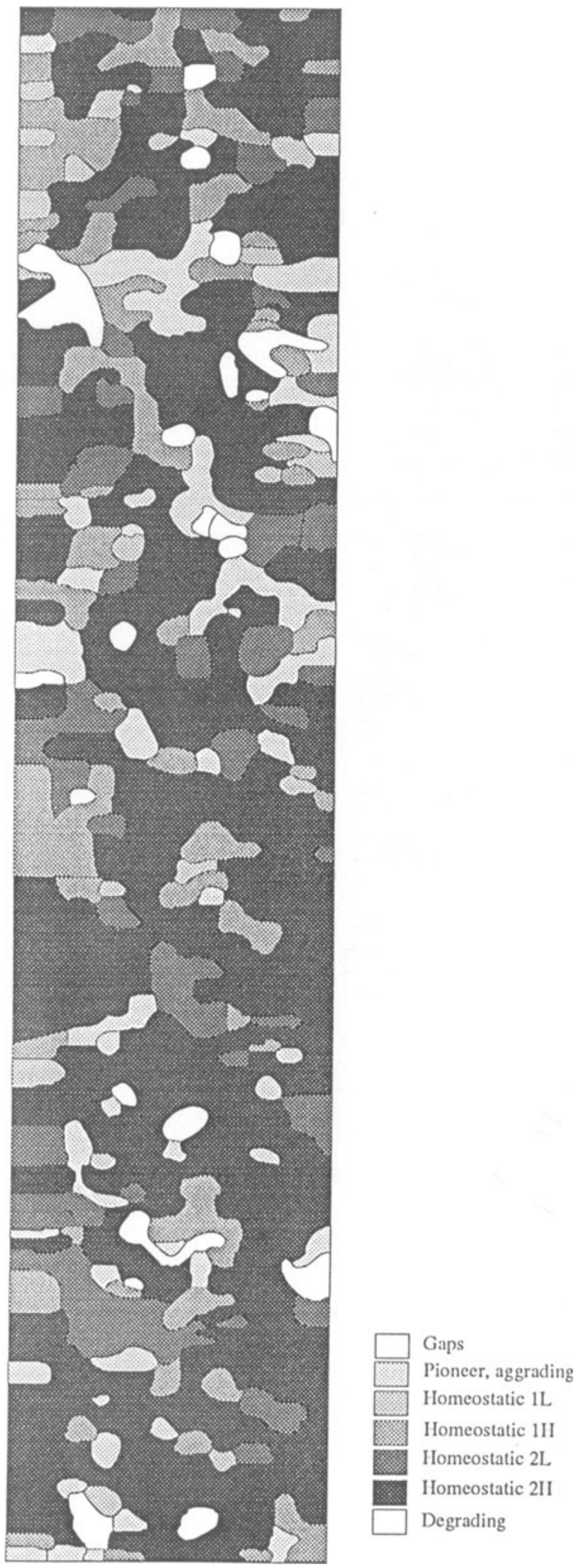


Fig. 52. Mosaic of sylvatic units in a lowland rain forest in Pasirmayang, Jambi (after Torquebiau, 1986). The canopy static phases cover 84% of the total area, and are almost exclusively represented by the "Homeostatic 2H" stage.

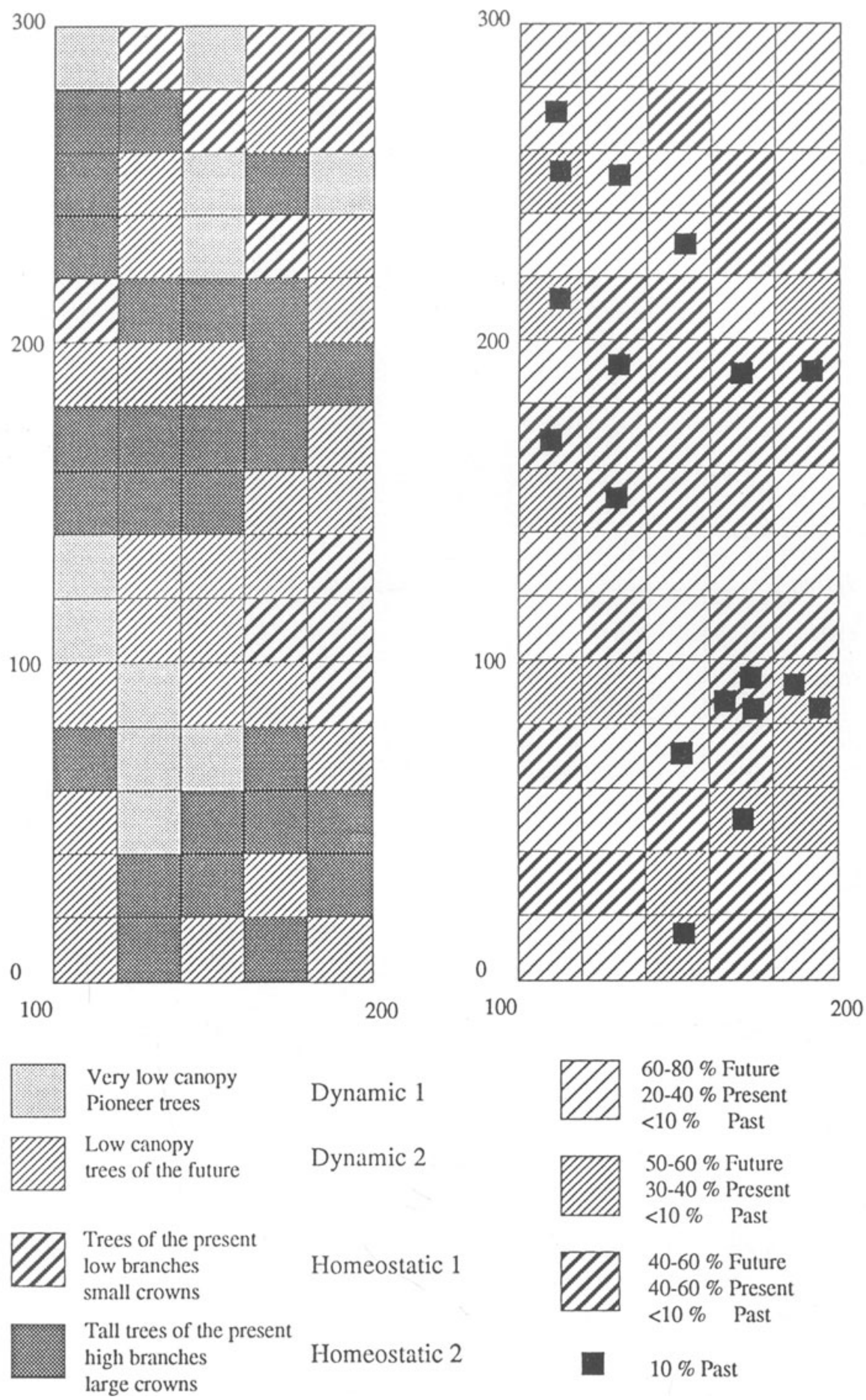


Fig. 53. Comparison between mean volume occupied by trees and the map of the dynamic status for a 20 × 20 m plot grid in a lowland dipterocarp rain forest, Pasirmayang, Jambi.

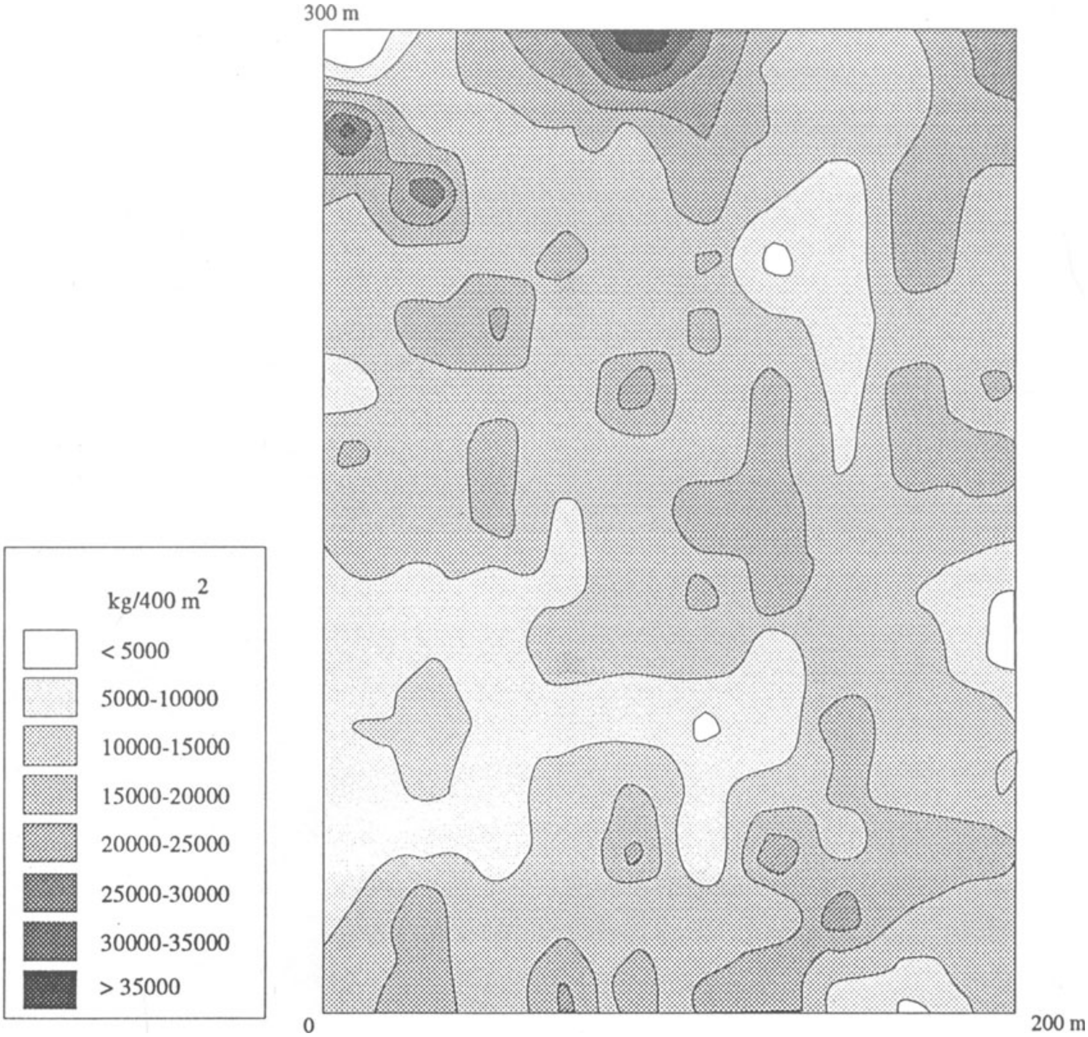


Fig. 54. Map of the above-ground phytomass at SPOT XS pixel resolution (1 pixel = 400 m^2); lowland dipterocarp forest, 6 ha, Pasirmayang, Jambi.

is fallacious in tropical rain forests where many species show aggregational distribution. Its widespread application in these regions is not justified and leads to an unsound floristic classification of forest types. Rather, each parameter should be considered separately in the analysis of a given forest type.

Except for *Shorea macroptera*, the most 'abundant' species are generally those forming lower structural ensembles. These species are, according to all sampling carried out on the eastern plains (trees with a diameter $\geqslant$ 10 cm): *Gironniera hirta* (Ulmaceae), *Neoscortechinia kingii* (Euphorbiaceae), *Palaquium oxleyanum* (Sapotaceae), *Monocarpia marginalis* (Annonaceae), *Ixonanthes icosandra* (Linaceae), and *Gymnacranthera bancana* (Myristicaceae).

As for the dominance calculated after estimating the ground projection area of the crown of these same species, the Dipterocarps come first with the most dominant species in central Sumatra being *Shorea lumutensis*, *S. acuminata*, *S. macroptera*, an *Eugenia*, *Ixonanthes icosandra*, *Shorea parvifolia*, *Santiria griffithii* (Burseraceae), *Neoscortechinia kingii*, *Dipterocarpus crinitus* (Dipterocarpaceae), *Palaquium oxleyanum*.

In order to compare tree diversity of these lowland forests of the eastern plains, the author has tested several diversity indices such as the Simp-

Table 11. Mean annual growth (mm/year) for some abundant species in the lowland dipterocarp forest of Jambi, Central Sumatra.

maximum	species	mean
1.45	*Shorea acuminata*	0.47
1.26	*Shorea parvifolia*	0.40
0.68	*Shorea ovalis*	0.31
0.57	*Gymnacranthera bancana*	0.25
1.58	*Shorea macroptera*	0.24
0.45	*Shorea singkawang*	0.24
2.45	*Pimelodendron griffithianum*	0.24
0.86	*Polyalthia hypoleuca*	0.20
1.75	*Palaquium oxleyanum*	0.20
1.37	*Ixonanthes icosandra*	0.19
0.55	*Scaphium macropodum*	0.18
0.60	*Eugenia 5*	0.18
0.73	*Santiria griffithii*	0.17
0.40	*Parashorea lucida*	0.17
0.43	*Anisoptera laevis*	0.16
2.60	*Monocarpia marginalis*	0.14
0.28	*Shorea lumutensis*	0.13
1.00	*Neoscortechinia kingii*	0.11
0.50	*Gironniera hirta*	0.08

Table 12. Abundance and dominance of the ten most represented families in lowland dipterocarp forest in Sumatra (trees with diameter ⩾ 10 cm).

Relative abundance		Relative dominance (Crown suurface)		Relative dominance (Basal area)	
Euphorbiaceae	11%	Dipterocarpaceae	17%	Dipterocarpaceae	25%
Dipterocarpaceae	9%	Euphorbiaceae	9%	Myrtaceae	7%
Burseraceae	8%	Myrtaceae	8%	Burseraceae	7%
Myrtaceae	6%	Burseraceae	7%	Euphorbiaceae	6%
Annonaceae	6%	Leguminosae	6%	Leguminosae	6%
Sapotaceae	5%	Annonaceae	5%	Myristicaceae	4%
Myristicaceae	5%	Sapotaceae	4%	Annonaceae	4%
Leguminosae	4%	Guttiferae	4%	Sapotaceae	4%
Lauraceae	4%	Lauraceae	3%	Anacardiaceae	3%
Ulmaceae	3%	Myristicaceae	3%	Guttiferae	3%

Table 13. Diversity indices (Simpson, Ds; Shannon, H'; Equitability R) for various lowland forest localities in Sumatra (trees and lianas with ⩾ 10 cm).

locality	nbr of parc. 1/4 ha	Ds		H'		R	
		x	SD	x	SD	x	SD
Lampung	2	0,8900	0,033	4,703	0,060	0,805	0,005
South Sumatra	2	0,938	0,025	5,015	0,066	0,840	0,005
Jambi	24	0,992	0,001	5,307	0,042	0,890	0,005
Riau	8	0,973	0,013	5,141	0,046	0,860	0,005
West coast	2	0,925	0,030	4,995	0,060	0,835	0,005
West coast	2	0,898	0,045	4,724	0,060	0,810	0,005
Northwest coast	8	0,941	0,012	5,035	0,060	0,845	0,005

son diversity indice (D) which varies from 0.890 to 0.992, the Shannon entropy (H') and the equitability (R) ranging respectively from 4,703 to 5,307 and from 0,805 to 0,890 (Table 13). These various indices of diversity always have very similar high values, they are of very little use for differentiating between forest types. Generally, floristic input did help to differentiate between regions which are climatically and pedologically similar and to propose a division of the island on an eco-floristic basis, which could be further refined by more detailed studies at a later stage.

Obviously, this level of diversity poses problems of sampling representativeness. The area/species curve computed for the permanent plot we established in a lowland forest in Pasirmayang (Muarabungo, Jambi) levels off for a 5 to 6 ha sample (Fig. 55).

Height distribution of species. The upper structural ensembles ('high' canopy and emergent trees, leaf mass 35 to 45 m above the ground) are mainly dominated by dipterocarps, a few Fabaceae, above all Caesalpiniaceae (*Koompassia*) and Anacardiaceae (Table 14). *Dyera costulata*, *Fagraea gigantea*, *Heritiera sumatrana* and *Scaphium macropodum* are also frequently encountered at this height.

In the mid-level structural ensembles constituting a major part of the canopy 25 to 30 (35) m high, floristic diversity is maximum with the main dominant species being Burseraceae, Euphorbiaceae, Sapotaceae, Myristicaceae and Annonaceae (Table 15). Dipterocarps are more discreet at this level and a few palm trees such as *Oncosperma horridum* or *Livinstona kingiana* reach these heights.

Lower structural ensembles 15 to 20 (25) meters high, are occupied by Euphorbiaceae (*Antidesma coriaceum*, *Aporusa elmeri*, *A. lucida*, *Neoscortechinia kingii*, *Drypetes longifolia*, *D. kikir*), Mimosaceae (*Archidendron bubalinum*, *A. microcarpum*), Ulmaceae (*Gironniera hirta*, *G. nervosa*), Ebenaceae (*Diospyros buxifolia*, *D. rigida*), Rubiaceae (*Diplospora singularis*, *Timonius hydrangefolius*), Sapindaceae (*Nephelium cuspidatum*, *N. uncinatum*, *N. ramboutan-ake*), Polygalaceae (*Xanthophyllum ellipticum*, *X. elmeri*, *X. ngii*), and Burseraceae (*Santiria apiculata*, *Dacryodes rugosa*).

The diversity of the species of the Present trees decreases considerably below a height of 15 m. Amongst the arborescent and shrub species making up these lower structural groups (5–10(15)m), which are not young individuals belonging to the architectural ensembles mentioned above, we observe an extreme abundance and dominance of a Fabaceae (*Fordia* cf. *johorensis*), and to a lesser degree Euphorbiaceae (*Koilodepas glanduligerum*, *Baccaurea javanica*, *Croton oblongus*, *Aporusa frutescens*), Annonaceae (*Popowia hirta*) and Meliaceae (*Aglaia tomentosa*).

A further level can be distinguished below, at a height of 2–5 meters occupied by a stemless *Pandanus*, and by palms such as *Licuala ferruginea*, *L.* aff. *longipes*, and *Pinanga malaiana*. A few small-sized shrub species are also encountered like *Agrostistachys longifolia*, Euphorbiaceae often very abundant, *Gonocaryum gracile*, (Icacinaceae), *Rothmannia macrophylla*, *Psychotria robusta*, *P. rostrata* (Rubiaceae), and *Rinorea anguifera* (Violaceae). A small tree fern (*Cyathea moluccana*) often grows in the most humid sites along rivulets.

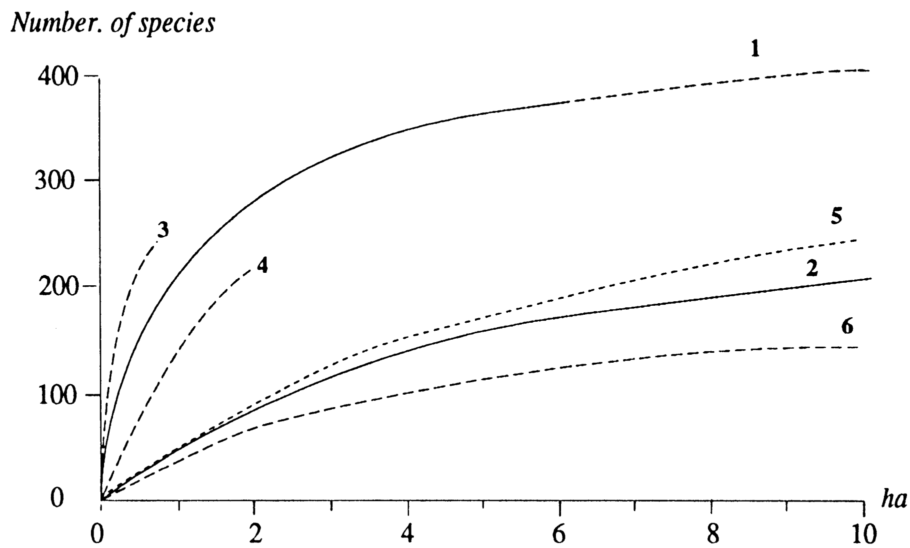


Fig. 55. Species area relationship for some lowland forests in Malesia and elsewhere. 1. Pasirmayang, Sumatra, $\phi \geq 10$ cm, this study; 2. Pasirmayang, Sumatra, $\phi \geq 30$ cm, this study; 3. Rengam, Malaya, Wyatt-Smith (1966), circ. $\geq$12 inch; 4. Andulau, Brunei, circ. $\geq$12 inch., Ashton (1964); 5. Jengka, Malaya, circ. $\geq$0.91 m, Ho et al. (1987); 6. Barro, Colorado, Costa Rica, $\phi \geq 20$ cm, Hubbell and Foster (1983).

Table 14. Species of the upper canopy (35–45 m) in the eastern lowland forests of Jambi, Central Suimatra.

ANACARDIACEAE
Mangifera rigida
Mangifera torquenda
Pentaspadon velutinus
ANNONACEAE
Polyalthia hypoleuca
APOCYNACEAE
Dyera costulata
DIPTEROCARPACEAE
Anisoptera costata
Anisoptera laevis
Anisoptera marginata
Anisoptera megistocarpa
Dipterocarpus crinitus
Dipterocarpus lowii
Hopea dryobalanoides
Parashorea lucida
Shorea acuminata
Shorea dasyphylla
Shorea hopeifolia
Shorea lumutensis
Shorea macroptera
Shorea ovalis
Shorea parvifolia
CAESALPINIACEAE
Dialium laurinum
Koompassia malaccensis
LOGANIACEAE
Fragraea gigantea
MELIACEAE
Dysoxylum acutangulum
MYRISTICACEAE
Myristica gigantea
STERCULIACEAE
Heritiera sumatrana
Scaphium macropodum

Table 15. Species of the upper canopy (35–45 m) in the eastern lowland forests of Jambi, Central Suimatra.

Burseraceae		Clusiaceae	
	Santiria conferta		*Calophyllum depressinervosum*
	S. rubiginosa		*C. pulcherrimum*
	S. tomentosa		*C. calaba*
	S. griffithii	Caesalpiniaceae	
	Dacryodes incurvata		*Dialium maingayi*
Euphorbiaceae		Myristicaceae	
	Aporusa nervosa		*Gymnacranthera bancana*
	Baccaurea costulata		*G. farquhariana*
	Blumeodendron tokbrai		*Horsfieldia pulcherrima*
	B. calophyllum		*H. triandra*
	Pimelodendron griffithianum	Polygalaceae	
	Ptychopyxis sp		*Xanthophyllum amoenum*
	Trigonopleura malayana		*X. rufum*
Annonaceae			*X. sulphureum*
	Cyathocalyx ramuliflorus		*X. vitellinum*
	Monocarpia marginalis	Sapindaceae	
	Polyalthia sumatrana		*Nephelium lappaceum*
	Xylopia ferruginea		*Xerospermum norhonianum*
	X. malayana	Olacaceae	
	Shorea gibbosa		*Scorodocarpus borneensis*
	S. johorensis		*Ochanostachys amentacea*
	Vatica stapfiana		*Strombosia ceylanica*
Sapotaceae		Celastraceae	
	Palaquium oxleyanum		*Kokoona reflexa*
	P. cryptocariifolium		*Lophopetalum beccarianum*
	Payena acuminata	Arecaceae	
	P. endertii		*Oncosperma horridum*
	Pouteria malaccensis		*Livingstonia kingiana*

On the ground, the most common plants are essentially Gesneriaceae (*Didymocarpus*), Myrsinaceae (*Labisia pumila*), Flagellariaceae (*Hanguana malayana*), and several varieties of ground Orchidaceae (*Cystorchis* cf. *saceosepala*), Cyperaceae (*Mapania cuspidata*) and ferns such as *Lindsaea doryphora*.

Lianas and climbing palms are abundant, mostly represented by rattans such as *Daemonorops geniculata*, *D. depressiuscula*, *Korthalsia rigida*, and *Calamus flabellatus* (the only species of economic value). Several other families are represented: Annonaceae, Apocynaceae, Connaraceae, Fabaceae, Moraceae and Rubiaceae whose main species are given in Table 16.

Floristic and structural variations north-south and east-west.

Generally, the physiognomy and the structure of these lowland forests is identical throughout the island (Laumonier 1981). The greatest structural variations we observed mainly involved forests at the extreme South-east end of the island which originally occupied the eastern part of the present day Lampung province. Today, these forests have practically disappeared. Here, the lower physiognomy of the forest matrix is accompanied by a greater number of individuals per hectare for the same number of structural ensembles, and therefore by a larger crown coverage (Fig. 56). There are also floristic differences. The canopy of these

Table 16. Most common climber species in Central Sumatra lowland forest.

Annonaceae
- Artabotrys gracilis
- A. suaveolens
- Fissistigma kentii
- Oxymitra biglandulosa
- O. obtusifolia

Apocynaceae
- Willughbeia firma
- W. tenuiflora

Connaraceae
- Agelaea macrophylla
- Rourea mimosoides

Convolvulaceae
- Erycibe ramiflora
- E. maingayi

Dilleniaceae
- Tetracera spp.

Hippocrateaceae
- Salacia macrophylla

Icacinaceae
- Sarcostigma paniculata

Leguminosae
- Phanera fulva
- Spatholobus sp.
- Millettia spp.

Liliaceae
- Smilax leucophylla

Linaceae
- Hugonia costata

Loganiaceae
- Strychnos spp.

Moraceae
- Ficus spp.

Rubiaceae
- Uncaria calophylla
- U. cordata
- U. elliptica

Vitaceae
- Ampelocissus sp.

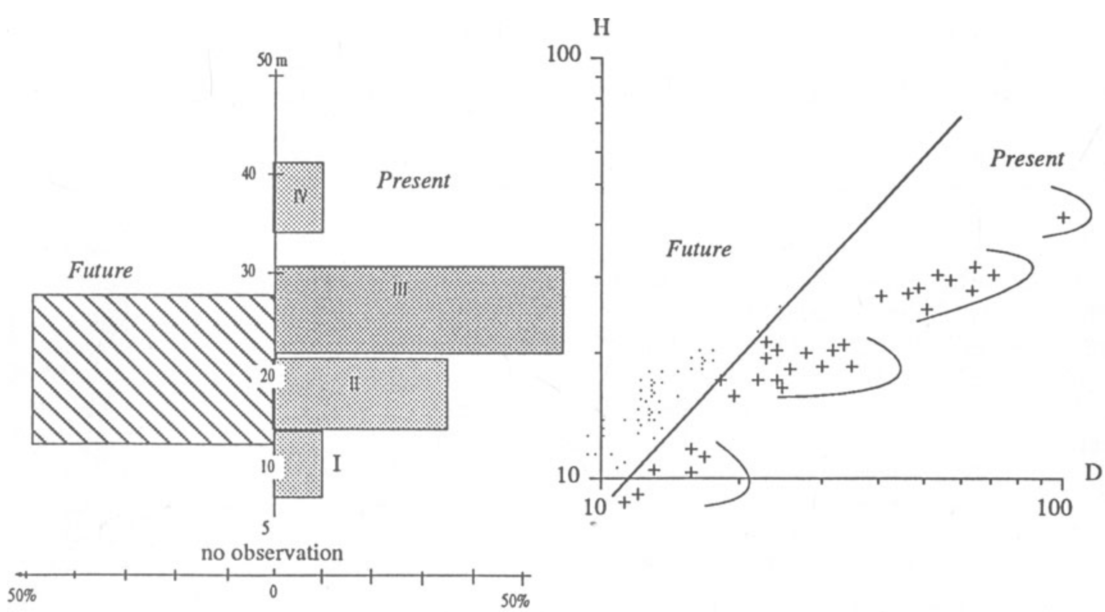


Fig. 56. Height-diameter relationship, stratification, number and cover of various architectural ensembles in the eastern lowland rain forest type of East Lampung. General physiognomy and structural organisation are similar. The forest matrix is lower, but the number of individuals is higher.

Crown planimetry (m2)			Relative cover	
			% total surf.	% cover surf..
Trees of thePresent				
Structural ensemble IV	471		24	26
Structural ensemble III	1049		52	57
Structural ensemble II	612		31	34
Structural ensemble I	254		13	14
	Total	**2386**	119	131
Trees of the Future		853	43	47
Trees of the Past		57	3	3
	Total	**3296**	165	181
Plot surface		2000	100	
Gaps		175	9	
Covered surface		1825		100
Crown overlapping on		1471		81

Fig. 57. Mixed dipterocarp lowland rain forest of the south-west coast. Coverage of the structural ensembles (Pedamaran, Lampung province). Only the right part of the profile diagram shows a complete organisation (four structural ensembles for the trees of the Present), while in the central part of the plot traces of former tree-fall gaps are visible, and in the left part indication of former disturbance like that low fork for Shorea No. 1 can explain the incomplete stratification. (Fold out.)

forests is occupied by *Dipterocarpus gracilis*, *Shorea guiso* and *Anisoptera costata* which tend to form groups, and *Hopea mengarawan*, *Shorea hopeifolia*, *S. leprosula*, *Hopea semicuneata*, *Dillenia excelsa*, *Engelhardtia serrata* and *Schima wallichii*. The last two species are habitually found in mountainous areas. The presence of *Triomma malaccensis*, *Osmelia philippina*, *Xanthophyllum erythrostachyum* and *Dillenia excelsa* could be linked to the existence of that more intense dry season indicated earlier. The lower structural groups include *Chrysophyllum lanceolatum*, *Knema rubens*, *Aquilaria microcarpa*, *Ardisia lurida*, species which are not found further North.

The forests of Langsa along the narrow coastal strip in the north-east are now extremely degraded. They were once reputed to be the island's most productive in term of hardwood dipterocarps. They were notable for their abundance in a much sought-after dipterocarp timber: the 'Damar laut' (*Shorea maxwelliana*).

Forests on the south-west coast show similar physiognomy and structure to those of the east-central regions (Fig. 57 and 58). They differ by a greater abundance of *Dipterocarpus*, especially *D. humeratus* and *D. kunstleri* which sometimes constitute 80% of the canopy surface area, associated with *Koompassia malaccensis*, *Shorea assamica*, *Canarium megalanthum*, *C. pseudodecumanum*, *Dillenia excelsa*.

The lower tree ensembles are astonishingly rich in Fagaceae (*Lithocarpus blumeanus*, *Quercus argentata*), Lauraceae (*Cinnamomum altissimum*, *Litsea nidularis*), Magnoliaceae (*Magnolia gigantifolia*), numerous Meliaceae (*Aglaia elliptica*, *A. leucophylla*, *Dysoxylum parasiticum*, *D.* cf. *excelsum*, *Aphanamixis grandifolia*) and Euphorbiaceae (*Aporusa arborea*, *A. lunata*, *Cleistanthus myrianthus*, *Mallotus echinatus*, *M. laevigatus*, *M. oblongifolius*, *M. penangensis*, *Phyllanthus oxyphyllus*).

The most commonly encountered lianas include *Calamus bengkulensis*, *Daemonorops* cf. *grandis* and *Korthalsia rostrata*, a few Connaraceae (*Agelaea trinervis*, *Connarus monocarpus*, *C. odoratus*), and Fabaceae (*Dalbergia rostrata*, *Millettia* sp).

Ground vegetation is composed of Marantaceae (*Phrynium capitatum*, *P. basiflorum*), Zingiberaceae (*Amomum* cf. *compactum*, *Costus speciosus*), ferns including a Marattiaceae (*Christensenia aesculifolia*), many Araceae and a few isolated Poaceae (*Leptaspis urceolata*).

Further North between Bengkulu and Painan, sampling carried out near the Indrapura plain (Sungai Lasi) gives evidence of a forest where, besides *Dipterocarpus*, the abundance of *Shorea*

Fig. 57

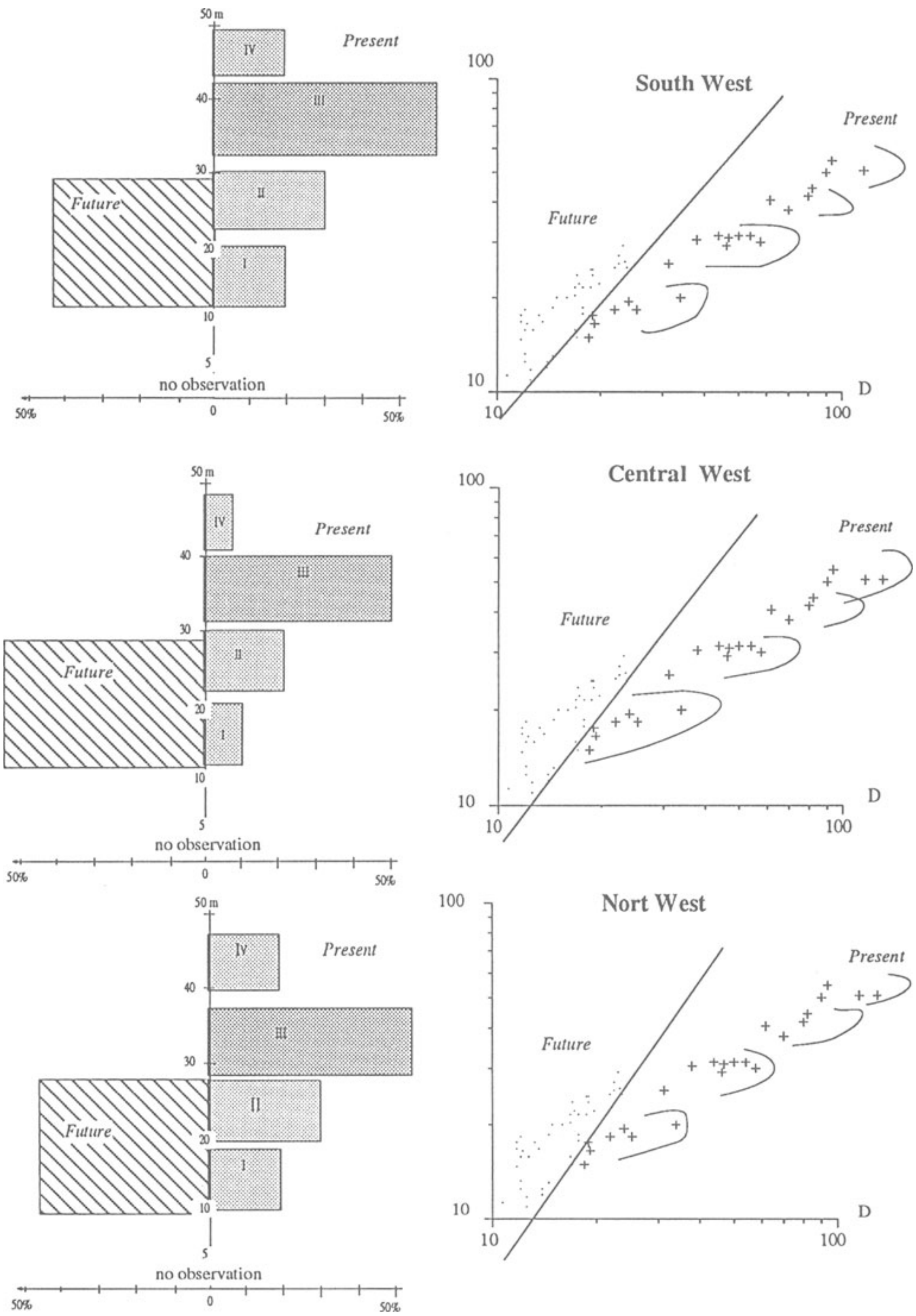


Fig. 58. Height-diameter relationship, stratification, number and cover of architectural ensembles in the west coast lowland rain forest types. Besides obvious floristic differences with the forests of the eastern plains, west coast types are generally taller with more space between foliage layers.

atrinervosa and *S. multiflora* associated with *Koompassia* and emergent Anacardiaceae of the genus *Swintonia* (*S. schwenkii*) is characteristic. The canopy is made up by many species which are common throughout the island. *Shorea atrinervosa* is significantly dominant, and the presence of *Mangifera torquenda*, *Hopea dryobalanoides*, *Elateriospermum tapos*, *Lithocarpus sundaicus*, *Endospermum quadriloculare*, *Horsfieldia majuscula*, *H. superba*, *H. wallichii*, *Knema intermedia*, *Heliciopsis cf. incisa*, *Pentace curtisii* is noteworthy.

Koilodepas longifolium, an extremely abundant Euphorbiaceae, develops in the ecological niche occupied by *Agrostistachys longifolia* in the eastern plains. The rattan *Calamus leloi* is one of

Crown planimetry (m2)				**Relative cover**	
				% total surf.	% cover surf.
Trees of the Present					
Structural ensemble IV	112			11	12
Structural ensemble III	682			68	72
Structural ensemble II	316			32	33
Structural ensemble I	41			4	4
		Total	**1151**	115	121
Trees of the Future			620	62	65
Trees of the Past			115.5	12	12
		Total	**1887**	189	199
Plot surface			1000	100	
Gaps			50	5	
Covered surface			950		100
Crown overlapping on			936.5		99

unidentified, 8,53, 51,59,15,62,9,65,60,5,65, Anisophyllea sp. 13, Aquilaria malaccensis 34,2,25,48, Artocarpus sp. 25,50, Barringtonia scortechinii 24,43, Calophyllum calaba 27,19, Calophyllum depressinervosum10,20, Calophyllum incumbens7, Calophyllum rubiginosum 60, Carallia sp. 35, cf. Adinandra 76, cf. Polyosma 4, Dacryodes costata 22, Dacryodesrostrata 20, Diospyros sp. 33,3,62,12, Durio griffithii 17,5,46,70,66,58, Dyera costulata 46, Elateriospermum tapos 52, Endospermum quadriloculare 7, 71, Engelhardtia serrata, Eugenia sp. 57,8,21, Ganua sp. 1, Garcinia scortechinii 18, Garcinia sp. 32,23,4,38,42, Goniothalamus umbrosus 28, Gymnacranthera bancana 63, Heritiera sumatrana 59, Hopea dryobalanoides 24,13,23,81,18,32,42, 56,40,72,68,78,35,44, Horsfieldia majuscula 37, Horsfieldia superba 51, Horsfieldia wallichii 22, Kayea sp. 45, Knema intermedia 30, Lithocarpus sundaicus 29, Litsea sp. 40, Mangifera torquenda 74,3, Palaquium sp. 14, Parinari 19, Payena leerii 16,48 Payena lanceolata 37 Pentace curtisii 17,47, Pouteria malaccensis 52, Santiria conferta 64, Santiria laevigata 34, Shorea atrinervosa 61,41,55,3,58,54, Shorea multiflora 49,3,15,11,32,44, Streblus sp. 36,25, Swintonia schwenkii 39, Syzygium sp. 45, Teijsmanniodendron coriaceum 9.

Fig. 59. Mixed dipterocarp lowland rain forest of the west coast. Floristic composition and coverage of the structural ensembles for a ridge facies (Sungai Lasi, West Sumatra). The forest is very dense with a high crown overlapping and a more even upper canopy than the nearby forest on slopes.

Fig. 59. Continued.

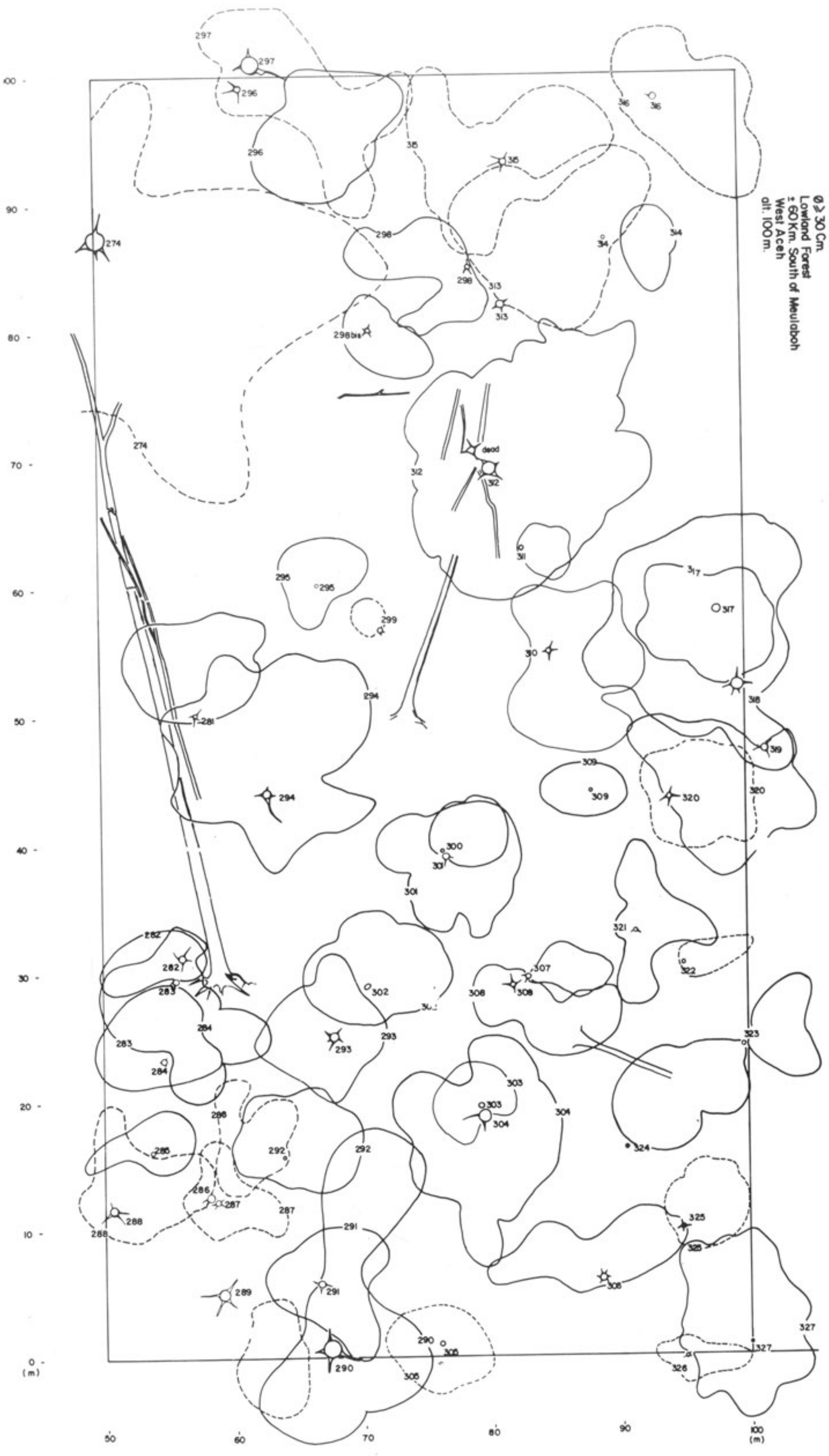


Fig. 60. Mixed dipterocarp lowland rain forest of the north-west cosst. Floristic dominance and coverage of the structural ensembles (Meulaboh, Aceh). Differences with either the forests of the eastern lowlands (Mahato, Fig. 48), or those of the south-west coast are more floristic than structural.

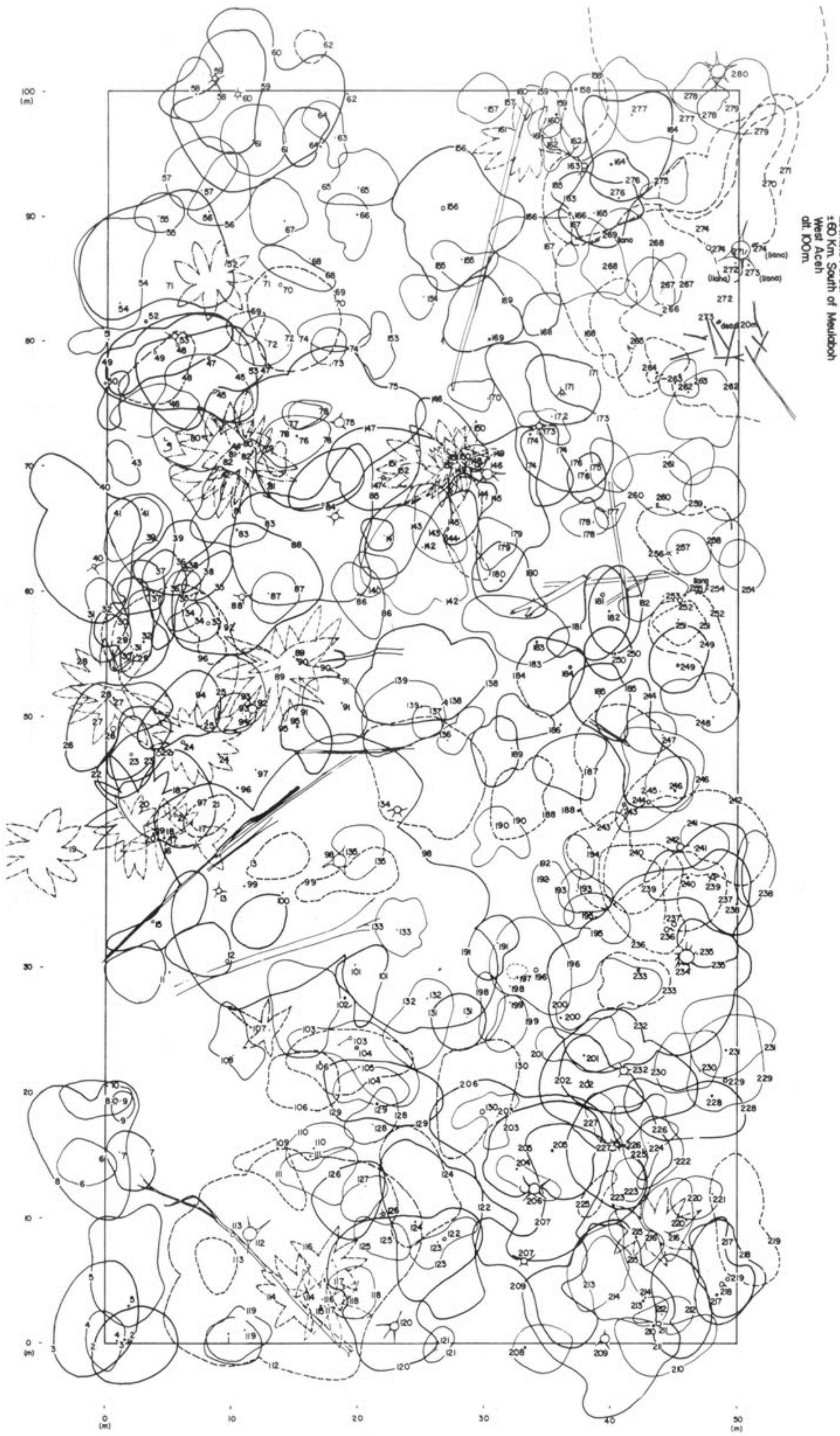

Ø ≥ 10 Cm.
Lowland Forest
±60 Km. South of Meulaboh
West Aceh
alt. 100m.

Fig. 60b.

Crown planimetry (m2) for tree diameter ≥ 30 cm				Relative cover	
				% total surf.	% cover surf.
	Trees of the Present				
		Total	**2682**	54	90
	Trees of the Future		165	3	6
	Trees of the Past		1419	28	48
		Total	**4266**	85	143
Plot surface			5000	100	
Gaps			2015	40	
Covered surface			2985		100
Crown overlapping on			1281		43

Crown planimetry (m2) for diameter ≥ 10 cm						Relative cover	
						% total surf.	% cover surf.
	Trees of the Present						
		Structural ensemble IV	1263			25	30
		Structural ensemble III	1238			25	29
		Structural ensemble II	927.5			19	22
		Structural ensemble I	758			15	18
				Total	**4186**	84	99
	Trees of the Future				2357	47	56
	Trees of the Past				2008	40	48
				Total	**8551**	171	203
Plot surface					5000	100	
Gaps					788	16	
Covered surface					4212		100
Crown overlapping on					4339		103

Dominant trees of the Present P		Dominant trees of the Future F	
Dipterocarpus	*hasseltii*	*Dipterocarpus*	*hasseltii*
Shorea	*sumatrana*	*Scaphium*	*cf. linearicarpum*
Shorea	*lepidota*	*Horsfieldia*	*wallichii*
Scaphium	*cf. linearicarpum*	*Artocarpus*	*integer*
Blumeodendron	*kurzii*	*Shorea*	*sumatrana*
Palaquium	*sp.*	*Cephalomappa*	*cf. penangensis*
Dipterocarpus	*kunstleri*	*Madhuca*	*sp.*
Eugenia	*sp.*	Rosaceae	
Artocarpus	*integer*	*Shorea*	*lepidota*
Eugenia	*sp.2*	*Myristica*	*maxima*
Durio	*sp.*	*Durio*	*sp.*
Litsea	*sp.*	*Knema*	*conferta*
Nephelium	*lappaceum*	*Litsea*	*sp.*
Santiria	*laevigata*	*Dipterocarpus*	*kunstleri*

Fig. 60c.

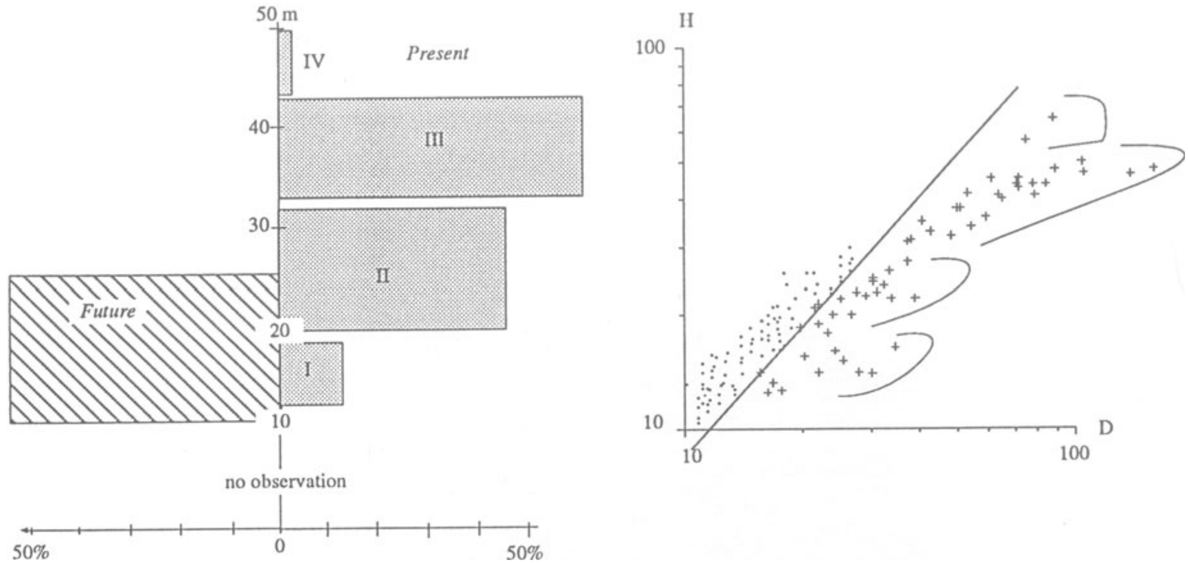


Fig. 61. Height-diameter relationship, stratification, number and cover of architectural ensembles in a lowland rain forest on limestone (Calang, Aceh). Structural differences with forest on other lithology are noticeable. Vertical distribution of the various ensembles remain the same, but horizontal structure is more clumped, as gaps are more important above rock outcrops.

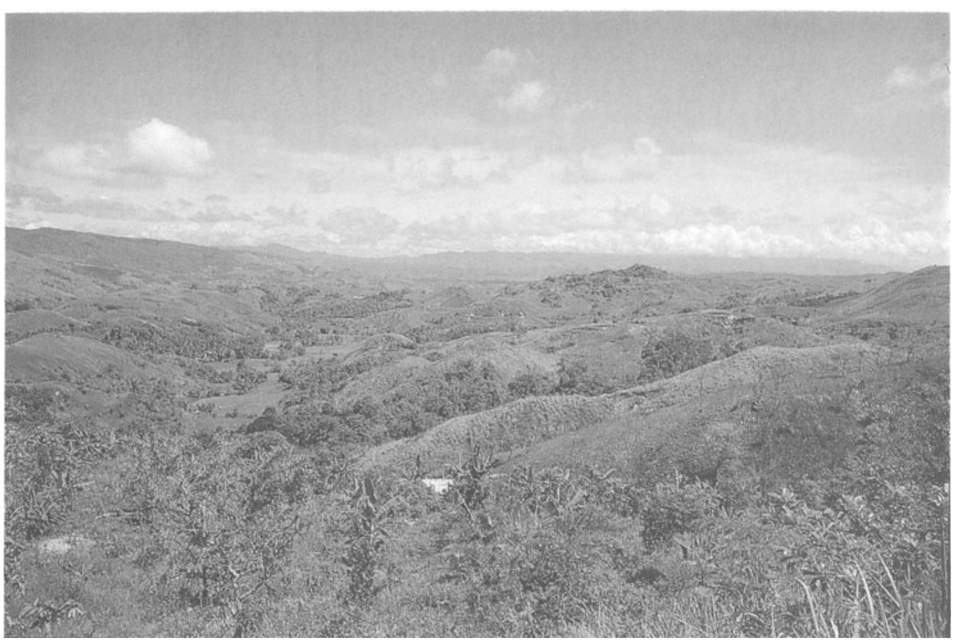


Photo 9. Developed over sandy soils, the Padanglawas grasslands, may have supported "Kerangas" forest in the past. The area is also famous for its drying winds occuring from May to October (South Tapanuli, North East Sumatra).

the most common lianas together with *Uncaria longiflora* and several species of *Tetracera*. *Buettneria curtisii*, a small creeping Sterculiaceae is a noteworthy undergrowth component.

Few structural differences are observed, except perhaps at the summits of narrow ridges (Fig. 59) where stem density is higher and the canopy somewhat more even.

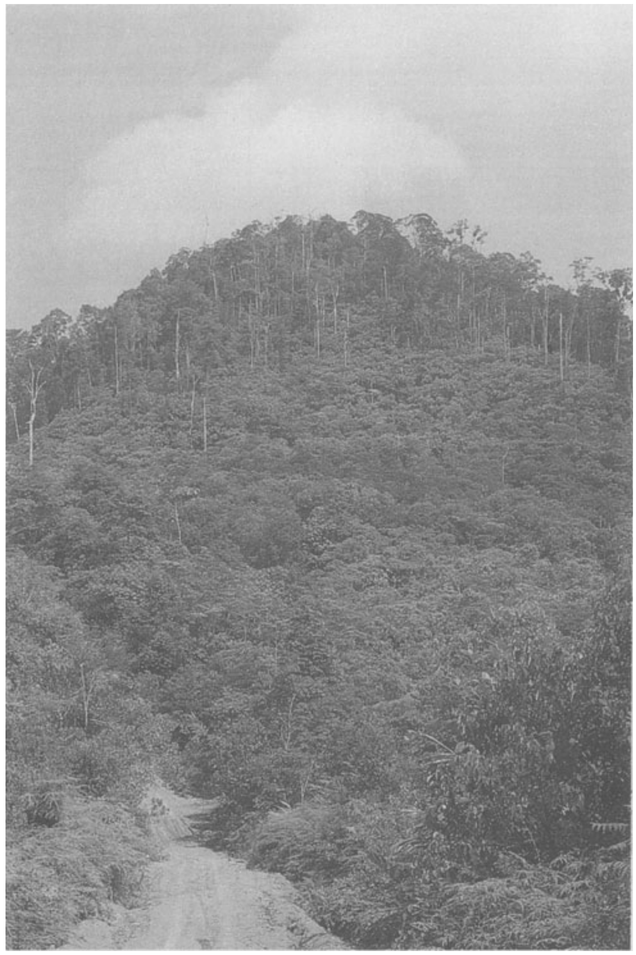


Photo 10. Secondary vegetation mosaic: there is a whole series of degraded stages, difficult to classify and quantify. A seven years old belukar is seen in front of a remnant forest at the top of the hill (Pemunyin area, Muarabungo, Jambi). (Photo: V. Trichon).

On the Meulaboh plain in the extreme north-west (Fig. 60 a and b), a further sample again revealed that differences are more floristic than structural, essentially as far as the canopy dipterocarp composition is concerned. The upper structural groups are more open, and while the flora remains basically the same, with, (as in the South), a great abundance of *Dipterocarpus* (*Dipterocarpus hasseltii*, *D. verrucosus*, *D. kunstleri*), these forests seems to contain a wider variety of *Shorea* species (*S. lepidota*, *S. ovalis*, *S. sumatrana*, *S. parvifolia*). Generally speaking, an increasing gradient in the diversity of *Shorea* species is observed from South to North along the west coast.

The composition of the lower structural ensembles is relatively similar to their equivalents in the eastern plains although there is a noteworthy abundance of *Polyalthia rumpfii*, *Madhuca ligulata*, *Palaquium hexandrum*, *Scaphium linearicarpum*, *Whitfordiodendron atropurpureum* for medium height species and *Aglaia aspera*, *A. oligocarpa*, *Horsfieldia wallichii*, *Xanthophyllum flavescens*, *Symplocos rubiginosa* for the smaller trees.

Calamus rhomboideus ('rotan lilin') amongst the rattans and *Uncaria* cf. *canescens* for other lianas complete this floristic glance at the north-west lowland forest types.

Variations in forest facies

Monodominant species formations. Although the lowland formations are dominated by the dipterocarp family, the actual floristic composition varies considerably at certain places. The best example is the facies dominated by the 'Bulian' tree, *Eusideroxylon zwageri*, a Lauraceae with very hard wood. The simultaneous occurrence of species-mixed forests and near-monodominant ones has stimulated research on causality and maintenance mechanisms governing plant diversity in tropical environments (Janzen 1974, Hart et al. 1989, Hart 1990).

Franken and Ross (1981), Suselo (1983), Whitten et al. (1984) have described these populations in Sumatra, which are apparently similar to the 'Empran' forests described by Whitmore (1973). Koopman and Verhoef (1938) observed the presence of pure stands in South Sumatra and Jambi province near the rivers on lower slopes. Witkamp (1925) observed that this species is confined to well drained but continuously moist sandy soils. The canopy is very dense, occasionally penetrated by *Koompassia excelsa*, *Shorea leprosula*, *Pometia pinnata* or *Sterculia macrophylla*. The floristic composition is similar to the adjacent dipterocarp forest, but species diversity decreases significantly in the upper canopy (Franken & Ross, 1981).

In the case of *Eusideroxylon* in Sumatra, its occurrence does not seem to result from any particular chemical composition of the substratum (Suselo 1983). The *Eusideroxylon* forest is perhaps less subject to treefalls, which could constitute an obstacle to the maintenance of a high diversity, but above all this species seems to have a high regeneration capability and to be relatively well protected against damage by herbivores.

Other populations with a monodominant tendency have been observed, consisting of *Dryobalanops oblongifolia*, a dipterocarp described by Van Zon (1915) forming islets in the middle of the Bengkalis swamp forests (Riau). The present author was not able to retrace the location of these populations in the area, which is unfortunate since there seems to be a confusion with *D. sumatrensis* (*D. aromatica*) in old publications on this region of Sumatra. Doubtlessly, they were relics of the 'Riouw Pocket' flora described by Corner (1978). Gregarious populations of *Cotylelobium melanoxylon* (Dipterocarpaceae) are also found in Riau province, North of Pekanbaru. This is the only known location for this species in Sumatra.

On the west coast, north of the Talamau volcano up to the region of Barus, other populations with a tendency towards monodominance have been described, mainly consisting of 'Kapur' tree (*Dryobalanops sumatrensis*) yet again, well known for the incense extracted from it which once made for a flourishing trade (the 'Baros or Borneo campher'). In these regions, *Dryobalanops* may account for up to 80% of the wood volume of all marketable species (Alrasjid 1982).

Edaphic variations. One of the many variants of very low altitude forests linked to the characteristics of the substratum are the forest types on sandy coastlines. These pantropical forests, very simplified from the floristic standpoint, are particularly well developed on the west coast of the island. Forests of *Casuarina equisetifolia*, characteristic of beaches or prograding dune systems, can be distinguished from *Barringtonia asiatica* formations which are characteristic of regressing coastlines. A list of the main species is given in Table 17.

Other forests which are determined by soil type, the 'Kerangas' on white sand and tropical podzols, do not occupy extensive areas as they do in Borneo or on the Bangka and Belitung islands (Van Steenis 1935, Whitten et al. 1984). The grasslands region of Padanglawas South of Lake Toba developed over very sandy soils (the 'Zandsteppen' described by Frey-Wyssling 1933), and could have supported a particular kind of forest similar to the 'Kerangas forests', but this has never been proven. Other descriptions have been given for Riau province (Koorder 1895, Steup 1941), and we observed secondary *Ploiarium alternifolium* formations in the metamorphic hills which could be the degraded stages of this forest type, also called 'padang' in the literature. Small 'Kerangas forests' reportedly exist to this day on the foothills of the Tigapuluh mountains at the borderline between Riau and Jambi provinces (JM Bompard, pers. com.).

At very low elevation, forested limestone massifs are still rare. On the north-west coast of Aceh province karst formations occur at an altitude of approximately 300 m (Calang). In these areas the forests are operated in the same manner as those on non-calcareous substrates.

The structure differs from the bordering non-calcareous formations (Fig. 61). Generally, the upper structural groups are sparser. Topography is rough with numerous rocky outcrops.

Emerging trees are mainly *Shorea maxwelliana*, *S. atrinervosa*, *Shorea* sp., and *Xanthophyllum* amoenum which often exceed heights of 40, even 50 m. At a height ranging from 30 to 40, the fairly open canopy is mainly composed of younger individuals of *Shorea maxwelliana* and *Xanthophyllum amoenum*, associated with *Artocarpus lanceifolius*, *Myristica iners*, and *Mezzettia* sp.

Below that, between 20 and 30 meters, *Dio spyros fasciculosa*, *Pometia pinnata*, *Calophyllum rubiginosum*, *Cephalomappa* sp., *Aidia cochin chinensis*, *Neonauclea* cf. *cyrtopoda*, *Cyathocalyx* sp. were collected more than four times each on a one hectare plot.

From 10 to 20 meters above the ground, *Knema laurina*, *K. conferta*, *K. rubens*, *Garcinia scortechinii*, *Whitfordiodendron purpuraceum*, *Aglaia odoratissima*, *A. eximia*, *Lansium* are the most abundant species, whereas *Anaxagorea javanica*, an Annonaceae, is often encountered in the undergrowth.

Low altitude formations on calcareous terrain also exist in the central east part of Barisan (North-east Kerinci), and are apparently intact. They remain to be explored more intensively.

Secondary types

The secondary formations resulting form clear cutting of the primeval vegetation have nothing in common with the formations following the progressive degradation of the primary forest, such as after logging and successive cultivation by local populations. There is a whole series of degraded stages, difficult to classify and quantify. From an ecological point of view, these depleted forests do not have many points in common with new forest regrowth, even when mature. A large number of primary species are still present and, depending on the degree of degradation, will either die out or contribute to healing the forest and restoring it towards its original state.

Grasslands, shrub savanna and thickets (< 5 *m*)

Alang-alang (*Imperata cylindrica*) grassland formations occupy large areas in the lowlands, mainly in the South of the island. These formations are the first stage of recolonization after regular clearing and burning help to maintain them. Their composition is then 90% *Imperata*. When associated with *Chromolaena odorata*, *Stachytarpheta jamaicensis*, *Paspalum conjugatum*, *Hyptis brevipes*, *Melastoma malabathricum* and other Melastomataceae, they represent the most degraded stage after several burning and farming operations. Without the effects of fire, *Chromolaena odorata* can form pure populations which will grow then into dense shrub or woody thickets where *Bridelia glauca*, *Vitex pubescens*, *Glochidion obscurum*, *Ficus glomerulata* and *Trema orientalis* appear (Eussen & Wirjahardja 1973). *Chromolaena* then disappears gradually, dominated at the next stage by species such as *Melanolepis multiglandulosa*, *Villebrunea rubescens*, *Lantana camara*, *Grewia glabra*, or *Peronema canescens*. The process is often stopped at this stage by further burning.

Young secondary forest (5–15 *m*)

In Malay, the term 'belukar' is given to the phase following the 'thicket' described above. As we have seen, in the South of the island the belukar is dominated by *Schima wallichii* and *Dillenia obovata* associated with numerous Euphorbiaceae. An impenetrable thicket with a very even canopy develops below mainly composed of *Breynia* sp., *Glochidion superbum* (Euphorbiaceae), *Gaertnera vaginans*, *Uncaria* spp. (Rubiaceae), *Leea indica* (Leeaceae), *Geunsia farinosa* (Verbenaceae) and *Commersonia bartramia* (Sterculiaceae). Further North, the floristic composition of the belukar is different.

A 15 year old belukar (Fig. 62) has three characteristic strata. The canopy is dominated by *Anthocephalus chinensis* which have attained maturity. The underlaying tree strata most often include *Campnosperma auriculatum*, *Macaranga javanica*, *M. gigantea*, *M. conifera*, *M. trichocarpa*, *Commersonia bartramia*, *Symplocos rubiginosa*, *Gironniera hirta*, *Tabernaemontana sphaerocarpa*, *Alangium kurzii*, while the shrub strata is occupied by *Croton oblongus*, *Alchornea villosa* and species which foreshadow the primary forest such as *Shorea leprosula*, *S. bracteolata*, *S. ovalis*, *Scorodocarpus borneensis*.

At the center of the island between Kwantan and Batanghari, certain belukars are dominated by *Tetrameles nudiflora*. This fact is worth mentioning since the species is habitually considered as an indicator of more seasonal climates. Until now, it has often been cited as an example of a species with disjunct distribution since it is found at both ends of the islands. Its presence in

Table 17. Main beach forest species.

APOCYNACEAE	LEGUMINOSAE
Cerbera odollam	*Erythrina orientalis*
CASUARINACEAE	*Desmodium umbellatum*
Casuarina equisetifolia	*Pongamia pinnata*
COMBRETACEAE	*Caesalpinia bonduc*
Terminalia catappa	MALVACEAE
CONVOLVULACEAE	*Thespesia populnea*
Ipomoea pes-caprae	PANDANACEAE
CYCADACEAE	*Pandanus tectorius*
Cycas rumphii	RUBIACEAE
GOODENIACEAE	*Morinda citrifolia*
Scaevola sericea	SAPOTACEAE
POACEAE	*Planchonella obovata*
Spinifex littoreus	TACCACEAE
GUTTIFERAE	*Tacca leontopetaloides*
Calophyllum inophyllum	TILIACEAE
HERNANDIACEAE	*Hibiscus tiliaceus*
Hernandia nymphaeifolia	*Triumfetta procumbens*
LAURACEAE	VERBENACEAE
Cassytha filiformis	*Vitex trifolia*
LECYTHIDACEAE	
Barringtonia asiatica	

the central parts seems to indicate that the dry season is more intense than commonly thought in this region. The abundance of *Kleinhovia hospita* in the same area is another indication in support of this fact (T.C. Whitmore, pers. comm.).

Belukar formations throughout these eastern lowlands, are very often associated with a family-operated *Hevea* farming system which was established by the peasants as soon as rubber was introduced to these regions in 1913 (Scholtz 1983). This system of perennial crops combined with secondary vegetation cover immense areas which also extend into the piedmonts. Unfortunately, it is impossible to differentiate 'pure' secondary formations from those mixed with *Hevea* using remote sensing imagery. Plots are rarely cleared within the first ten years. Seven years after burning and planting with *Hevea*, a stage described by Djailany (1987) as physiognomically very homogeneous is dominated by *Hevea brasiliensis* and other Euphorbiaceae (*Macaranga gigantea*, *M. hosei*, *M. hypoleuca*, *M. javanica*, *M. trichocarpa*, *Mallotus macrostachus*, *M. paniculatus*), Moraceae (ten species of *Ficus*), Rubiaceae (*Anthocephalus chinensis*), Datiscaceae (*Octomeles sumatrana*) and Anacardiaceae (*Campnosperma auriculatum*).

Rattans often exist in number and the abundance of *Calamus caesius* could have more far-reaching economic implications (Dransfield 1974). Finally, it is worth noting large localized formations of *Bellucia axinanthera*, a Melastomataceae from South America which sometimes colonizes vast tracts of land, mainly in the eastern central area, at the feet of the Barisan.

Old secondary forests ($>20\,m$)

Old secondary forests are rare as belukar is often felled and replanted well before the forest reaches a stage similar to the primary.

At the center of the island, the author some-

Fig. 62. Secondary growth forest, "belukar", 10 to 15 years after clear felling. *Antocephalus chinensis* and *Sapium discolor* are dominant in the upper canopy, *Euodia alba* and *Glochidion* sp. below it.

times came across old secondary forests on river banks in areas which have remained isolated until today. A forty year old forest near the Ule river is not as dense as the surrounding primary forest. Planted fruit trees are still encountered, proof that the ground was once used as an orchard. There is an abundance of *Macaranga* (*M. hosei*, *M. triloba*, *M. conifera*, *M. diepenhorstii*, *M. hosei*, *M. hypoleuca*, *M. motleyana*, *M. semiglobosa*, *M. trichocarpa*) and other secondary species at the senescent stage such as *Endospermum diadenum*, *Camposperma auriculatum and Anthocephalus chinensis*.

Hillside formations

Location, extent and forest status

Further inland, above the piedmonts, one first encounters a landscape of low hills culminating at an altitude of roughly 500 m. Spared from logging until the beginning of the 80s, the hills have been often occupied by local populations since ancient time. There are also rubber jungle garden systems, as we mentioned for the piedmonts and eastern plains, as well as numerous coffee plantations in the South-eastern hills where the road network facilitated this crop at the beginning of the century. The forest cover in this low elevation hilly zone represents about 4% of Sumatra's total surface area.

Even at higher altitudes, ranging from 450 to 800 meters, the hills have not been spared by human activities. The colonization of access roads in the higher plateaux has greatly contributed to the replacement of the forests by extremely degraded formations in many places.

Except for anthropogenic *Pinus merkusii* stands at Aceh, traditional exploitation of the forestry resources on these hills mainly involved rattan. Over-exploitation of certain species such

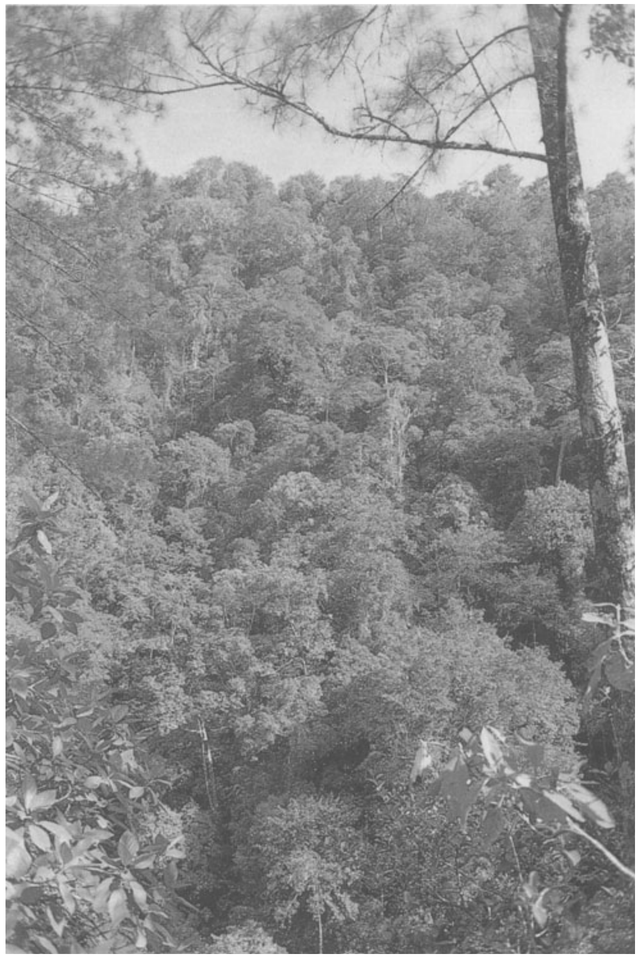


Photo 11. Natural populations of *Pinus merkusii* are common in the hill and submontane forests west of the Kerinci valley, between 500 and 1300 m elevation in the Tapan area. They represent the only known populations of that species south of the equator, and are often associated with *Agathis borneensis* between 1000 and 1300 m elevation.

as the 'manau' (*Calamus manan*), once an important source of income, reduced this activity (Siebert 1989), although it still flourishes today with species such as 'rotan udang' (*Korthalsia echinometra*), 'rotan lilin' (*Calamus javensis*), and 'rotan sega' (*Calamus caesius*). Due to the topography, forestry operations are disastrous for the environment but are on the increase since the lowland forests have practically disappeared. Forest cover is approximately 6% of the island's total surface area and 10% of all remaining forest. The main crops currently grown are coffee, cloves and cinnamon.

The physical environment

Geomorphology, topography

In the regions which form the real buttresses of the mountain ranges, the relief becomes rougher with slopes ranging from 8 to 16%, then from 16 to 30% as the altitude increases. Slope lengths are short to moderately short (50–150 m) and crests and summits are at an average altitude of 450–500 meters in the low elevation hill regions. The relief becomes often rougher at altitudes above (500–800 m), with slope lengths in the re-

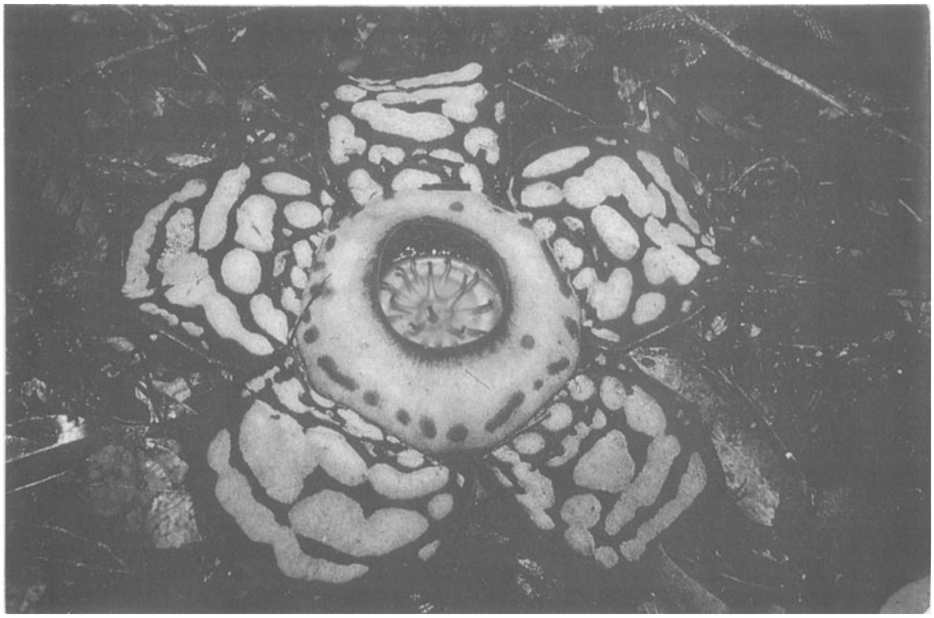


Photo 12. Less common than the better known *Rafflesia arnoldi*, *R. hasseltii* occurs in the north of Sumatra, and was discovered also recently in the central eastern hill forests. This specimen was found near the Merangin River in the Temiai area in Kerinci-Seblat National Park.

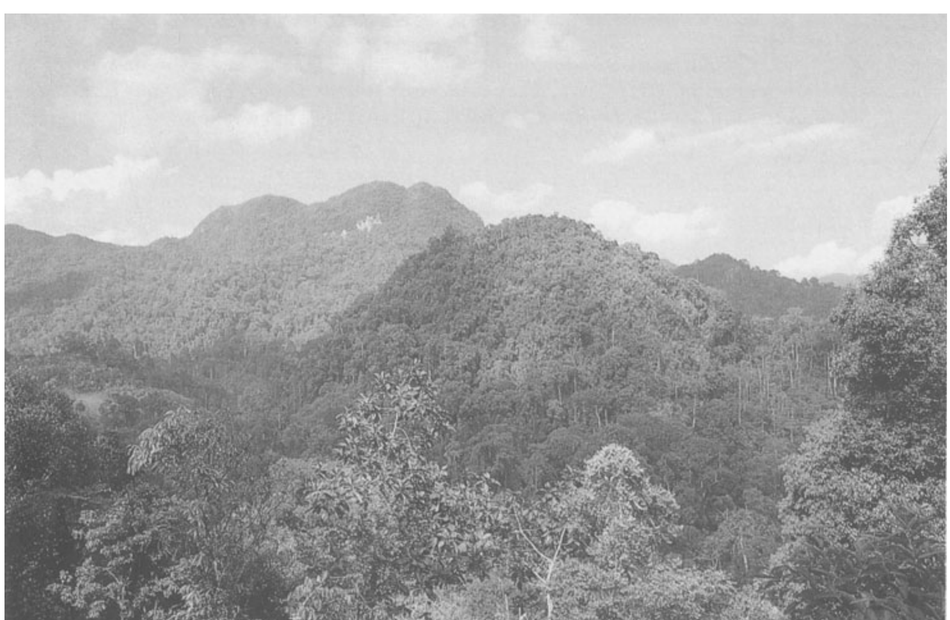


Photo 13. The easily accessible karst area of the eastern Barisan in West Sumatra: the massif extends from north-east of Kerinci peak (Gunung Sunggiri) to the Payakumbuh area. A more pronounced dry season adds to the singularity of the region.

gion of 200 to 300 m for gradients ranging from 30 to 60%.

In the lowest areas, the ancient sedimentary terrain, raised and folded, occupies large surfaces but gives way further up to alternating granite, metamorphic or volcanic massifs.

Soils

At low altitudes, ferralitic soils are still the main type and are similar to those previously described (Fig. 63), while the dominant soil types at higher altitudes, generally on more recent geological formations, are Cambisols. These brown soils have a gritty upper horizon 5 to 20 cm thick above a cambic B horizon with an angular or blocky structure. Although the clay content is conventionally maximum in the latter horizon, it is relatively even throughout the profile. The pH varies from 5 to 6,5 and increases with depth, at least on andesitic material. The organic matter content in the upper horizons varies from 3 to 15% with a C/N ranging from 8 to 12. The CEC of approximately 15 to 30 meq at the surface decreases with depth (Fig. 64). Calcium is habitually the dominant cation, but magnesium is also important. The humic Cambisols of the eastern Barisan hillsides can be distinguished from the poorer, more leached dystric Cambisols, located on the western slopes, where rainfall attains its records for Sumatra.

Bioclimate

These hilly regions have superhumid ($2500 < P < 3000$ mm/year, average rainy days; 140 to 170 a year) and, above all, hyperhumid bioclimate ($P > 3000$ mm/year), as in the case of the eastern slopes and most of the piedmonts on the western hillsides. On the west coast, where the island's record mean annual rainfall values are attained[4], pluviometrics are practically always higher than 4000 mm/year. The average number of rainy days a year varies from 180 to 220.

Low elevation, non karst hill plant formations (150–450 m)

Primary forests

Structure and floristics. Hillside forests are physiognomically and structurally similar to their lowland equivalents. The former classification system for differentiating them (Wyatt-Smith 1963, Symington 1943) has been challenged by Whitmore (1984) who does not consider any altitude-based division to be justified below 1000 m. It is true that a common flora exists for this range of altitudes and that the initial impressions based on studies carried out on small plots did not provide a correct overview of forest types. Nevertheless, east of the Barisan the landscape between 150 and 450 m undergoes visible changes which are accompanied by marked floristic variations in the canopy. The secondary series are themselves different, as are local farming practises and use of the environment. All this would seem to point out that, from a forestry, agricultural or conservational point of view, it would be preferable not to consider the forest as a single forest type ranging from 50 to 1000 meters elevation. This distinction (0–150/150–450) was not possible on the west coast where a single forest type is apparently occurring from 0 to 300 m.

The canopy remains dense and closely interwoven on low elevation hills. It is situated at a height ranging from 35 to 40 m with emergent trees reaching up to 45 or 55 m. These are all 'Mixed Dipterocarp Rain Forests', and the dominance of this family is still very high (50% abundance and 60% dominance over all plots at trunk diameters above 30 cm). Diversity remains also very high, with the Simpson index (D) varying from 0.942 to 0.993 from plot to plot and Shannon entropy from 4.236 to 5.315 for an equitability R of 0.820 to 0.895.

Certain species have either disappeared or become rare, while others, rare in the lowlands, are more abundant. Although it might seem pretentious in view of the sparseness of available botanical and taxonomic information, certain remarks can be made on the distribution of part of the flora which illustrate the changes observed.

Sampling in the east Barisan foothills (trees with a diameter ≥ 10 cm) show that significant differences exist between forests established on sedimentary rock and those on granite:

On sediments, (90–120 individuals /ha for diameters $\geq$ to 30 cm; 600–700 individuals /ha with diameters ≥ 10 cm), the majority of the lowland Dipterocarps described in the previous chapter are present although much less abundant while others no longer grow such as *Dipterocarpus lowii*, *D. crinitus*, or *Shorea macroptera*. Lower

[4]Muaraaman, Bengkulu, alt. 335 m, P = 6163 mm; Kapaladatar, W Sumatra, alt. 840 m, P = 7757 mm

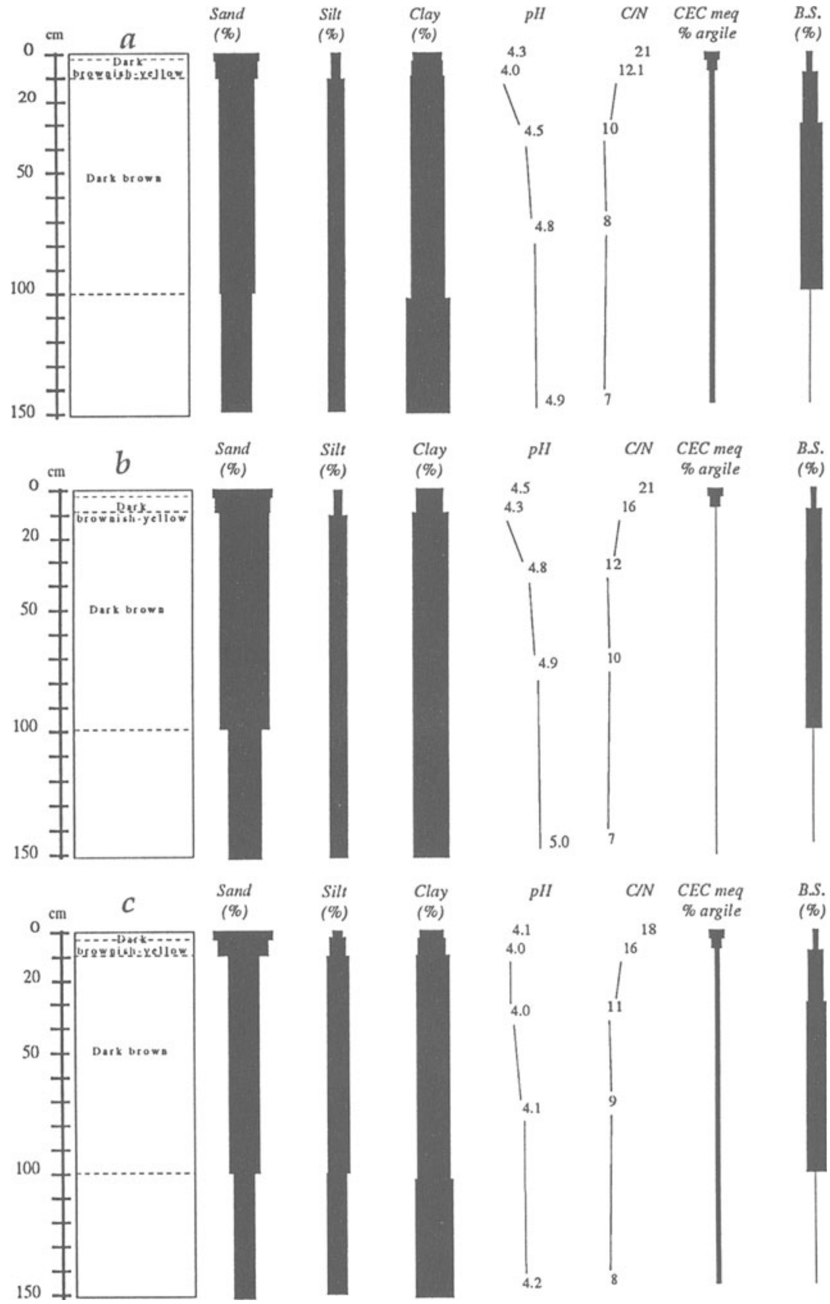


Fig. 63. General trends for Ferralsol developed on granites in the foothills. There are not many differences with those developed on sedimentary rock (Fig. 43) a: lower slope; b: mid-slope; c: upper slope, ridge.

strata species which are extremely abundant in the lowlands disappear, as in the case of *Monocarpia marginalis*, *Gymnacranthera bancana*, *Horsfieldia superba* or the Fabaceae of the undergrowth *Fordia* cf. *johorensis*.

The dominant dipterocarps in these eastern Sumatra foothills are *Shorea hopeifolia*, *S. gibbosa*, and *S. bracteolata*, which are also found at lower altitudes, where they are rarer and much less vigorous. *Anisoptera* is less abundant and only *A. laevis* flourishes. Towards 250 m, species which are at their lower altitude limit start appearing

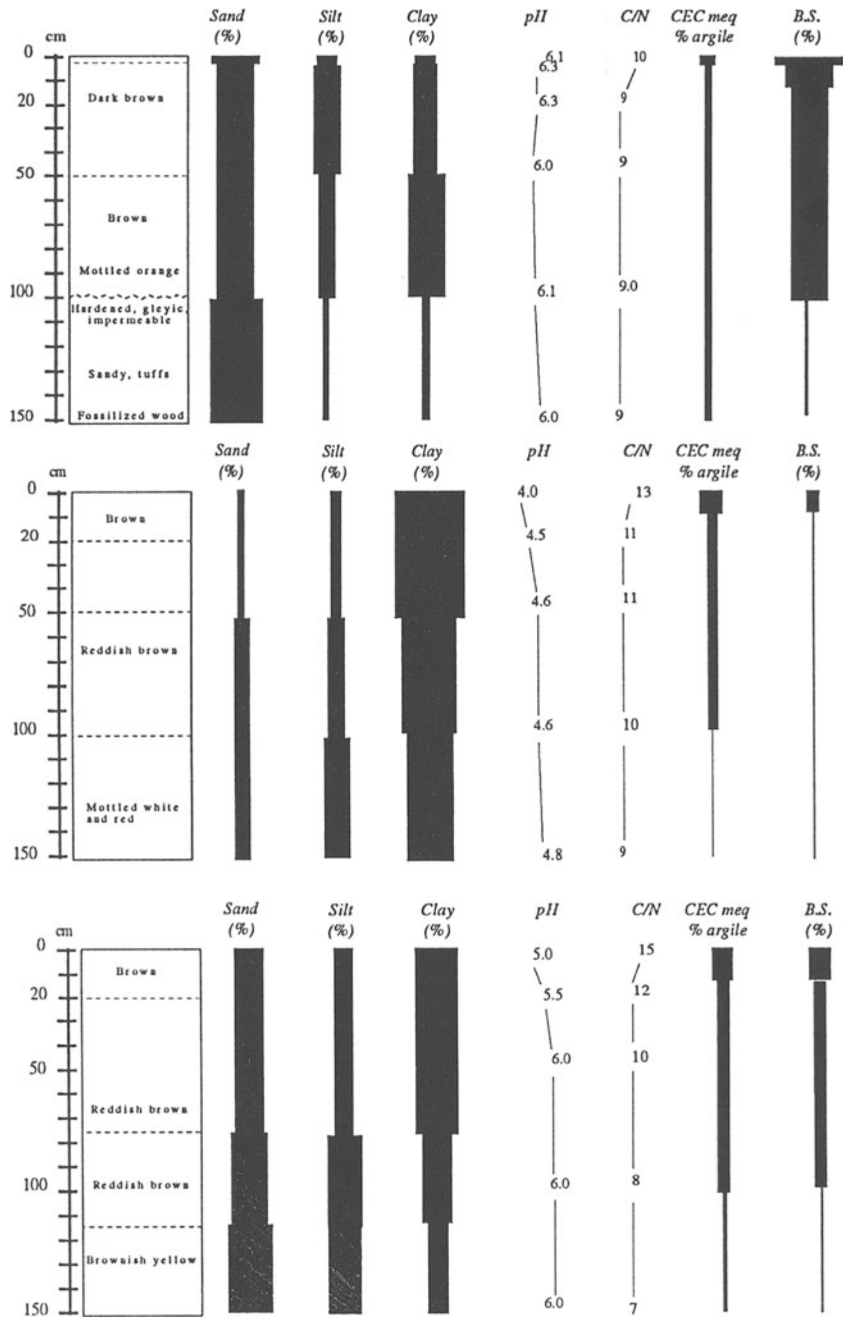


Fig. 64. Examples of soils in the hills. – Gleyic Cambisol on volcanic tuffs on slope (a): these soils are very distinctive with plant debris at a depth of 1.5 m below a gleyic horizon. – Ferric Cambisol on andesite on ridge (b) and Orthic Cambisol on sandstones on slope (c): these are typical Cambisols, brown soils with a maximum of clay content in the B horizon, often not too acidic, and with a low C/N.

Crown planimetry (m2) for tree diameter ≥ 30 cm		Relative cover	
		% total surf.	% cover surf.
Trees of the Present			
Total	**10310**	52	92
Trees of the Future	192	1	2
Trees of the Past	1710	9	15
Total	**12212**	61	109
Plot surface	20000	100	
Gaps	8819	44	
Covered surface	11181		100
Crown overlapping on	1031		9

Crown planimetry (m2) for diameter ≥ 10 cm			Relative cover	
			% total surf.	% cover surf.
Trees of the Present				
Structural ensemble IV	740,5		15	18
Structural ensemble III	1437		29	34
Structural ensemble II	1118		22	27
Structural ensemble I	914,5		18	22
Total		**4210**	84	101
Trees of the Future		1340	27	32
Trees of the Past		1245	25	30
Total		**6795**	136	163
Plot surface		5000	100	
Gaps		828	17	
Covered surface		4172		100
Crown overlapping on		2623		63

Dominance trees of the Present P			Dominance trees of the Future F		
DIPT	*Parashorea*	*lucida*	SAPO	*Palaquium*	*sp.*
DIPT	*Shorea*	*conica*	DIPT	*Shorea*	*conica*
ANAC	*Mangifera*	*swintonioides*	ULMA	*Gironniera*	*subaequalis*
DIPT	*Anisoptera*	*laevis*	DIPT	*Parashorea*	*lucida*
STER	*Sterculia*	*sp.*	STER	*Sterculia*	*sp.*
MYRT	*Eugenia*	*sp.*	FLAC	*Ryparosa*	*kunstleri*
THYM	*Aquilaria*	*malaccensis*	MYRI	*Knema*	*latifolia*
SAPI	*Xerospermum*	*norhonianum*	ANAC	*Bouea*	*oppositifolia*
BURS	*Dacryodes*	*rostrata*	ANNO	*Cyathocalyx*	*cf. kingii*
EUPH	*Endospermum*	*diadenum*	EUPH	*Aporusa*	*sphaeridiophora*
MELI	*Chisocheton*	*sp.*	POLY	*Xanthophyllum*	*affine*
MYRT	*Eugenia*	*sp.2*	MELI	*unidentified*	
SAPO	*Payena*	*acuminata*	EUPH	*Pimelodendron*	*griffithianum*
SAPO	*Palaquium*	*sp.*	EUPH	*Macaranga*	*triloba*

a.

Fig. 65. Lowland mixed dipterocarp rain forest on granites, floristic dominance and coverage of the structural ensembles (Batang Ule, Jambi). Structure is similar to nearby forest on sedimentary rocks, with less trees per hectare and less crown overlapping. *Parashorea lucida* and *Shorea conica* are the most conspicuous species.

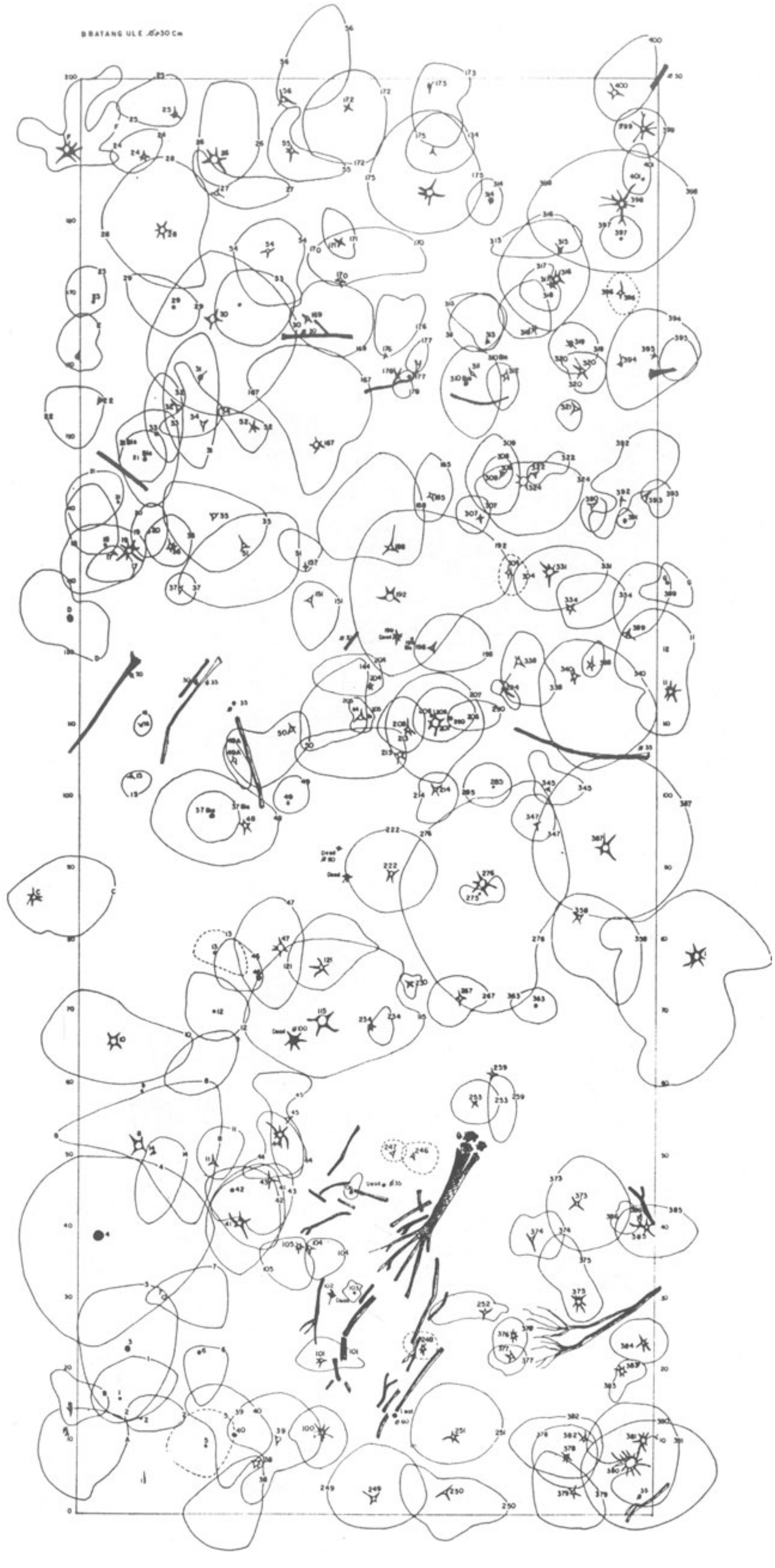


Fig. 65b.

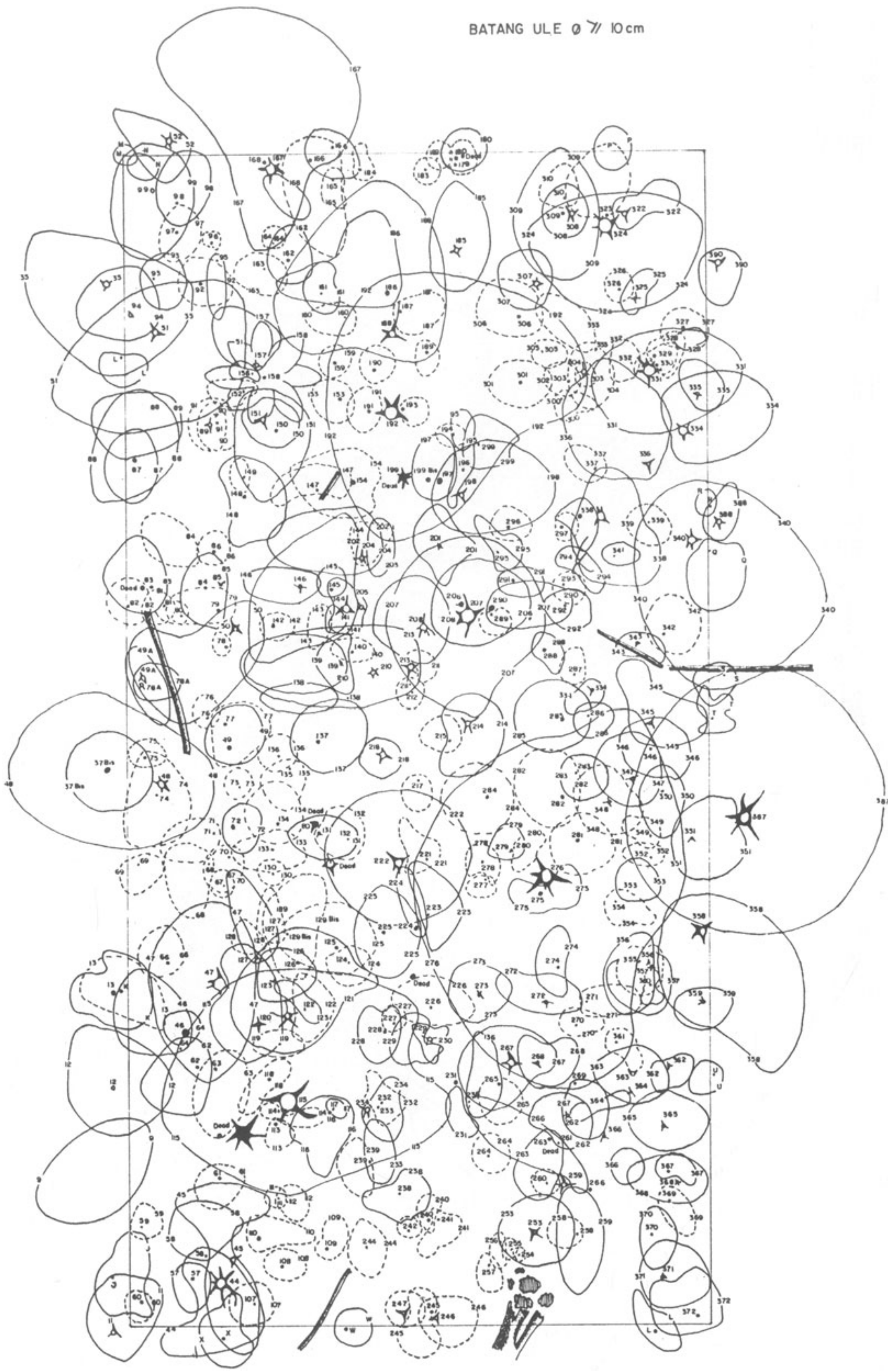


Fig. 65c.

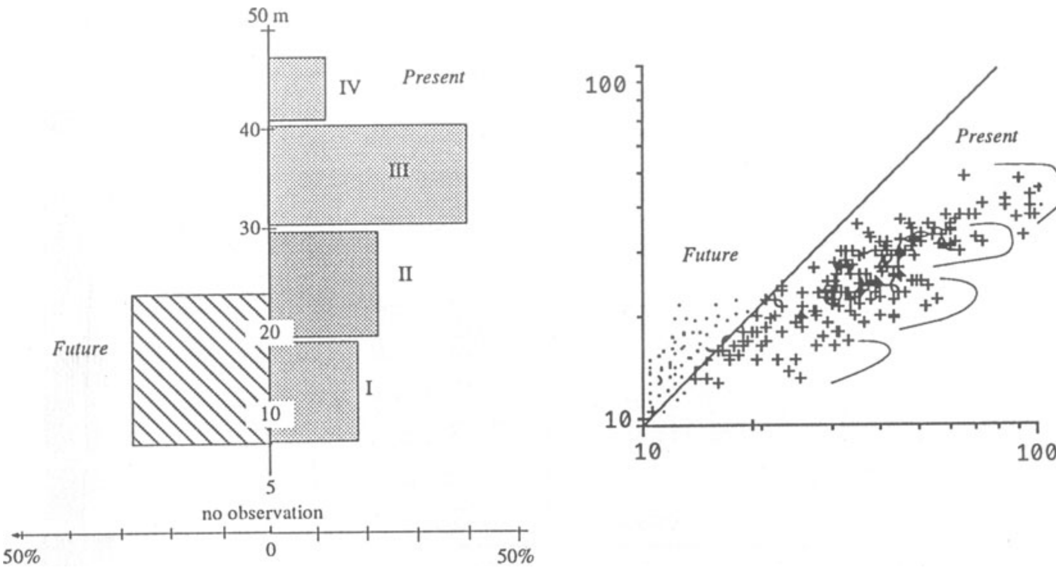


Fig. 66. Height-diameter relationship, stratification, number and cover of the structural ensembles in a low elevation hill forest on granites (Eastern Barisan foothills, Jambi). Tree density is lower and the tree crowns are smaller: the coverage per structural ensemble is then less than in the lowlands, besides an overall phytomass that remains high because of the abundance of large trees.

like *Shorea ovata*, *Hopea* cf. *auriculata* and *H.* cf. *beccariana*.

Species of the canopy include also *Parashorea lucida* and *P. aptera*, other dipterocarps which are more abundant than in the lowlands, *Alstonia scholaris* (Apocynaceae), *Albizia splendens* (Mimosaceae), and the appearance of *Whitfordiodendron atropurpurea* (Fabaceae), *Magnolia elegans* (Magnoliaceae), and *Artocarpus anisophyllus* (Moraceae) indicates a hillside habitat.

The middle and lower structural ensembles are occupied by most lowland Burseraceae (*Dacryodes laxa* often abundant), but differences are observed in the appearance or abundance of *Crypteronia griffithii* (Crypteroniaceae), *Kitabalia maingayi* (Monimiaceae), *Ctenolophon parvifolius* (Linaceae), *Chisocheton patens* (Meliaceae), *Gymnacranthera farquhariana*, *Horsfieldia polyspherula*, *H. wallichii*, *Knema* cf. *lampongensis* (Myristicaceae), *Pellacalyx lobbii* (Rhizophoraceae), *Aidia cochinchinensis* (Rubiaceae), and *Diospyros lanceifolia* (Ebenaceae).

On granite substrata, the forest structure changes somewhat. Tree density is lower than on the sediments (80–90 individuals /ha with diameters $\geqslant 30$ cm; 550–600 individuals ha^{-1} with diameters $\geqslant 10$ cm), but biomass remains high (390–420 t/ha) which means that globally, the large diameter classes are often dominant. Undergrowth is relatively sparse (Fig. 65 and 66).

Specific features appear when the representativeness of the various families is taken into consideration (Table 18).

Overall specific diversity remains high ($D = 0.975 \pm 0.005$ over four times 0.25 ha), and the major differences involve the respective representations of certain families. In particular, Meliaceae and Sapindaceae (and, to a lesser extent, Moraceae) occupy a position that they do not have in the lowlands. Specific diversity diminishes for numerous Dipterocarpaceae, Burseraceae, Clusiaceae, Fabaceae, and Polygalaceae, but the overall representation of these families remains high due to a greater number of individuals of the same species.

The importance of *Parashorea lucida* is noteworthy. This dipterocarp represents over 30% of all individuals and 25% in term of dominance for trees with a diameter greater than 30 cm. This dominance, which is also encountered in the metamorphic and limestone hills, cannot be explained compared with the forests on the surrounding sedimentary rock. The canopy dominated by *Parashorea lucida*, *Shorea parvifolia*, *S. conica* and to a lesser extent by *Shorea singkawang* and *S. bracteolata*, is also occupied by *Li-*

Table 18. Abundance and dominance of the ten most represented families in low elevation hill forests.

Abundance	*Dominance*
Euphorbiaceae	Dipterocarpaceae
Dipterocarpaceae	Euphorbiaceae
Meliaceae	Meliaceae
Sapotaceae	Fagaceae
Burseraceae	Myrtaceae
Flacourtiaceae	Anacardiaceae
Myristicaceae	Sapindaceae
Lauraceae	Sapotaceae
Myrtaceae	Moraceae
Sapindaceae	Burseraceae

thocarpus (Fagaceae), *Parinari* (Chrysobalanaceae) and *Eugenia* (Myrtaceae) unfortunately unidentified as yet, Anacardiaceae such as *Mangifera swintonoides*, Meliaceae like *Aglaia crassinervia*, *Chisocheton patens*, as well as by *Pometia pinnata*, a Sapindaceae, are often very abundant at higher altitudes. Two Euphorbiaceae easily reaching a height of 25 to 30 m, *Drypetes subsymetrica* and *Neoscortechinia forbesii*, are also abundant in the canopy.

Middle-level structural ensembles at 14 to 22 meters are still dominated by Euphorbiaceae (*Aporusa elmeri*, *A. lunata*, *Neoscortechinia forbesii*, *Drypetes subsymetrica*, *D. polyneura*, *Spathiostemon javensis*, *Cephalomappa penangensis*), numerous Meliaceae (*Aglaia aspera*, *A. forbesii*, *A. kabaensis*, *A. oligocarpa*, *Chisocheton pentan, drus*, *Dysoxylum macrocarpum*), and Myristicaceae (*Horsfieldia sucosa*, *Knema hookeriana*, *K.* cf. *lampongensis*, *K. latifolia*, *K. mandarahan*, *K. sumatrana*, *Myristica malaccensis*). These forests contain *Terminalia bellirica*, a species characteristic of regions with a marked dry season.

The palm *Arenga obtusifolia* is often characteristic of the tree undergrowth, and is associated with *Xanthophyllum affine* (Polygalaceae), *Nauclea officinalis* (Rubiaceae), *Brucea bruceadelpha* (Simaroubaceae) and *Gonocaryum gracile* (Icacinaceae), frequently encountered.

North-south variations. The low hills are almost completely deforested in the South and North of the island, and it was therefore impossible to compare the forest types of these regions with those of the center. At this time, it is imperative to establish permanent plots in the few regions which are still fairly intact and to widen the scope for comparative sampling between the forest types growing on granite, metamorphic, volcanic and sedimentary rocks. Comparisons must no longer be limited to structure and floristics, but must also be made between the way ecosystems function.

Plant formations on medium altitude non-karst hill zones (450–800 *m*)

ɿe primary forest

Structure and floristics. Several structural ensembles are still visible. Architectural analysis is feasible in spite of the steep slopes and gives rise to a few general remarks (Fig. 67).

On volcanic rocks east of the Barisan (Batang Merangin, Bukit Lengayang), the canopy is high overhead on the crests of hills (35–40 m) with emergent trees often reaching heights of 55 meters (Fig. 68). Dipterocarps are less abundant but remain co-dominant with Fagaceae and Burseraceae (Tab. 19). *Shorea platyclados* appears as from an altitude of 500 m, but the most abundant and dominant species is *Hopea* cf. *beccariana* which becomes the major component of the canopy, reaching impressive sizes on the crests. These giants are accompanied by *Shorea ovalis*

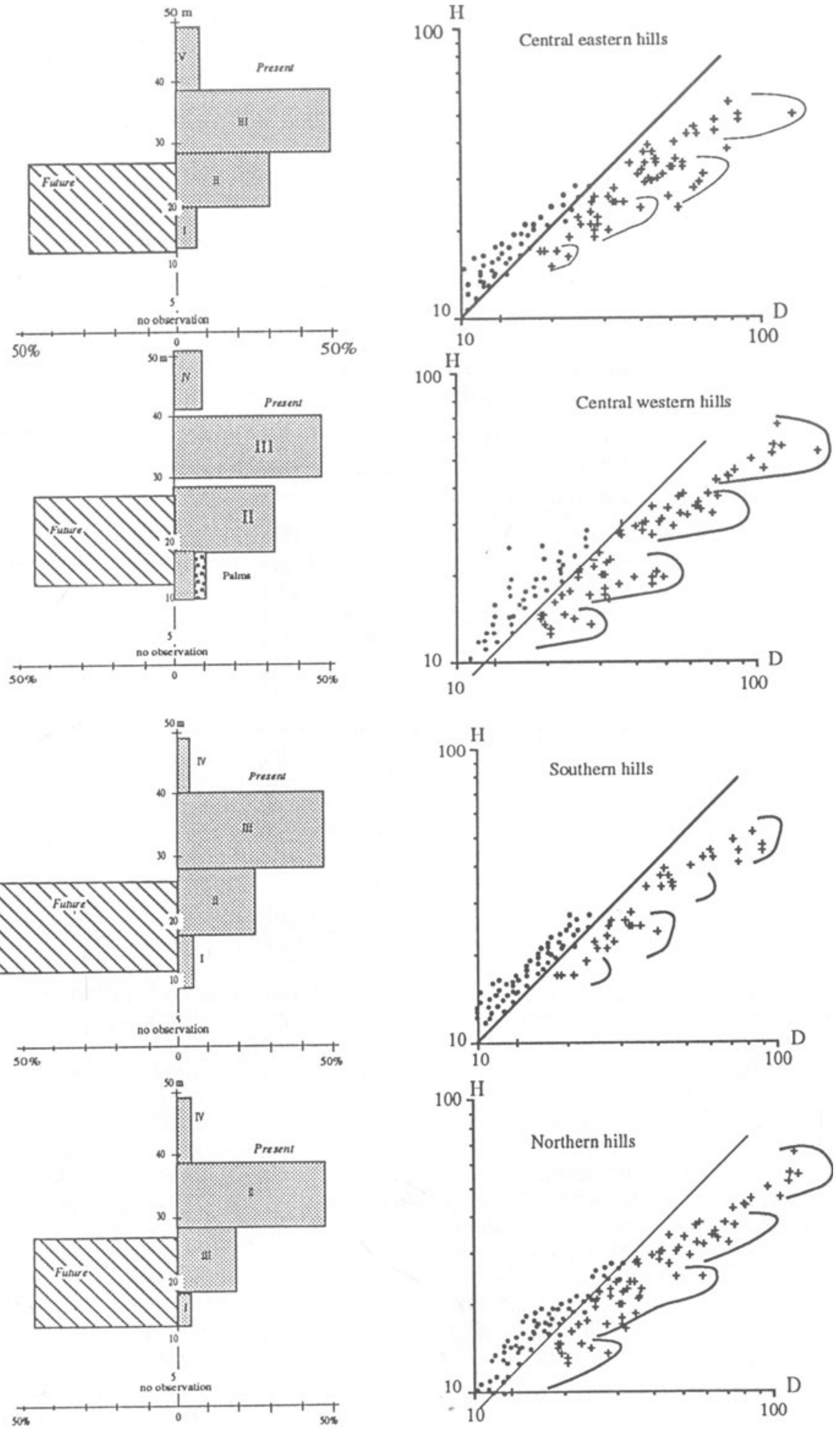


Fig. 67. Height-diameter relationship, stratification, number and coverage of the architectural ensembles in the medium elevation hill forest type (400–800 m). Overall forest architecture is similar within this zone for the entire island. Vertical structure is similar to that of the lowland forest, but cover is less, because of the very steep slopes that seem to influence tree density.

Crown planimetry (m2)				Relative cover	
				% total surf.	% cover surf.
Trees of the Present					
	Structural ensemble IV	452		23	24
	Structural ensemble III	840		42	45
	Structural ensemble II	516		26	28
	Structural ensemble I	111		6	6
		Total	**1919**	96	104
Trees of the Future			1538	77	83
Trees of the Past			125	6	7
		Total	**3581**	179	193
Plot surface			2000	100	
Gaps			149	7	
Covered surface			1851		100
Crown overlapping on			1730		93

Gordonia excelsa (31,27,20,44,74,63,69,65), Helicia serrata (75,76,77,82 ,66,93,111),Callophylum flavo-ramulum (53,123,92,99), Hydnocarpus kunstleri (17, 105,43,87), Hopea cf. beccariana (33,28,37), Lithocarpus pseudomoluccus (1,24,48), Lithocarpus sp. 2 (9,2,48), Lithocarpus cf. encleisacarpus (121, 110,60), Mastixia trichotoma (56,39,41), Quercus argentata (3,49,126), Quercus sp. (26,15,127), Santiria cf. laevigata (57,54,72), Castanopsis cf. johorensis (115,131), Cinnamomum porectum (36,116), Diospyros sp. (16,91), Diospyros cf. frutescens (11,19), Diplospora singularis (118,98), Elaeocarpus cf. palembanicus (83,97), Eugenia sp (85,52), Ganua palembanica (32, 73), Litsea (88,129), Pometia pinnata (20,25), Santiria rubiginosa (100, 103), Acer caesium ?, Adinandra acuminata 70, Aglaia elliptica 95, Aquilaria malaccensis 67, Ardisia 45, Artocarpus sp 22, Baccaurea cf. pyriformis 125, Barringtonia scortechinii 124, Bhesa paniculata 112, Bouea oppositifolia 59, Buchanania sessilifolia 21, Calophyllum pulcherrimum 35, Canarium caudatum 106, Canarium patentinervium 68, cf. CELASTRACEAE 144, Endiandra 12, ICACINACEAE 23, Lauraceae 5, ROSACEAE 78, EUPHORBIACEAE 108, Chionanthus 8, CONNARACEAE 103, Cratoxylum 104, Drypetes sp 81, Drypetes cf. polyneura 94, Engelhardtia serrata 64, Eugenia cf. lineata 7, Euodia cf. aromatica 79, Eurya acuminata 71, Garcinia 60, GUTTIFERAE indet 109, Hopea pachycarpa 90, Horsfieldia 6, Lithocarpus sp. 1 29, Lithocarpus lucidus 46, Macaranga sp 128, Madhuca magnifolia 42, Nephelium ramboutan-ake (62,113), Nothaphoebe sp 58, Palaquium sp 86, Payena leerii 25, Persea 84, Popowia pisocarpa 117, Prunus sp 50, Ptychopyxis javanica 18, Quercus subsericea 30, RUBIACEAE 4, Santiria tomentosa 130, Schima wallichii 119, Shorea ovalis 120, Shorea platyclados 14, Eugenia magnoliaefolia 89, Urophyllum sp 101, Paranephelium xantophyllum (107,80), Ziziphus angustifolius 61.

Fig. 68. Hill dipterocarp rain forest on ridge: species composition and structural ensembles planimetry (Bukit Lengayang, alt. 800 m, andesitic rocks, Merangin, Jambi). The cover of ensemble IV is generally high because of the huge *Shorea platyclados* and *Hopea* cf. *beccariana*. Noteworthy also is the importance of the future tree cover; regeneration seems always better on the ridge than on the slopes of the hills. (Fold out.)

Fig. 68
Bukit Lengayang (Kerinci National Park)
Upper Batang Merangin
JAMBI
Alt. 750-800 m a.s.l.

ssp. *sericea*, *S. ovata*, *Quercus argentata* and *Santiria laevigata*.

The following are also well represented in the canopy: Clusiaceae such as *Calophyllum flavo-ramulum*, *C. pulcherrimum*, Burseraceae like *Canarium patentinervium* and *C. caudatum*, Anacardiaceae such as *Buchanania sessilifolia* and *Drymicarpus luridus*, Sapotaceae such as *Ganua* cf. *palembanica* and other species which have not as yet been determined, many Fagaceae such as *Lithocarpus* cf. *pseudomoluccus*, *L. lucidus*, *L.* cf. *encleisacarpus*, *Quercus subsericea*, and also *Cinnamomum porrectum* (Lauraceae), *Acer caesium* (Aceraceae), *Nephelium ramboutan-ake* (Sapindaceae), *Eugenia magnoliaefolia* (Myrtaceae).

In middle and lower structural groups, the most representative species are Euphorbiaceae, *Baccaurea pyriformis*, *Drypetes* cf. *polyneura*, *Ptychopyxis javanica*, *Aporusa frutescens*, some Theaceae, *Gordonia excelsa* and *Adinandra acuminata* and Rubiaceae *Diplospora singularis*, *Urophyllum arboreum*, *Lasianthus chrysotrichus*, associated with *Hydnocarpus kunstleri* (Flacourtiaceae), *Helicia serrata* (Proteaceae), *Castanopsis* cf. *johorensis* (Fagaceae), *Aglaia elliptica* (Meliaceae), *Ziziphus angustifolius* (Rhamnaceae), and *Euodia* cf. *aromatica* (Rutaceae).

Important phenological and productivity studies undertaken at Ketambe in the north of the island by van Schaik and Mirmanto (1985), and van Schaik (1986) enhance our understanding of the dynamics of these forest types. These reveal close relationships between structure, litter production and substratum age. As substratum fertility decreases, litter production diminishes, the surface area of the mature phases increases and clearings and treefalls consequently diminish. Annual litter production (leaves) varies from 4.67 to 8,31 tonnes/ha. The phenological production cycles of young leaves, flowers and fruit follow seasonal rhythms. Considerable differences were noticed between two adjacent valleys, which again stresses the danger of generalizing on the strength of insufficient sampling and measurements in tropical rain forest.

North-south and east-west variations. The structure of the forest is similar at the same altitude on the western sides of the Barisan (Fig. 69 a and b, Muarasako), and many species common to both locations are, of course, encountered. There are differences in emergent trees and the canopy. Here, *Shorea assamica* and *S. platyclados* are associated with *Hopea* sp. nov. (aff. *auriculata*), and also with *Octomeles sumatrana*, a very abundant *Sterculia*, *Santiria laevigata* and numerous *Terminalia*, enormous *T. subspathulata* and a much more common species which is as yet undetermined.

In the canopy, located at a height ranging from 28 to 34 meters, the dominant species are Burseraceae (*Canarium caudatum*, *C. denticulatum*, *C. dichotomum*), Lauraceae (*Beilschmiedia assamica*, *Cinnamomum porectum*), Anacardiaceae (*Dracontomelon dao*, *D. costatum*), Sapindaceae (*Pometia pinnata*), Bignoniaceae (*Radermachera glandulosa*), Juglandaceae (*Engelhardtia spicata*), and Staphyleaceae (*Turpinia* sp.).

At lower levels (20–25 m), diversity is very high with numerous species of *Vatica*, (*V. perakensis*, *V. cinerea* and *V. obovata*), Euphorbiaceae such as *Blumeodendron kurzii*, *Neoscortechinia forbesii*, *Ptychopyxis bacciformis*, various Meliaceae such as *Aglaia argentea*, *A.* cf. *ganggo*, *A. eximia*, *A. teijsmanniana* and, above all, *Aglaia odoratissima*, *Dysoxylum alliaceum*, *D.* cf. *cauliflorum*, *D. densiflorum*, *Chisocheton* cf. *macrophyllus*, and the abundant *Sandoricum koetjape*. The following are still often encountered: Myristicaceae *Horsfieldia majuscula*, *H. triandra*, Styracaceae *Styrax paralleloneurum*, *S. serrulatum*, Clusiaceae *Calophyllum exiticostatum*, *C. venulosum*, as well as *Mastixia trichotoma* (Cornaceae), *Distylium stellare* (Hamamelidaceae), and *Artocarpus lanceifolius* (Moraceae).

The lowest levels are occupied by many Euphorbiaceae *Antidesma montanum*, *Baccaurea* cf. *parviflora*, *B.* cf. *racemosa*, *B. lanceolata*, *B. parviflora*, *B. sumatrana*, *Botryophora geniculata*, *Drypetes* cf. *minahassae*, *Glochidion* cf. *lutescens*. A large number of species grow here, particularly Clusiaceae, *Garcinia parvifolia*, *G. scortechinii*, Proteaceae, *Heliciopsis* cf. *insisa*, and the extremely abundant *Helicia serrata*, Rhizophoraceae, *Anisophyllea griffithii*, *Carallia brachiata*, and also *Scolopia spinosa*, *Distylium stellare*, *Knema malayana*, *Ziziphus angustifolius*, *Neonauclea lanceolata*, *Grewia laurifolia*, *Saurauia* sp., *Euonymus javanicus*, and *Crypteronia paniculata*.

These forests on steep slopes are the perfect habitat for Rafflesiaceae. One still encounters *Rafflesia arnoldi*, *R. gadutensis* (Meijer 1984) and

a b

Crown planimetry (m2)				Relative cover	
				% total surf.	% cover surf.
Trees of the Present					
	Structural ensemble IV	971		24	27
	Structural ensemble III	2552		64	71
	Structural ensemble II	1667		42	47
	Structural ensemble I	562		14	16
		Total	5752	144	161
Trees of the Future			1932	48	54
Trees of the Past			291	7	8
		Total	7975	199	223
Plot surface			4000	100	
Gaps			428	11	
Covered surface			3572		100
Crown overlapping on			4403		123

		Muarasako, slopes > 30°			
	Dominance trees of the Present			Dominance trees of the future	
DIPT	Hopea	sp.aff.auriculata	MORA	Artocarpus	sp.
DIPT	Shorea	platyclados	DIPT	Vatica	perakensis
SAPO	Payena	sp.	PROT	Helicia	serrata
FAGA	Castanopsis	sp.	EUPH	Glochidion	sp.
GUTT	Calophyllum	sp.	ACER	Acer	caesium
BOMB	Durio	sp.	STER	Sterculia	sp.
MELI	Sandoricum	koetjape	MYRS	Rapanea	sp.
DIPT	Vatica	perakensis	MORA	Artocarpus	lanceifolius
		Muarasako slopes < 30°			
	Dominance trees of the Present			Dominance trees of the future	
COMB	Terminalia	subspathulata	EUPH	Neoscortechinia	forbesii
BURS	Santiria	laevigata	LAUR	Actinodaphne	sp.
DIPT	Shorea	assamica	MELI	Sandoricum	koetjape
SAPO	Palaquium	sp.	SAPO	Palaquium	sp.
STER	Sterculia	sp.	POLY	Xanthophyllum	affine
DIPT	Shorea	platyclados	SAPI	Pometia	pinnata
SAPI	Pometia	pinnata	TILI	Grewia	laurifolia
EBEN	Diospyros	sp.	MELI	Dysoxylum	alliaceum

Fig. 69. Hill dipterocarp rain forest on slope: floristic dominance and coverage of the structural ensembles (Andesitic rocks, alt. 600 m, Muarasako, western Barisan, West Sumatra). On these sometimes very steep slopes, large trees are grouped, tree-fall gaps are common and much more damaging to nearby forest. This results in a more "clumped" forest physiognomy with more tree crown overlap than for the forest on ridges. *Shorea assamica*, *S. platyclados*, *Hopea* sp. nov. (aff. *auriculata*), *Octomeles sumatrana Terminalia* spp. are conspicuous emergents.

Rhizanthes zippelii, a much more modest species, but just as astonishing.

The forest types described above are entirely comparable to those studied further North by Hotta and his collaborators (Hotta et al. 1984, 1986, 1989). Ogino et al. (1984), Kohyama & Hotta (1986), Kohyama et al. (1989) described the structure and biomass. For a structure equivalent to that of Muarasako, they measured biomasses ranging from 33 to 60 kg/m^2. Although their low altitude plots were fairly disturbed (near Padang), their floristic inventory contains the

Table 19. Abundance and dominance of the ten most represented families in medium elevation hill forests.

Abundance		Dominance	
Euphorbiaceae	8,5	Fagaceae	13,5
Fagaceae	7	Dipterocarpaceae	10,7
Burseraceae	6,6	Burseraceae	9
Meliaceae	5,8	Sapotaceae	6,6
Myrtaceae	5,6	Meliaceae	4,7
Dipterocarpaceae	5	Euphorbiaceae	4,6
Guttiferae	3,8	Moraceae	4,4
Sapotaceae	3,8	Sterculiaceae	3,8
Sapindaceae	3,6	Guttiferae	3,8
Lauraceae	3,4	Myrtaceae	3,7

main species characteristic of these hillside forests of the west coast.

Variations in facies and secondary types

The most noteworthy facies include forest types developed on volcanic tuffs. These highly unstable terrains are subject to intense erosion. Cliffs are often observed, like those along the Merangin near Temiai (Kerinci). Soils are rather distinctive, with, in that particular case plant debris buried at depths of 1.5 to 2 m below a gley horizon (cf. Fig. 64 a).

The species encountered on this terrain are reminiscent of the flora on granite massifs, although the forest structure is quite different (Fig. 70). Dipterocarps are poorly represented on steep slopes at an altitude of 500 to 800 meters, and emergent trees are mainly Anacardiaceae such as *Dracontomelon costatum*, Fagaceae, *Quercus argentata*, Sapindaceae, *Pometia pinnata*, Meliaceae *Dysoxylum acutangulum*, Sterculiaceae, *Pterospermum javanicum*, Simaroubaceae, *Irvingia malayana*, and many species of hemi-epiphytic figs commonly known as 'strangling' figs due to the thick root network they develop around the trunk of the supporting tree. The canopy is lower, between 25 and 30 m, and is characterized by *Podocarpus wallichianus*, *Alseodaphne oblanceolata*, *Chisocheton ceramicus*, *Neonauclea calycina* and many of the species mentioned above.

The lower levels are mainly occupied by:

- Meliaceae *Aglaia* cf. *speciosa*, *A. crassinervia*, *Lansium domesticum*
- Sapotaceae *Ganua* cf. *kingiana*, *Payena* cf. *dantung*
- Euphorbiaceae *Baccaurea pyriformis*, *Aporusa frutescens*
- Myristicaceae *Knema sumatrana*, *Myristica crassa*
- Sapindaceae *Paranephelium xestophyllum*, *Nephelium lappaceum*
- Annonaceae *Stelechocarpus cauliflorus*, *Polyalthia rumphii*
- Rubiaceae *Neonauclea lanceolata*
- Moraceae *Artocarpus anisophyllus*
- Aceraceae *Celtis rigescens*.

A liana, *Ziziphus horsfieldii*, is particularly abundant, and the undergrowth especially rich in species of *Mallotus* (*M. rufidulus*, *M.* cf. *miquelianus*, *M. oblongifolius*). The most common ground species include *Donax canniformis*, Marantaceae, and *Trevesia burckii*, Araliaceae. *Rafflesia hasseltii*, which until now had only been observed further North, was also collected in this environment. *Casuarina nobilis* is abundant on rocky outcrops.

Although not enough samples were taken on hillsides, it is worth reporting the state of the forests dominated by *Dryobalanops oblongifolia* in the Sibolga regions. Their structure is identical to the formations studied further South, with emergent trees reaching heights of 40 to 45 m for a canopy situated at 20 to 30 m. Besides *D. oblongifolia* we encountered the species of classic hillside flora such as *Shorea maxwelliana*, *S. ovalis*, *S. ovata*, and *Hopea* cf. *beccariana*.

As a reminder, it is also worthwhile mentioning the forest types which we did not study as intensely i.e., riverside forests in hilly and mountainous zones. These formations often grow along the banks of torrents where rheophytes sometimes establish (Van Steenis 1981). Crowns of *Pometia pinnata*, *Pterospermum javanicum*, *Aglaia argentea*, and the architecture of *Octomeles sumatrana*, *Bombax valetonii*, *Terminalia* spp. are recognizable in the valley landscapes. That is also the natural habitat for a number of *Macaranga*, *Mallotus*, *Ficus* and *Dendrocnide*, Rubiaceae such as *Nauclea officinalis*, *N. orientalis*, *N. subdita*, species like *Bischofia javanica*, *Firmiana malayana*, or *Harpullia arborea* ('Kayu pacet'), fairly rare and sought after for its veined sapwood in the Kerinci region.

Landslides on steep forest slopes are mainly colonized by Euphorbiaceae *Macaranga heynei*, *M. hullettii*, *Mallotus korthalsii*, *M. resinosus* associated with *Ficus semicordata*, *Firmiana malayana* and *Villebrunea rubescens*.

At these altitudes, secondary formations are also extremely varied. *Ficus* cf. *padana* colonize the hills of Lampung while *Piper aduncum* soon takes over from the alang-alang in the eastern-Central region.

Secondary *Musa* formations are also found in these areas composed mainly of *M. acuminata* subsp. *halabensis* and *M. salaccensis*, but the most frequently found types are secondary thickets of *Eupatorium inulifolium*, *Clibadium surinamense* or *Lantana camara* colonized by *Macaranga tanarius*, *Debregeasia longifolia*, *Villebrunea rubescens*, *Geunsia pentandra*, *Callicarpa albida*, *Commersonia bartramia*, or *Homalanthus populneus*.

Towards an altitude of 700–800 m, the most degraded formations correspond to grasslands with *Arundinella setosa*, *Thysolaena maxima* or *Themeda arundinacea* punctuated with islets of shrubs: *Rhodoleia championi*, *Saurauia distasosa*, *Brucea javanica*, *Nauclea* cf. *cyrtopoda*, *Rhodomyrtus tomentosus*, *Daphniphyllum glaucescens*, *Weinmannia blumei*, *Eurya acuminata*, *Adinandra dumosa*, *Itea* sp. and *Wendlandia* sp..

Thickets of *Baeckea frutescens* (Myrtaceae) whose tree shape is reminiscent of *Casuarina* are often observed on the abrupt and rocky slopes of the metamorphic ranges.

Plant formations on karst hills

Location, extent and forest status

In Sumatra, karsts occupy large areas mainly to the north-west of Aceh province, but have not as yet been explored. Today, they are fast being converted into quarries for the cement industry. The island's center also has some interesting massifs located between Payakumbuh and Sijunjung (Ullastre-Martorell 1980), and also North-east of Mount Kerinci (Bukit Cermin – Gunung Sunggiri). We were able to perform detailed studies only for a massif located in the eastern range of the Barisans not far from the town of Sungaidareh, where the more pronounced dry season adds to the singularity of the region. The whole limestone vegetation only accounts for approximately 1% of the islands surface area, but its high endemism, plus the natural beauty of the scenery, make it a priority habitat for conservation. Today, most karst mountain ranges are located outside reserves.

The physical environment

Geomorphology. Karst mountains have a wide variety of habitats, depending on the slope, soil thickness, the nature of the bed rock itself, especially its purity, and also the duration of the erosion processes. In Sumatra, these ranges are often table-like, frequently alternating with veins of quartzite or slate. Five morphological units are easily distinguished, which were sampled using vegetation transects: the bottom of slopes with a 30° to 45° gradient, slopes steeper than 45° beyond the cliffs, crests and crevassed pinnacles, cliffs and 'mesa' type summits (Fig. 71).

Soils. Soils are generally shallow on summits and pinnacles. They are dark brown-red, fine textured with a granular structure and have developed on materials rich in calcium or magnesium carbonate. Water percolates through them very quickly, which causes a water deficiency during the short dry periods. The calcium carbonate content is high, giving a pH in the region of 7 in the A horizon. A good texture and the high organic matter content give a CEC above 50 meq/100 gr of clay (Fig. 72 a).

Lower down on moderate slopes, soils become

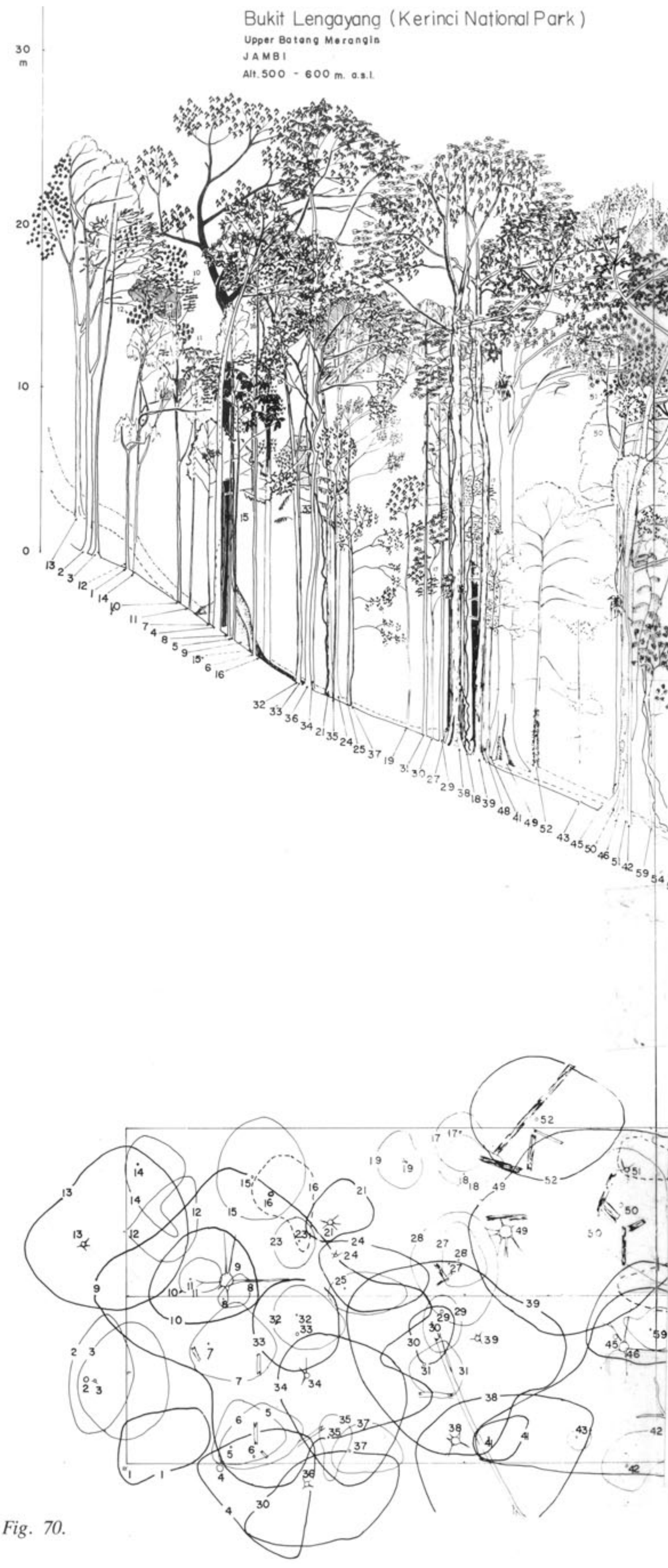

Bukit Lengayang (Kerinci National Park)
Upper Batang Merangin
JAMBI
Alt. 500 - 600 m. a.s.l.
30 m
20
10
0

Fig. 70.

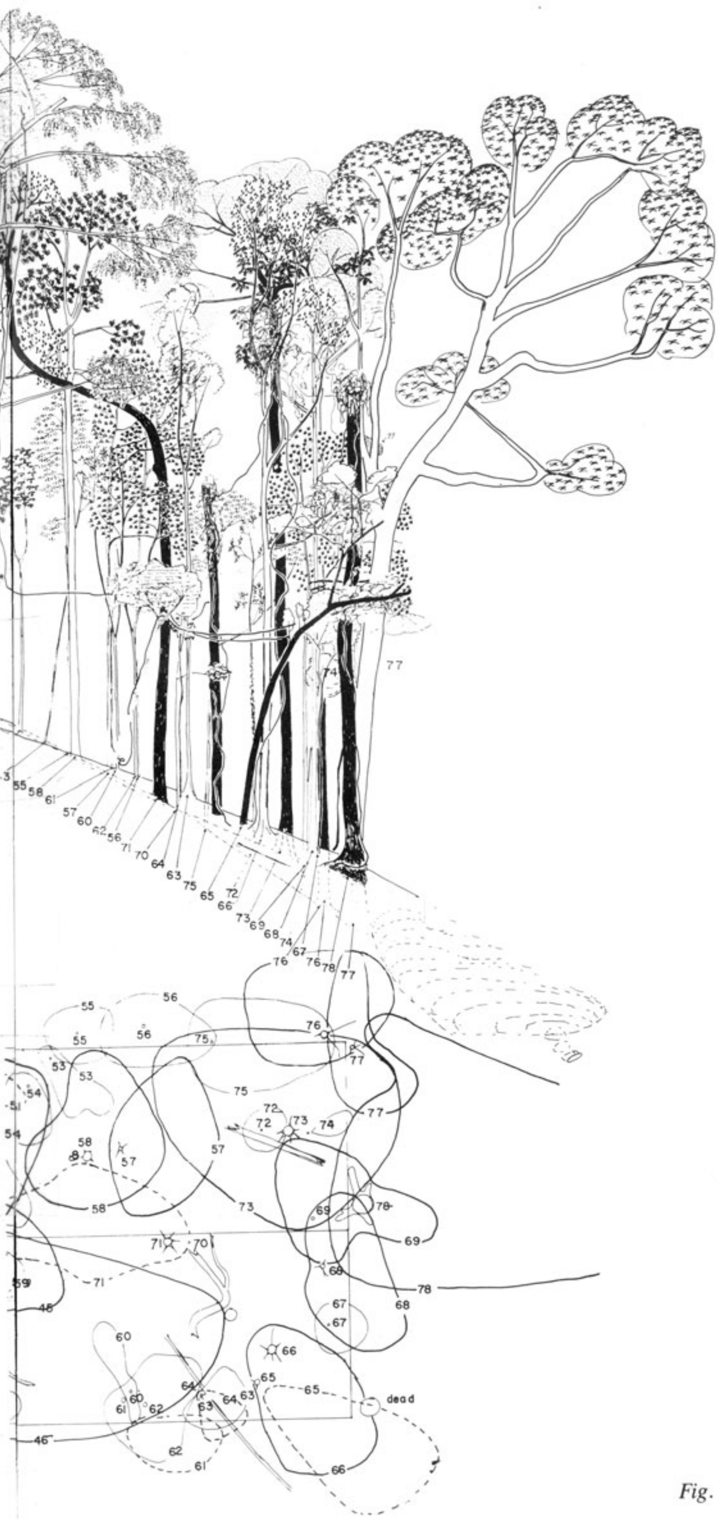


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Fig. 70.

Neoscortechinia forbesii (75,55), Acronychia 14, Aglaia crassinervia (36,54), Aglaia cf. speciosa 64, Alangium 3, Alangium 73, Alseodaphne oblanceolata 25, ANNONACEAE 29, Aphanamixis 47, Aporusa frutescens (30,22,41), Artocarpus integer 45, Artocarpus anisophyllus 12, Baccaurea 57, Baccaurea cf. pyriformis (5,44), Celtis sp 61, Celtis rigescens 68, Chisocheton ceramicus 16, Cyathocalyx sp 50, Dacryodes costata 2, Diospyros 23, Diospyros buxifolia 27, Diospyros cf. frutescens 20, Dracontomelon costatum 63, Dysoxylum acutangulum 78, Elaeocarpus valetonii, 65, Eugenia sp (1,43,26), Eugenia cf. lineata (70,53), Ficus 46, Ganua palembanica 58, Ganua kingiana 59, Gironniera subaequalis (18,48,31), Helicia serrata 33, Irvingia malayana 38, Knema sumatrana 60, Lansium domesticum (17,10), Lithocarpus 39, Litsea sp 6, Mitrephora sp 74 ?, Myristica crassa 21, Neonauclea calycina 51, Neonauclea lanceolata (62,69,15), Nephelium lappaceum (11,37), Paranephelium xestophyllum (24,67), Payena dantung (56), Podocarpus wallichianus 4, Pometia pinnata (34,8), Quercus argentata (19,35,71), Quercus sp (9,66), Santiria rubiginosa (76,49), Semecarpus 40, Stelechocarpus cauliflorus (28,7,52), STERCULIACEAE 72, Ziziphus angustifolius (32,77).

Crown planimetry (m2)				Relative cover	
				% total surf.	% cover surf..
Trees of the Present					
	Structural ensemble IV	235		24	27
	Structural ensemble III	569		57	65
	Structural ensemble II	214		21	24
	Structural ensemble I	27		3	3
		Total	1045	104	119
Trees of the Future			313.5	31	36
Trees of the Past			83.5	8	9
		Total	1442	144	164
Plot surface			1000	100	
Gaps			121	12	
Covered surface			879		100
Crown overlapping on			562.5		64

Fig. 70. Hill rain forest on tuffs: floristic composition and coverage of the structural ensembles (Tuffs, alt. 600 m, Bukit Lengayang, eastern Barisan, Merangin, Jambi). The tree density is less than on other geological formations at the same elevation. Openings in the canopy represent a rather large area (10% of the total plot surface) and crown overlapping is low. Dipterocarps are almost absent, replaced by *Dracontomelon costatum*, *Quercus argentata*, *Dysoxylum acutangulum* and *Pterospermum javanicum*. Strangling figs are common. In the area, *Rafflesia hasseltii* is often encountered.

brown-yellow and the texture is rougher with a not well differentiated structure. pH is lower (6,4 to 6,7) (Fig. 72 b).

Bioclimate. In the region studied, total average rainfall is high at the nearest weather station (Sungaidareh), which is not very representative as it is too far east, just on the border of the area where the effects of the dry season can be more severe. Variability is high and certain dry seasons can last for up to 2 months (Fig. 73). The karst region forms part of this 'sheltered' zone east of Lake Singkarak. This rainfall regime has a considerable effect on the geomorphology and pedogenesis of these karsts in comparison with those of the west coast where rainfall is always high. Unfortunately, weather stations are almost non-existent near limestone formations.

The primary forest

Structure and floristics. The structure of the forest on the lower slopes around 500 meters in altitude is similar to that found at the same altitude on non-karst hills. The canopy seldom exceeds a height of 25–30 meters, but the occasional emer-

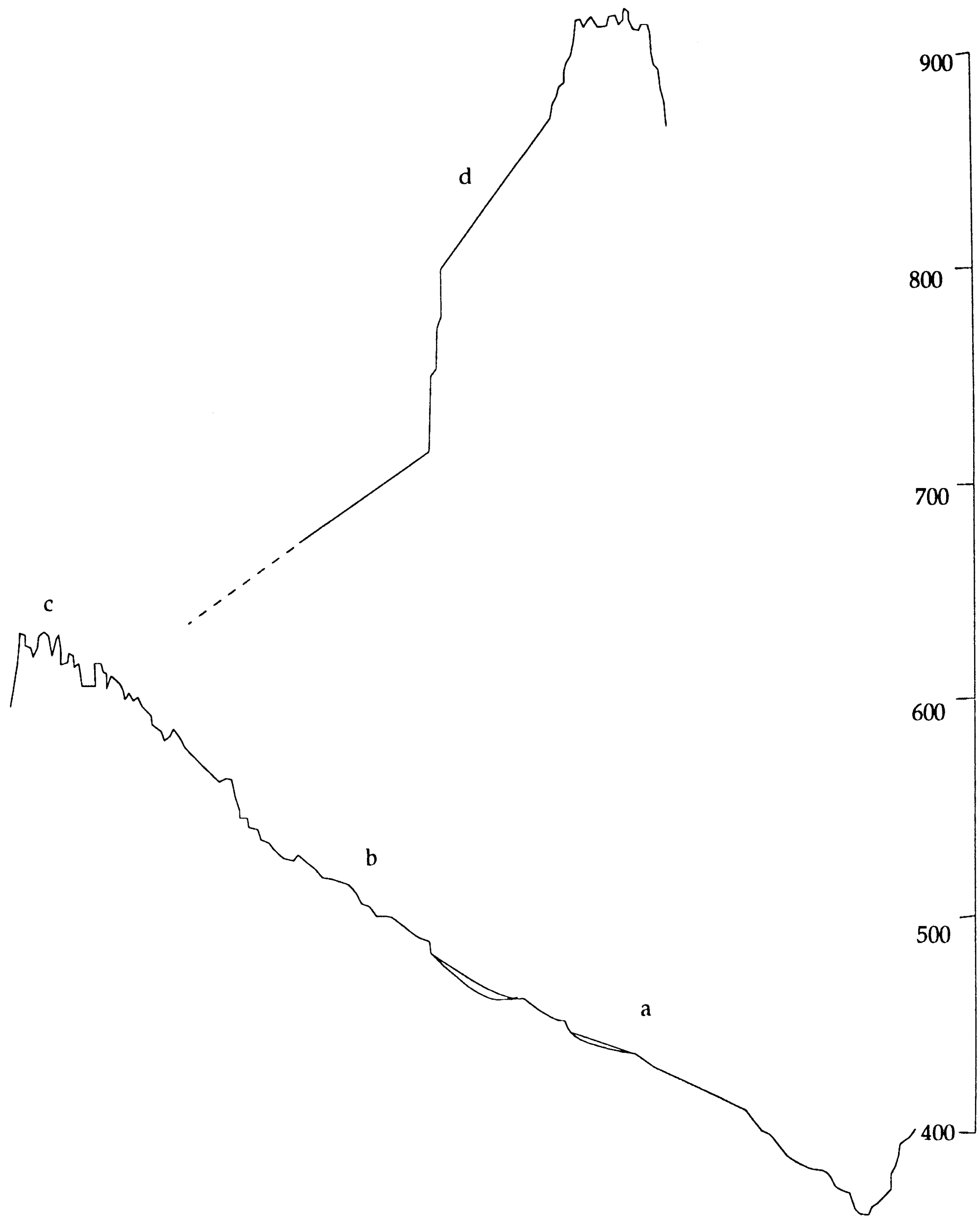


Fig. 71. Karst morphological units in Central Sumatra hills; location of vegetation sampling, Bukit Sebelah, Sungaidareh, West Sumatra.

gent tree can reach heights of 50 to 55 meters above the ground (Fig. 74). These trees are mainly *Parashorea lucida*, *Pometia pinnata* and a number of hemi-epiphytic figs, which are somewhat rarer. The canopy itself, dominated by these same species, is further occupied by *Aglaia oligocarpa*, *A. argentea*, *A. ganggo*, *Dysoxylum macrocarpum*, *Cratoxylum sumatranum*, *Schoutenia furfuracea*, *Dracontomelon dao*, *Margaritaria indica*, *Macaranga tanarius* (25 m high with a diameter of 40 cm!) *Ryparosa javanica*, *Diospyros toposoides*, *D. apiculata*, *Celtis philippensis*, *Vatica* cf. *cinerea*.

Species we collected from the lower structural groups include:

- Simaroubaceae, *Picrasma javanica*
- Flacourtiaceae, *Casearia tuberculata*
- Anacardiaceae, *Drimycarpus luridus*
- Annonaceae, *Stelechocarpus cauliflorus*, *Cyathocalyx sumatranus*

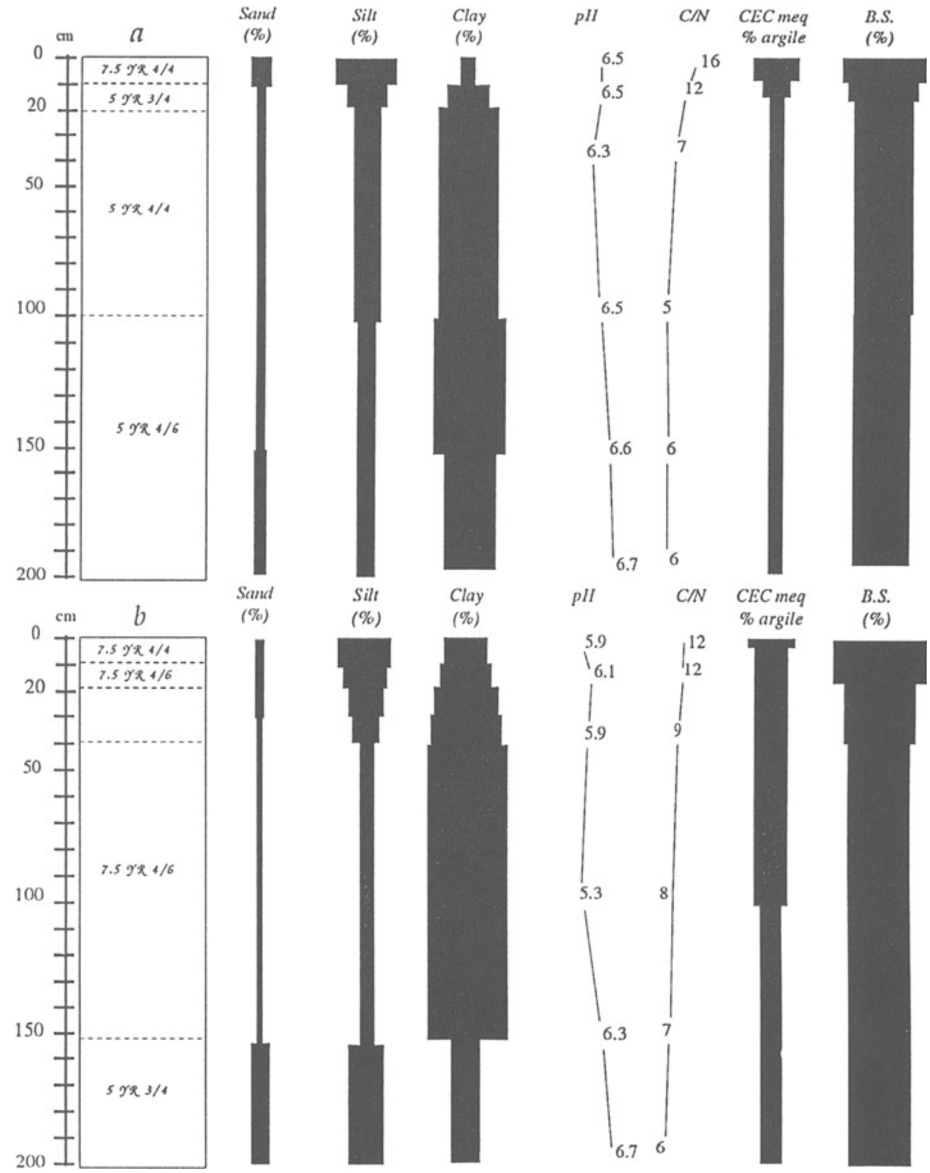


Fig. 72. Properties of soils on limestones: a: Lower slopes: soils are deep, dark yellowish brown, with a coarse sandy texture, and are weakly structured. They are a bit more acidic than soils of upper slopes. b: Upper slopes: soils are shallow, dark reddish brown, with a fine texture and a well-developed crumb structure. They have a higher organic content, at least in the upper horizons.

- Sapindaceae, *Paranephelium xestophyllum*
- Dichapetalaceae, *Dichapetalum gelonoides*
- Myristicaceae, *Horsfieldia sucosa*, *Knema stenophylla*
- Euphorbiaceae, *Croton* cf. *cascarilloides*, *C. argyratus*
- Ulmaceae, *Gironniera subaequalis*
- Hamamelidaceae, *Distyliopsis dunnii*
- Meliaceae, *Aglaia curtisii*, *A. elliptica*, *Chisocheton macrophyllus*
- Araliaceae, *Brassaiopsis* cf. *glomerulata*
- Dipterocarpaceae, *Shorea ovalis*, *Hopea dryobalanoides* and *H. pachycarpa*.

On the ground, a rattan, *Calamus pandanosmus* and the palm tree *Arenga obtusifolia* are amongst the most common species until half way

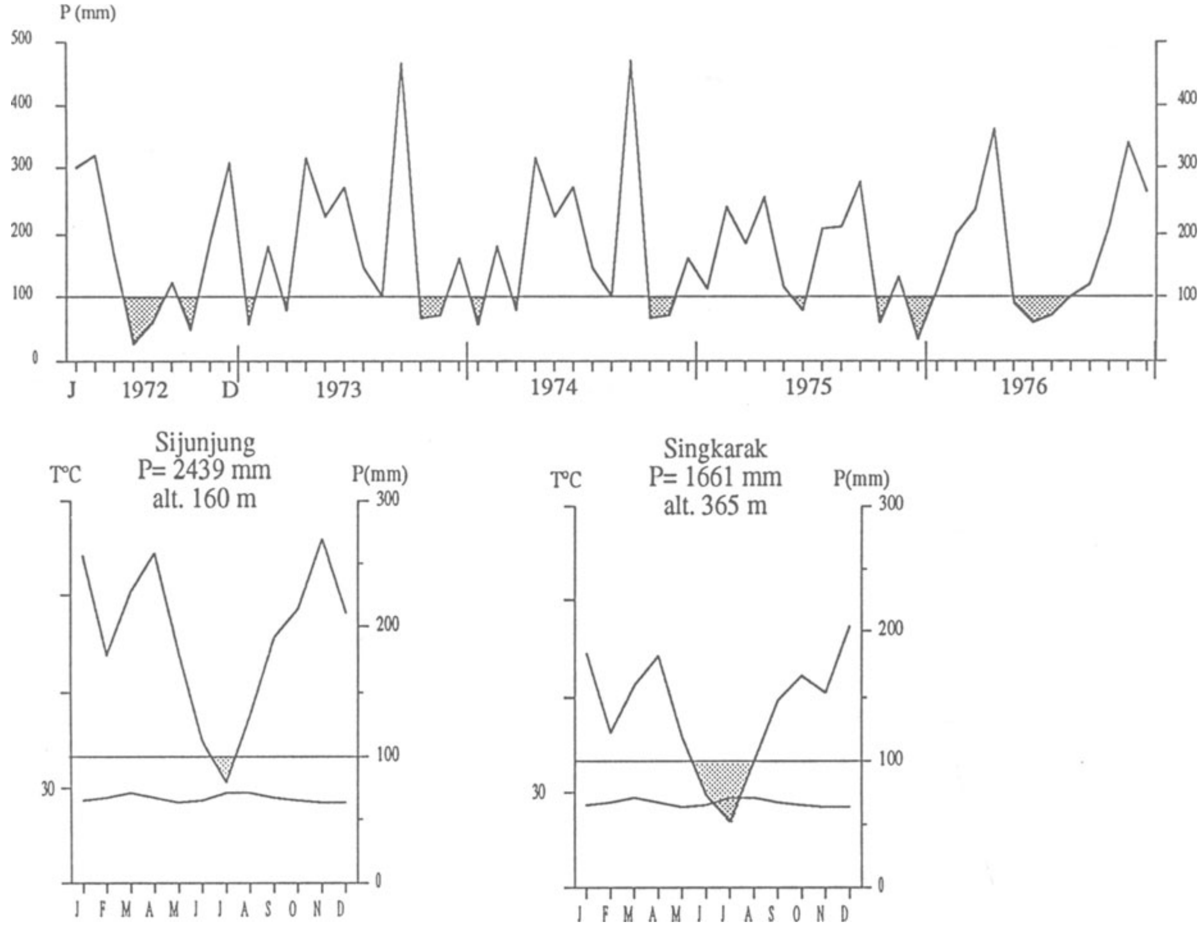


Fig. 73. Variability in length and period of occurrence of the dry season in the karst area east of lake Singkarak, West Sumatra. Mean value diagrams are almost meaningless.

up the slopes. This is also the favorite habitat of *Monophyllea hirtella* and *M. horsfieldii*, Gesneriaceae (Kohyama & Hotta 1986), as well as *Amorphophallus titanum* in the dampest places.

On the ridges, rocky outcrops break the surface everywhere and only the larger crevasses retain enough humus to support the tree growth. The forest diminishes considerably in size and is composed of a large number of thinner trunks (Fig. 74c and 75c). A few isolated emergent trees reach a height of 20 meters (*Cratoxylum sumatranum*, *Distyliopsis dunnii*, *Drypetes* sp., *Ganua* sp, *Eugenia* sp), but most trees culminate 5 to 10 (15) meters above the ground. Floristic diversity diminishes brutally in these facies dominated by *Distyliopsis dunnii*, *Celtis philippensis*, *Memecylon* cf. *edule* and *Cratoxylum maingayi*, often associated with species of *Drypetes*, *Chionanthus* and an as yet indeterminate *Pandanus*.

This same *Pandanus* is sometimes very abundant on cliff faces, accompanied by numerous Gesneriaceae (*Boea*), Begoniaceae and Lycopodiaceae (*Lycopodium squamosum*), *Diploclisia glaucescens* (Menispermaceae), a *Ventilago* (Rhamnaceae) and *Vallariopsis lanceifolia*, a hemi-epiphytic Apocynaceae.

Above the cliff faces, the forest is still high (Fig. 76). On these 55° slopes at an altitude of 800 meters one still encounters *Shorea platyclados*, well developed but rare, while the dominant canopy species are *Schima wallichii*, another indeterminate Theaceae (?*Ternstroemia*), *Quercus gemelliflora*, *Santiria apiculata*, *Casuarina nobilis*, *Hopea dryobalanoides*, *Santiria apiculata* and *Bhesa robusta*.

Calophyllum teijsmannii, *C. canum*, *Litsea grandis*, *Magnolia villosa*, *Knema mandarahan*, *Mallotus penangensis*, *Macaranga gigantea* and

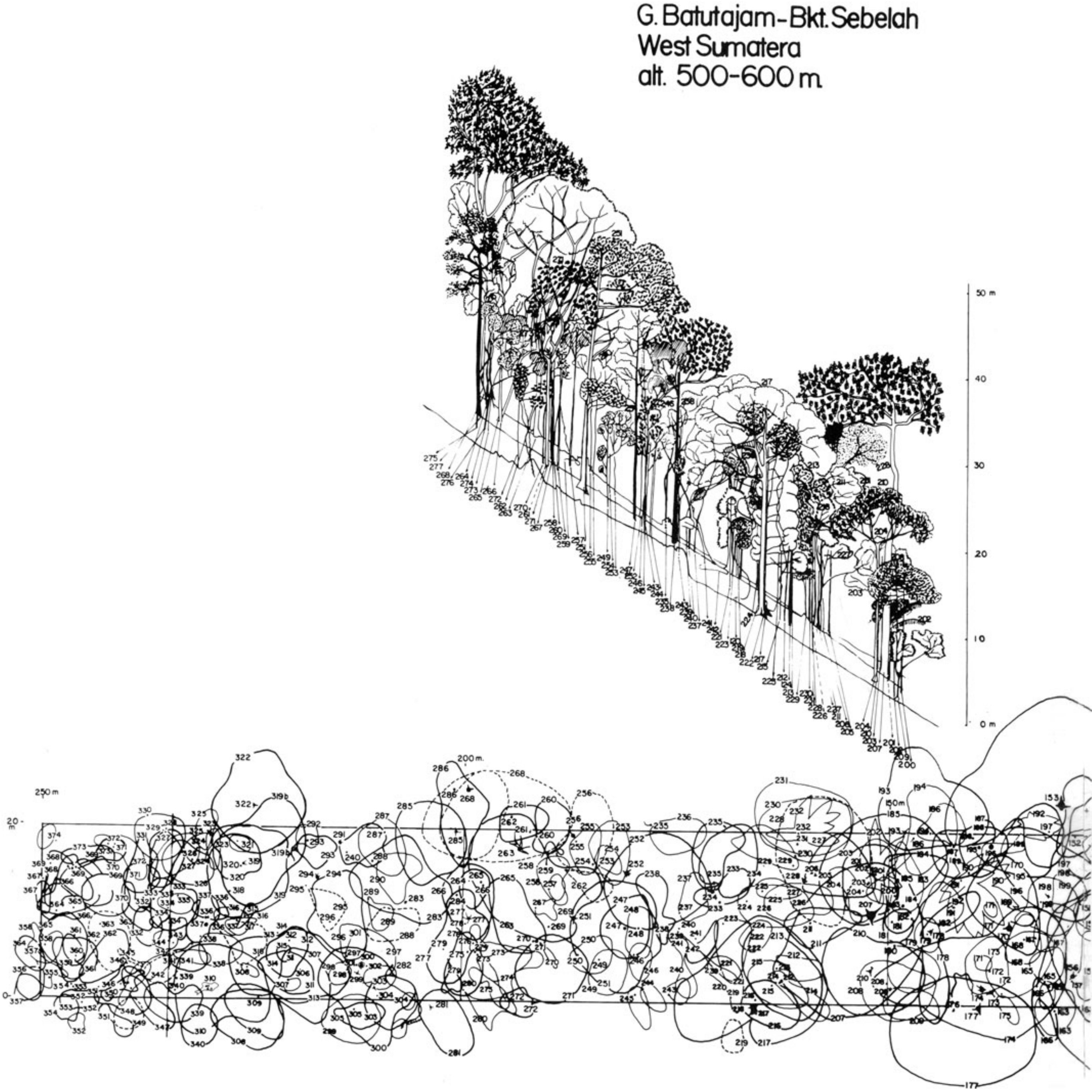

G. Batutajam-Bkt. Sebelah
West Sumatera
alt. 500-600 m.
50 m
40
30
20
10
0 m
250 m
200 m.
150m
20 m
0

Fig. 74a.

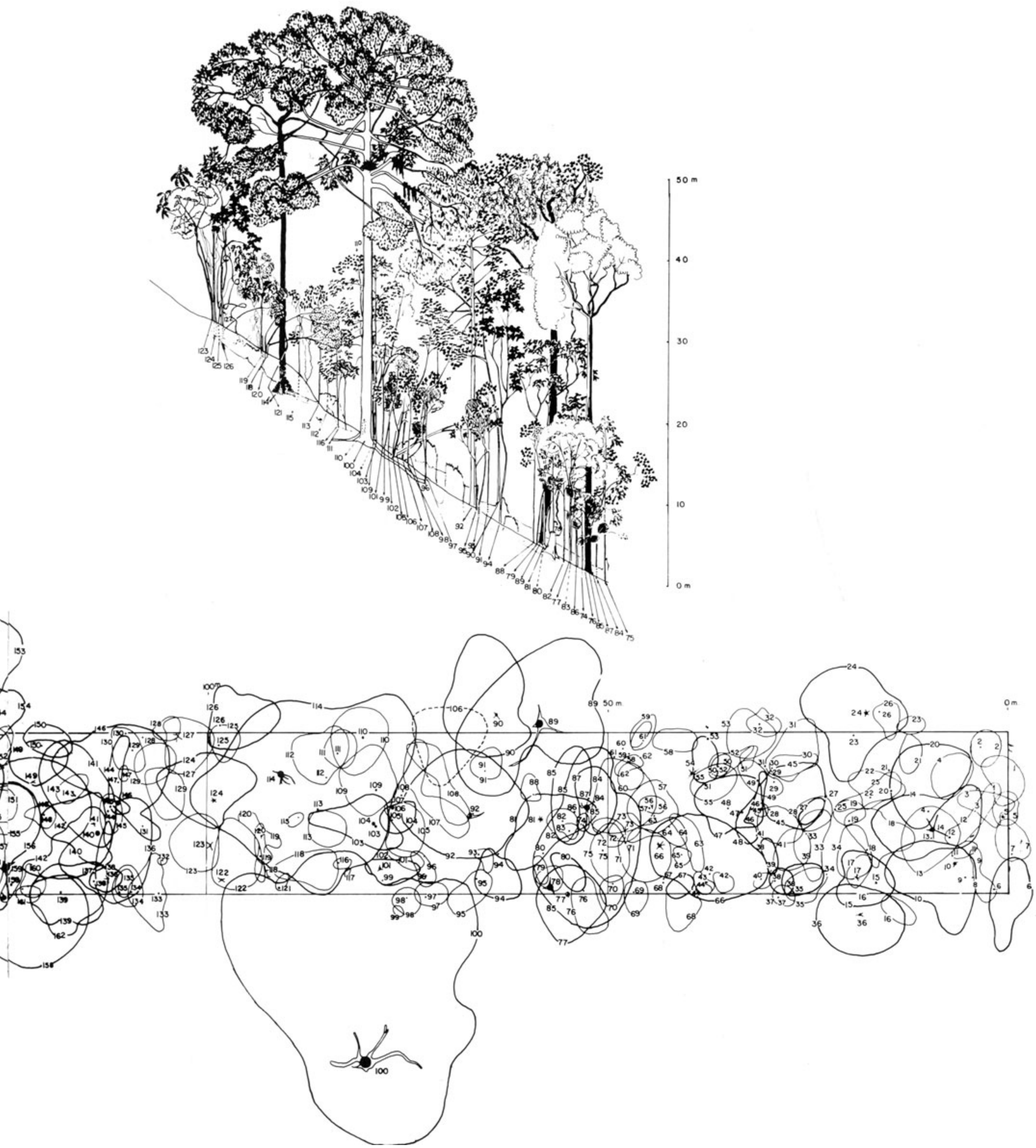


Fig. 74b.

a / *Aglaia argentea (81), Alangium (77), Baccaurea (96), Canarium pseudodecumanum (120), Celtis sp. (95), Cinnamomun (113), Croton argyratus (84,87), Croton cf. cascarilloides (74), Cyathocalyx sumatranus (125, 106), Diospyros apiculata (79,97,104,107,117), Diospyros 1 (76,78,82), Ficus (126), Glochidion (102), Homalanthus populneus (112), Hopea cf. tenuinervula (101), Hopea dryobalanoides (83), Knema stenophylla (93), Margaritaria indica (90), Mitrephora (105), Paranephelium xestophyllum (86), Parashorea lucida (89), Pometia pinnata (114,122,85,94), Semecarpus (108), Stelechocarpus cauliflorus (75,103), Toona (124) Turpinia (121) Villebrunea (118) EUPH (88), ANNO1 (111), ANNO2 (110), ANNO3 (140,92), ANNO4 (98), ANNO5 (99), Unidentified (80,91,100 109 115 116 119 123).*

b / *Aglaia argentea (227,237,255,260) Aglaia ganggo (212), Aglaia oligocarpa (216,243,268) Arenga obtusifolia (202), Artocarpus integer (245), Artocarpus sp. (257), Barringtonia sp. (201), Calophyllum sp. (272), Canarium sp. (210), Celtis (263), Celtis philippensis (217) Cleistanthus (238, 239, 266) Diospyros apiculata (219,225,262, 270, 273) Diospyros toposoides (258, 261) Diospyros sp. (244) Drymicarpus luridus (274) Drypetes (236, 246) Eugenia (203, 228,256) Eugenia 2 (249, 253, 254) Ficus (205, 206) Gironniera subaequalis (231) Heritiera sp (267, 200) Hopea pachycarpa (211) Melanochyla (271) Meliosma (247) Paranephelium xestophyllum (213,214) Parashorea lucida (207, 208, 229, 251) Payena endertii (252) Pometia pinnata (234, 277) Ryparosa javanica (233) Stelechocarpus cauliflorus (215,221, 222, 224, 241, 248) Sterculia (269) Vatica cf. stapfiana (235) Ventilago (220) Villebrunea (209) Xerospermum (204) Unidentified (218,223,226,230,232,240,242,250,259,264,265,275,276,278).*

c / *Celtis philippensis (343,367,371,372,373), Celtis sp (323), Cratoxylum maingayi (339,346,352,368), Cratoxylum sumatranum (326), Distyliopsis dunnii (328,329,341,342,347,348,349,359,360,369), Drypetes (336,354), Endiandra (325), Eugenia (337), Eugenia (366), Ganua (310,361), Linociera (353), Memecylon edule (338), Memecylon (340,351,363,364), Pandanus (350,355,358,374), Polyalthia (331,334,370), Rapanea (357), Unidentified (324,327,330,332,333,335,344,345,356,362,365).*

Crown planimetry (m2) of the all transect (except c part)				**Relative cover**	
				% total surf.	% cover surf.
Trees of the Present					
	Structural ensemble IV	869		17	19
	Structural ensemble III	2569		51	56
	Structural ensemble II	1987		40	40
	Structural ensemble I	316		6	7
		Total	**5741**	115	126
Trees of the Future			2722	54	60
Trees of the Past			363	7	8
		Total	**8826**	177	193
Plot surface			5000	100	
Gaps			426	9	
Covered surface			4574		100
Crown overlapping on			4252		93

Fig. 74. Structural ensembles coverage and floristic composition of the subplots a, b and c within a forest transect in karst area (a: lower slope, b: mid-slope, c: rocky ridge; alt. 500–600 m, Bukit Sebelah, West Sumatra). On lower slopes, structure is similar to nearby forest on non-karst geology. Towards the top of the ridge, floristic diversity diminishes gradually and the structure simplifies to give a low forest type mainly dominated by *Distyliopsis dunnii*, *Celtis philippensis* and *Cratoxylum maingayi*.

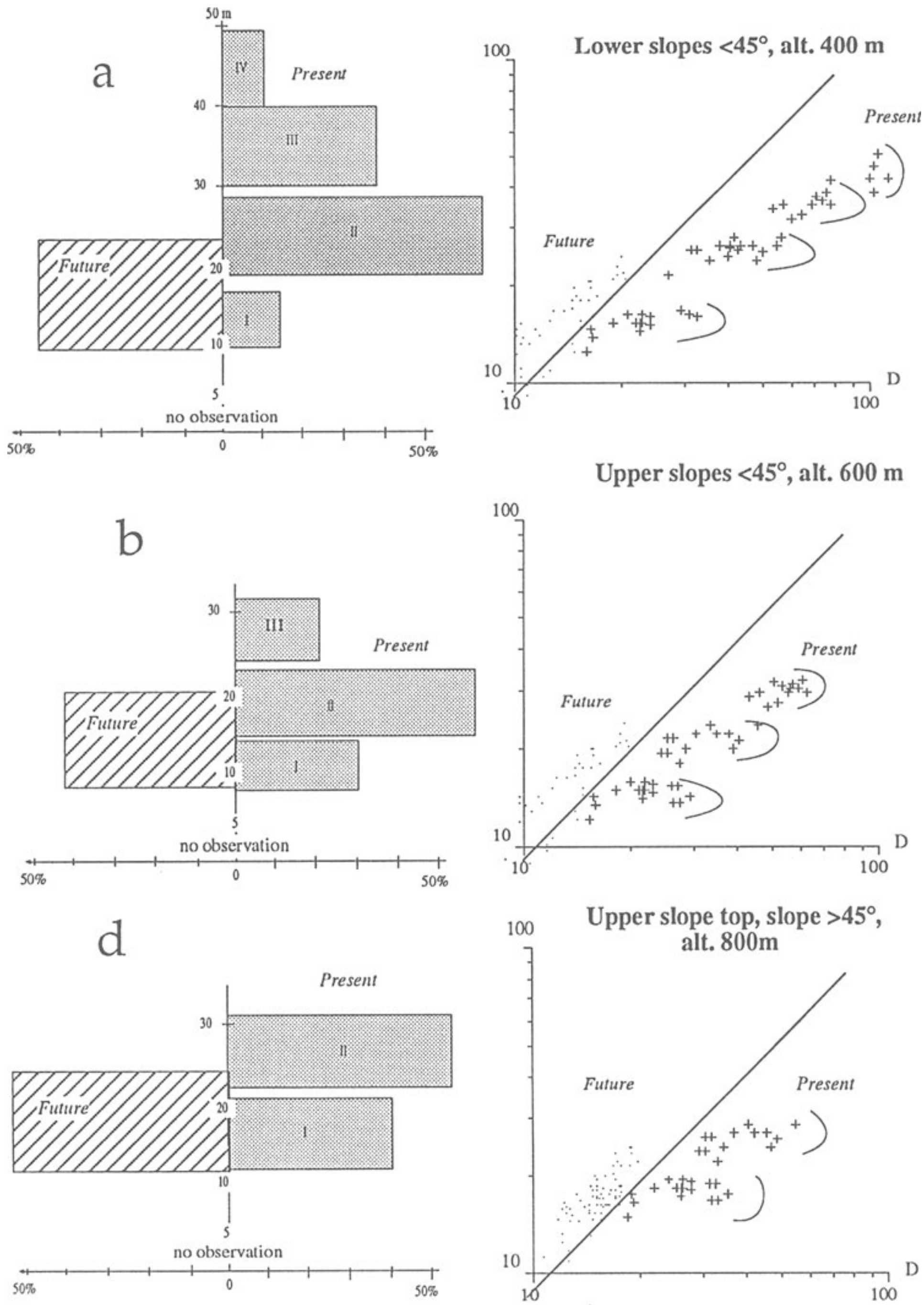


Fig. 75. Forest types on limestone. Height-diameter relationship, stratification, number and coverage of architectural ensembles along a vegetation transect from 300 to 800 m elevation. a: lower slopes, the forest is still high with four structural ensembles for the trees of the present. Structural set II has the highest cover. Upper slope (b), the large emergent trees have disappeared, while near the top, on the base of the final cliff, the very steep slopes make architectural analysis more difficult. Two structural ensembles are noticeable.

Photo 14. Submontane forests are just as imposing as those of the lowlands or the hills. It is possible to distinguish three or four structural groups of trees, and emergent species, approaching heights of 50 meters, are frequently encountered (*Shorea platyclados*). Pesagi massif, alt. 1200 m.

Pandanus sp. make up the lower structural groups, with a fair number of indeterminate species, particularly within the genera *Morinda*, *Hullettia*, *Flacourtia*, *Euodia*, and *Cynometra*.

Above yet another cliff, less abrupt and colonized almost exclusively by the same *Pandanus*, the vegetation on the summit of the karst pinnacle consists of fairly sparsely growing shrubs: *Schima wallichii*, *Glochidion pubicapsa*, *Podocarpus polystachyus*, *Decaspermum* sp, *Daphniphyllum* sp, *Eugenia* sp, and *Ganua* sp.

Secondary types. Our observations of secondary forests on limestone terrain are incomplete. In the metamorphic and limestone hills on the Central-east part of the island, *Chromolaena odorata* thickets are characteristic of recent new growth after ladang. While one still encounters classic *Macaranga*, *Laportea* and *Villebrunea rubescens* belukars, mainly along the river banks, secondary formations composed almost exclusively of *Piper aduncum* associated with *Macaranga curtisii*, *M. tanarius*, *Saurauia nudiflora*, *Pterospermum javanicum* are often found, and are an important element of today's landscape.

Xeromorphic savanna on limestone terrain exists west of lake Singkarak. *Dichanthium caricosum* and *Themeda villosa* constitute these grasslands colonized by few shrubs like *Leea*, *Moghania*, *Morinda* and *Vitex*, and where we also collected a small Gentianaceae (*Enicosanthum axillare*).

Mountain forests

In addition to the reports of the expeditions undertaken by Jacobson (1919), Van Leeuwen (1920), Frey-Wyssling (1931, 1933a), and studies by Van Steenis (1933, 1938), Jacobs (1958, 1972), Meijer (1961), Stein (1974), Oshawa et al. (1985), the forest structure and flora of the submontane, montane and subalpine regions have been described for the vegetation map in Central Sumatra (Kerinci, 3805 m, Singgalang, 2877 m, Talamau, 2910 m), and in the South (Dempo, 3150 m, Pesagi, 2200 m, Bk Pelelawan 1500 m).

Location, extent and status

Mountains are an important element of Sumatra's landscapes. Above 800 m altitude they constitute

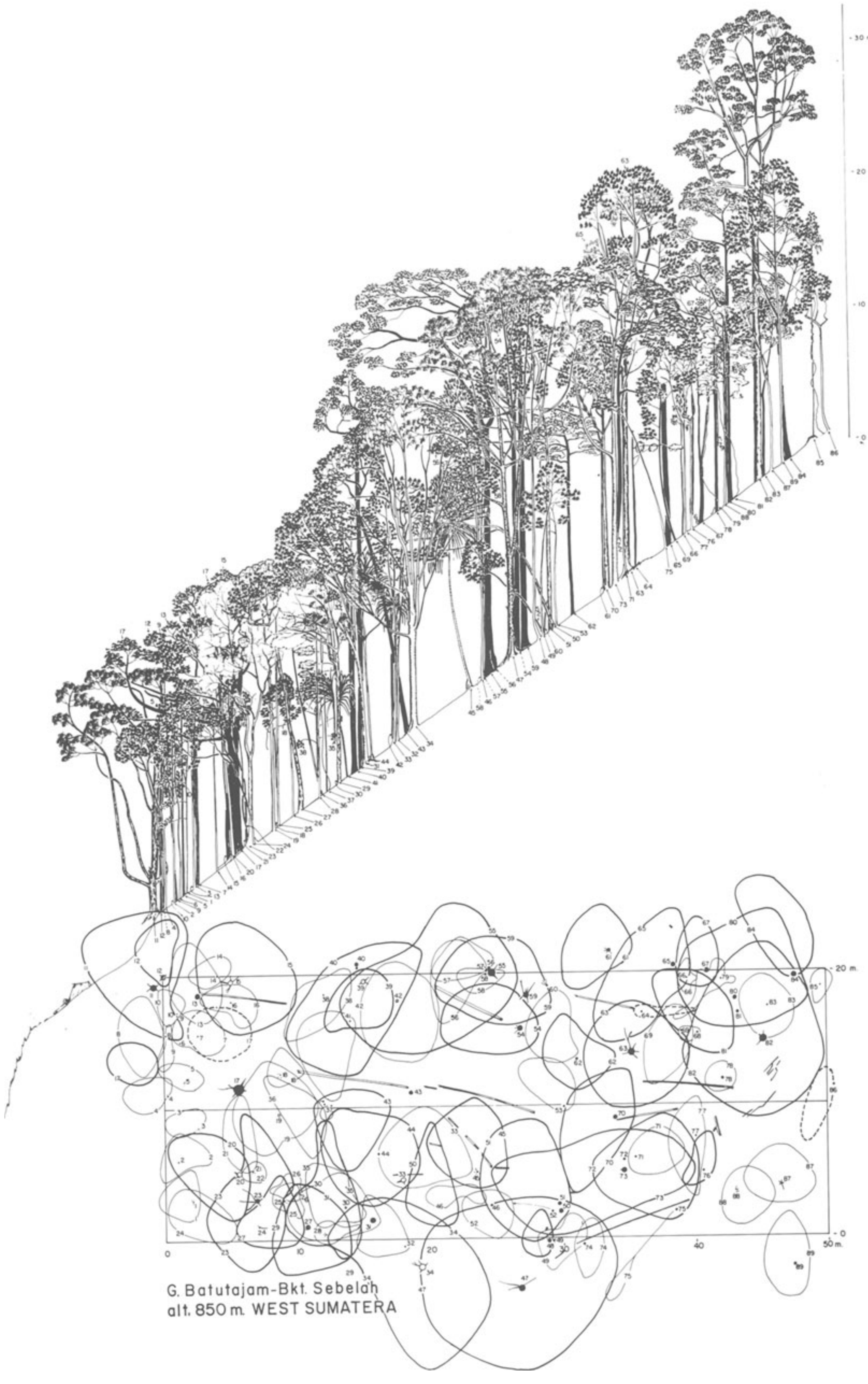


Fig. 76.

Schima wallichii (22,43,75,76,31,37,46,9,50,27,12,81) Gordonia (1,2,69,58,13,57,61), Palaquium sp. (54,33,63) APOCYNACEAE (42,48) Artocarpus (26,68) Calophyllum teijsmannii (14,51) Eugenia (3,70) Flacourtia sp. (64,77) Litsea grandis (20,15) Morinda sp. (60,32) Quercus gemelliflora (40,73) Acronychia (65) Bhesa robusta (55) Buchanania (18) Calophyllum canum (5) Canarium (74) Casuarina nobilis (11) Drypetes (71) Neolitsea (52) Cinnamomum (84) Chionanthus (23) Cynometra (85) Elaeocarpus cf. pedonculatus (8, 21) Endiandra (86) Euodia (53) Gardenia (83) Hopea dryobalanoides (56) Hulletia (29) Knema mandarahan (78) Litsea (89) Macaranga gigantea (36) Magnolia villosa (10) Mallotus penangensis (38) Palaquium sp (59) Pandanus sp (44) Payena sp (63) Payena enderti (49) Psychotria sp (25) Quercus (17) Santiria apiculata (34) Shorea ovata (16) Shorea platyclados (39) Swintonia sp. (24).

Fig. 76. Floristic composition of a hill forest on very steep slopes in karst area. Bukit Sebelah, alt. 800 m, West Sumatra. *Schima wallichii* and *Gordonia* sp. are dominant, *Casuarina nobilis* is often common, and dipterocarps still occur (*Shorea platyclados*, *S. ovata*, *Hopea dryobalanoides*). As for the other plots in this karst area, many species still unidentified, will probably be new to science.

about 15% of the island's overall surface area. The region around Lake Toba, the Minangkabau plateaux and certain high mountain valleys have been colonized since ancient times and forest cover in mountainous areas is today only about 8% of all Sumatra, mainly located at altitudes ranging from 800 to 1800 m. Deforestation (sometimes as high as 2000 to 2200 m) is most often due to cinnamon cultivation (*Cinnamomum burmanii*) until 1500 m, and to vegetable farming above this altitude.

The physical environment

Relief, geology and geomorphology

In 1917, Tobler described the mountain system of Sumatra, and distinguished between:

- the western part, known as the 'High Barisan', forming a more or less continuous range of mountains of medium altitude which for a long time constituted a barrier for the populations in the east.
- a central rift valley: characteristic tectonic structure which extends from North to South, sometimes dividing the Barisan into two parallel ranges. During the formation of this graben, an almost uninterrupted series of volcanic eruptions divided the central rift into a number of different sectors. The sectors were gradually filled with alluvial deposits and lakes often formed in the depressions (Singkarak, Kerinci). Occasionally whole volcanos exploded, creating vast calderas like those now occupied by Lake Toba, Maninjau or Ranau.
- an eastern zone, known as the 'Lower Barisan', at an average altitude ranging from 800 to 1200 meters, mainly consisting of reshaped metamorphic rock, karst ranges and large granite massifs.

Clearly visible at the center of the island, the rift valley disappears North of Lake Toba where the mountain massifs, which are older and of non-volcanic origin, no longer belong to the Barisan range (Leuser Massif, Gayo and Aceh mountains). Sumatra's volcanic products are very rich in plagioclases and are generally acidic (dacitic-liparitic). Andesites from old extinct volcanos should be differentiated from the highly acidic lava from old volcanos which are still active, and from intermediate lava released by Quaternary volcanos.

Soils

Although some soils have developed on limestone massifs in submontane regions (West Sumatra, Aceh), the great majority are 'Tropical Brown soils' leached to various degrees, often with a very high humus content, and Andosols.

Photo 15. Natural stands of bamboos (cf. *Schizostachyum* sp.) occur in certain valleys between 800 and 1200 m elevation in the hill or submontane forest zone.

The acidic, humus bearing 'Tropical Brown soils' in lower mountain areas are most often characterized by a rather thin layer of litter, an organic horizon at a depth of 5 to 10 cm, dark brown and often containing gravels. Alteration is *in situ*. The dividing line with the next horizon, which is organic-mineral and lighter in color, is not always precise. Beyond a depth of 30 cm, the mineral horizon gradually appears before giving way to the bed rock at a depth of 1 to 1. 5 m (Fig. 77).

In the upper mountain reaches, the soils are generally more leached and humus bearing, and their composition depends on the underlying geology and slopes. On these Barisan summits, they seem much poorer then those described for the same altitudes in New Guinea (Edwards 1982). On the Pesagi at 1800 m and Kerinci at 2300 m, the Andosols which have developed on volcanic materials are very rich in organic matter. The entire profile is extremely porous (allophanes) and the clay percentage is low (20–25%). These soils are acidic with a very high cation exchange capacity in the upper horizon (Fig 77 b). Van Beek (1982) and Whitten et al. (1984) obtained similar results respectively on the Leuser and the Kemiri in the Aceh region.

Climatic factors

Mountain climates are always hyperhumid (P > 3000 mm/year). Rainfall does not necessarily increase with altitude, and the regions which receive most rain are often the hills. Although

Photo 16. Montane forest at Gunung Talamau, alt. 2000 m: it is still relatively high showing three distinct structural groups, with a canopy mainly composed of *Castanopsis*, *Elaeocarpus*, *Haemocharis*, and *Lithocarpus* spp. In the lower strata *Lithocarpus suffruticosus*, *Drypetes talamauensis*, and *Eugenia* spp. are well represented. Their trunks are moss covered.

very little rainfall data exist for high altitudes, Sumatra's summits are far from dry. At 2877 m Mt. Singgalang registers 3500 mm/year. Only the very high summits culminating at altitudes greater than 3500 m are sometimes situated above the cloud ceiling which remains at 2000 to 3000 m during the dry season. This range of altitudes corresponds with the zone where relative humidity is at its highest value, being one of the most important ecological factors determining vegetation physiognomy at these heights.

Ultraviolet radiation, stronger than in the lowlands, also has an effect on high altitude plants. The main factor, however, remains the daily temperature fluctuation δt which is particularly high, varying from 15° to 25 °C. Weather stations supplying high altitude temperature readings are unfortunately rare. Braak (1925) was able to calculate an altitudinal gradient of 0.61 °C/100 m until 2000 m, and 0.52 °C/100 m thereafter.

Frost may occur around 2500 m, and, under certain conditions of exposure (at dawn after a clear night, in depressions with cold air ponding) as well as thermic inversion, even at lower altitudes (Van Steenis 1972).

Submontane forests (800–1400 *m*)

The primary forest

Structure and floristics. The forests are just as majestic as those in the lowlands or hills at these

Photo 17. At cloud level on some volcanoes, a belt of *Pandanus* cf. *sumatranus* is found. Its occurrence is not ecologically completely understood.

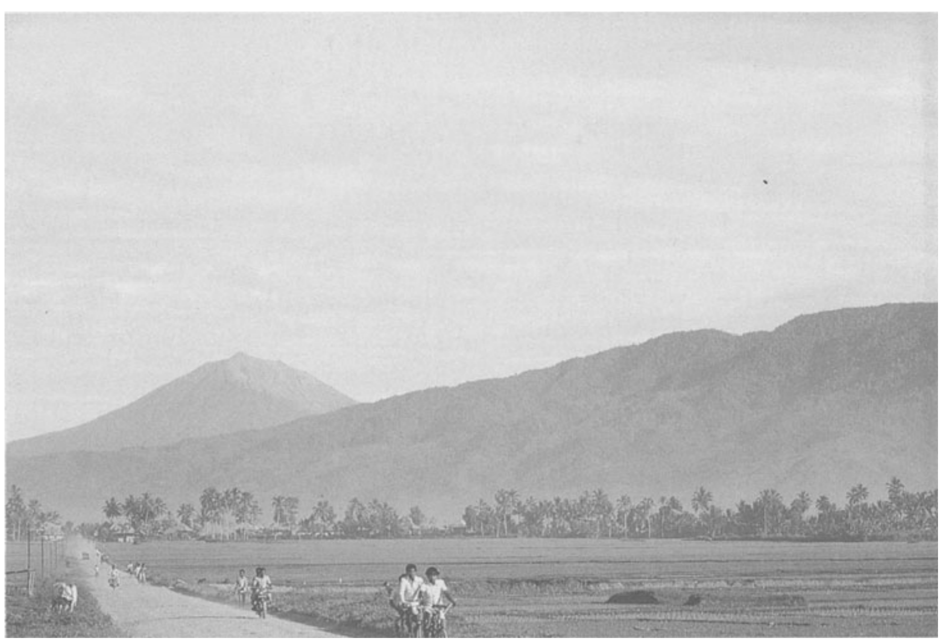


Photo 18. Highest peak in Sumatra: Mnt Kerinci above the Sungaipenuh valley. The vegetation disappears above 3400 m because of volcanic activity.

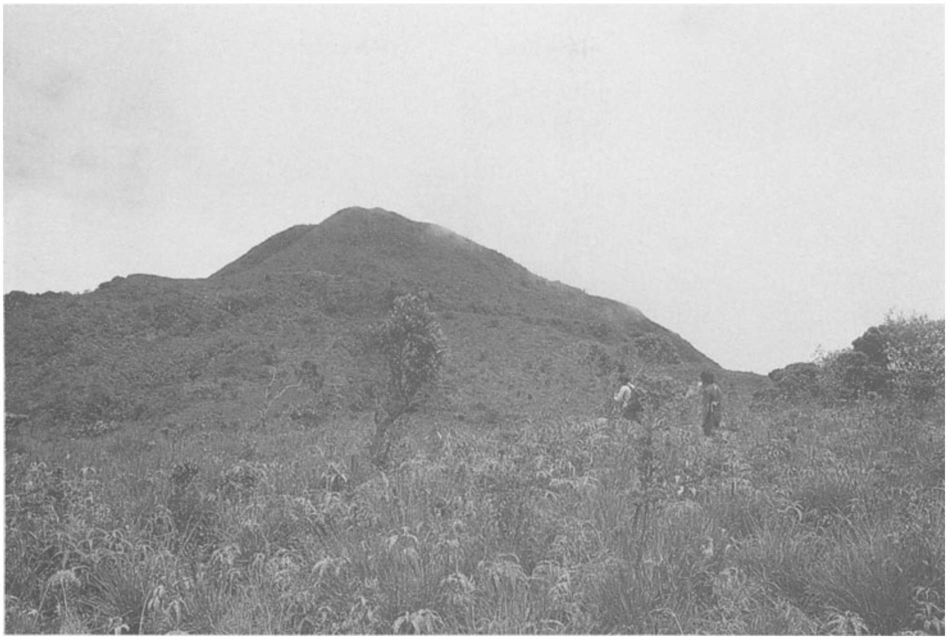


Photo 19. The low vegetation near the summit of Talamau peak (2800 m) is mainly composed of *Lycopodium* spp., Cyperaceae (*Gahnia javanica*) and a few Ericaceae shrubs (*Vaccinium*, *Rhododendron*, *Gaultheria*).

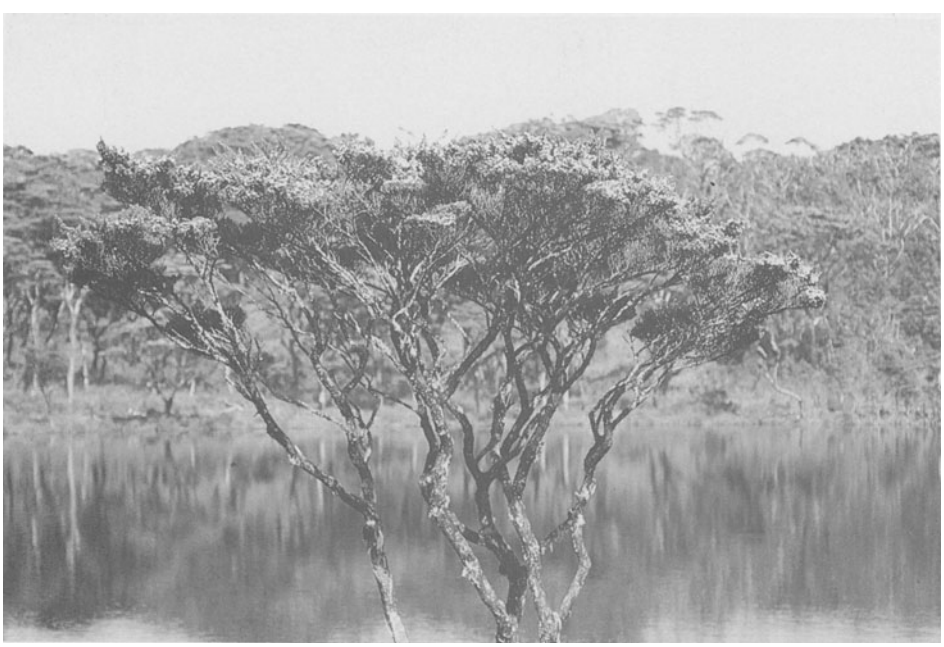


Photo 20. Singgalang peak near Bukittinggi in West Sumatra: at 2800 m, the mossy forest around the lake is dominated by large individuals of *Leptospermum javanicum*.

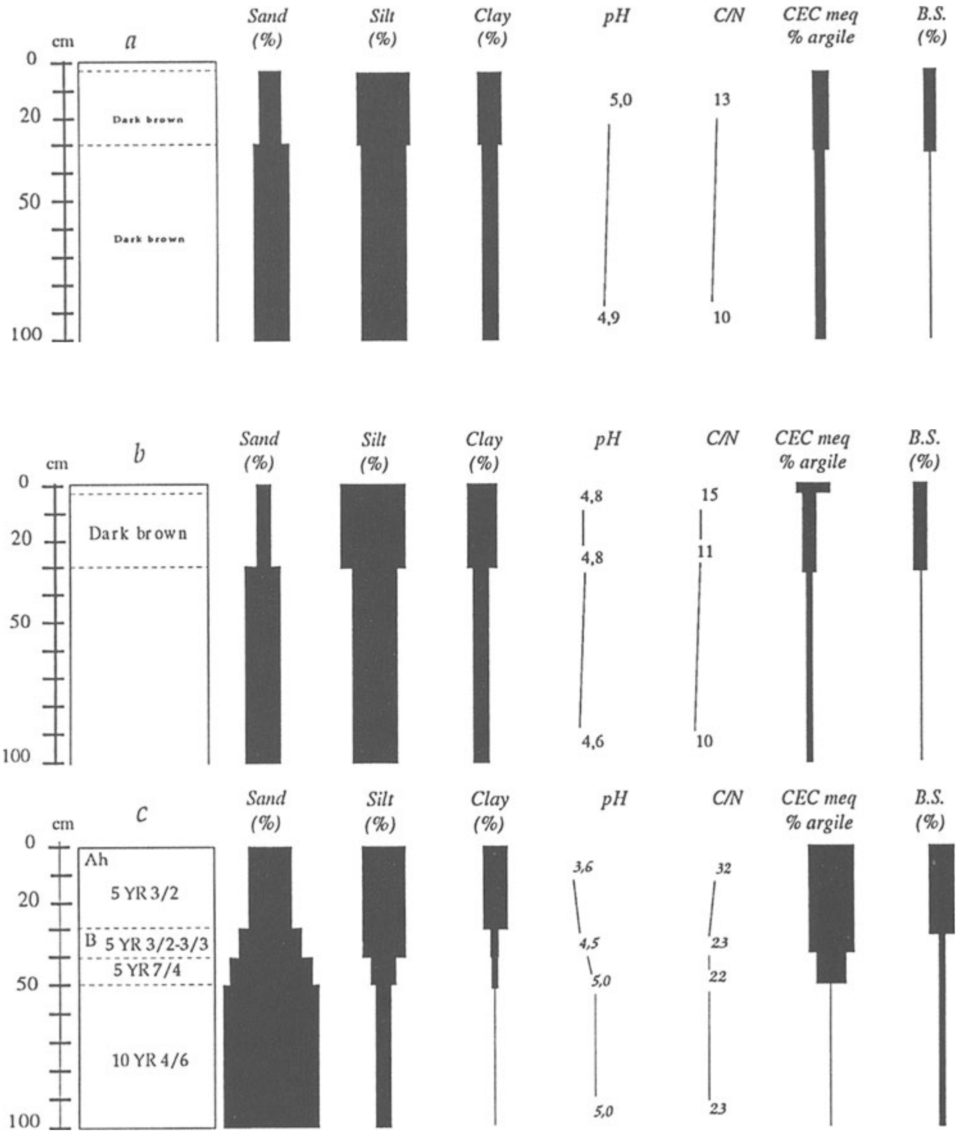


Fig. 77. Montane soil type. a: Acidic tropical montane brown soils (Pesagi, 1200–1400 m). Limits between horizons are not very precise. A (down to 10 cm deep) is more organic, followed by an organo-mineral B (down to 30–40 cm) above a more mineral horizon. b: Humic Andosols (Pesagi, 1800 m; Kerinci 2300 m): rich in organic matter, low clay content, transition to . . . c: Vitric Andosols (Singgalang, 2800 m): very rich in organic matter, extremely porous (allophane), low clay content with a very high CEC in the upper horizon.

altitudes, with only a few differences observed from north to south. Structural ensembles are harder to define on the slopes because of crown imbrication level phenomena (Fig. 78 and 79). Nevertheless, it is still possible to distinguish three or four structural groups of trees situated on average between 35 and 45, 20 and 30, 15 and 20, and 5 and 10 meters, until an altitude of approximately 1400 m (Fig. 80). Emergent trees approaching heights of 50 meters are still frequently encountered at these altitudes. Many species still have large buttresses. Lianas, hemi-epiphytic and epiphytic figs are also abundant. The leaf mass is mesophyllous, and numerous compound leaf families are observed (Burseraceae, Meliaceae, Sapindaceae, Fabaceae).

From a floristic standpoint, these submontane forests are traditionally characterized in literature

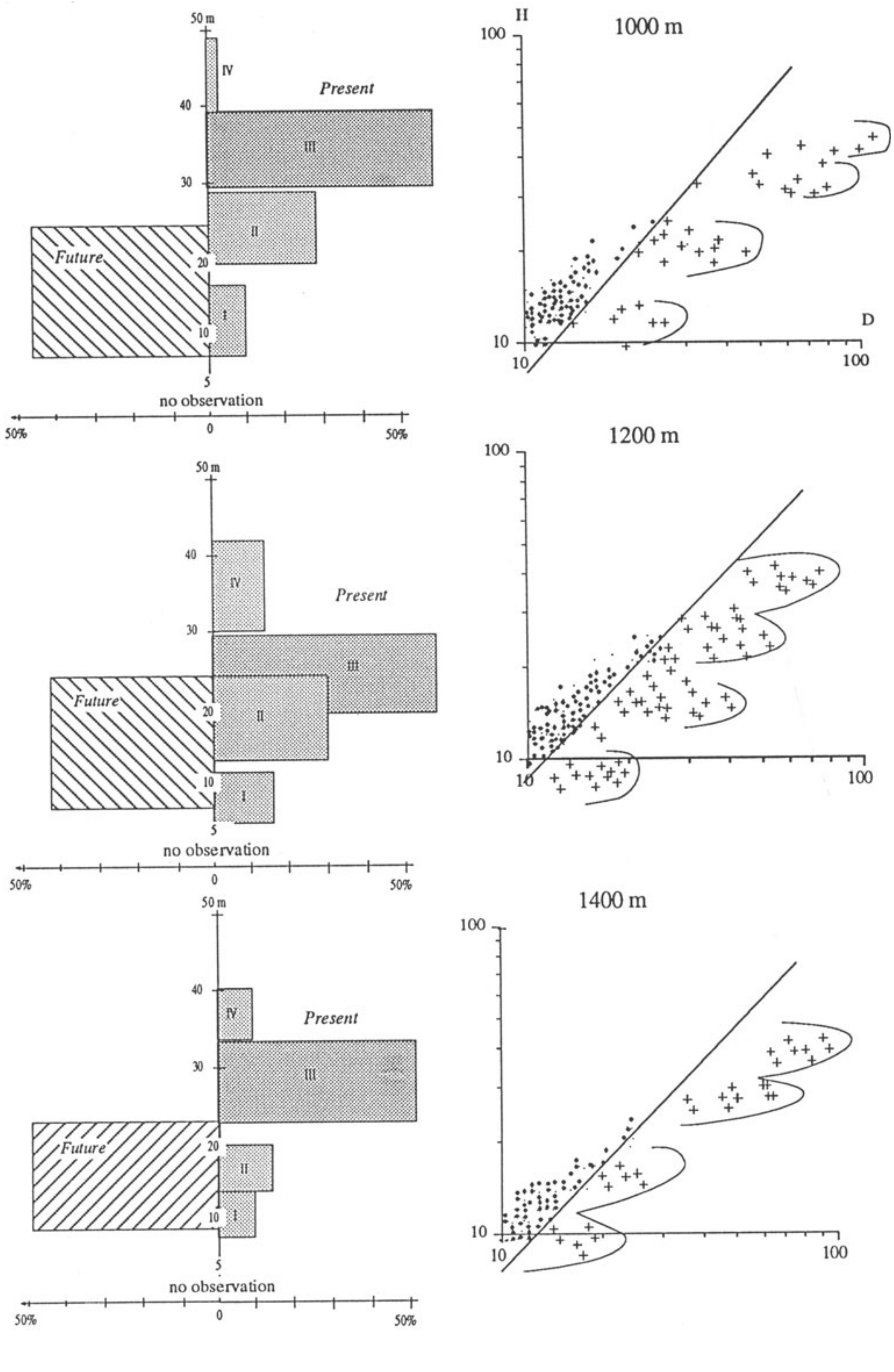


Fig. 78. Height-diameter relationship, stratification, number and coverage of architectural ensembles. Submontane forest types, alt. 800–1400 m. Forest remains tall with four structural ensembles for the trees of the present. On slopes, ensembles II and III are not always easy to differentiate.

by a dominance of Fagaceae, Lauraceae and Myrtaceae, families which are also well represented in the lowlands but which are favoured here by the absence of dipterocarps. In Sumatra, the importance of the Lauraceae in these forest types seems to have been somewhat usurped. All our plots at altitudes ranging from 900 to 1400 m, Myrtaceae, Clusiaceae and Euphorbiaceae are the characteristic families of these forests in order of abundance (trees above 10 cm in diameter), while from the dominance standpoint, the main families are Fagaceae, Myrtaceae and Moraceae (importance of large strangling figs) followed by Clusiaceae (Table 20).

The emergent *Agathis borneensis* is only found in the Kerinci region (mainly on ridges west of the lake, between 1000 and 1300 m, often in association with natural populations of *Pinus merkusii*). The most characteristic species elsewhere are *Shorea platyclados* (between 800 and 1200 m), *Altingia excelsa*, *Quercus oidocarpa*, *Neesia altissima*, *Podocarpus imbricatus*, *P. neriifolius*, *P. wallichianus*. *Lithocarpus hystrix*, *Parkia singularis*, *Santiria laevigata*, *Toona sinensis*, *Sarcosperma paniculatum*, *Drypetes minahassae* (Euphorbiaceae which reaches a height of 38 m), numerous species of strangling figs (*Ficus* cf. *binnendykii*, *F. disticha*, *F. elastica*) and *Eugenia* are commonly observed in the canopy.

Between heights of (20) 25 and 30 m, the abundance and dominance of the Myrtaceae (at least twenty species of *Eugenia*) and the Fagaceae is particularly noteworthy. Already identified species include: *Lithocarpus elegans*, *L. pseudomoluccus*, *Castanopsis* cf. *tungurrut*, *Quercus cf. subsericea*, *Q. longiflora* (Fagaceae), *Bhesa robusta* (Celastraceae), *Glochidion* cf. *pubicapsa* (Euphorbiaceae), *Chionanthus oxycarpus* (Oleaceae), *Cryptocarya ferrea*, *Litsea meijerii* (Lauraceae), *Talauma candolei* (Magnoliaceae), *Radermachera pinnata* (Bignoniaceae), *Engelhardtia serrata*, *E. roxburghiana* (Juglandaceae), *Neesia pilulifera* (Bombacaceae), *Terminalia myriocarpa* (Combretaceae), *Dacrydium elatum*, *D. beccarii*, *D. pectinatum* (Podocarpaceae), *Casearia tuberculata* (Flacourtiaceae).

At heights between 10 and 20 m, mature trees are less closely spaced and it is hard to find well defined architectural ensembles at this floristically rich level. The most abundant species are listed in Table 21.

Numerous species of the following families grow at heights ranging from 3 to 8 m above the ground, particularly:

- Rubiaceae (*Canthium horridum*, *Saprosma arboreum*, *Lasianthus rigidus*, *Mycetia cauliflora*),
- Myrsinaceae (*Ardisia blumii*, *A. javanica*, *A. odontophylla*, *A. vestita*),
- Euphorbiaceae (*Phyllanthus accrescens*, *Suregada glomerulata*),
- Flacourtiaceae (*Bennettiodendron leprosipes*, *Flacourtia rukam*),
- Ebenaceae (*Diospyros subrhomboidea*),
- Clusiaceae (*Garcinia urophylla*),
- Connaraceae (*Ellipanthus tomentosus*),
- Symplocaceae (*Symplocos fasciculata*),
- Rutaceae (*Glycosmis pentaphylla*, *Zanthoxylum acanthopodium*),
- Lauraceae (*Cinnamomum cuspidatum*, *Dehaasia sumatrana*, *Lindera subumbelliflora*),
- Icacinaceae (*Gomphandra fusiformis*, *G. javanica*, *Stemonurus secundiflorus*),
- Proteaceae (*Helicia serrata*).

On the ground, the species found include a large number of Marantaceae (*Phrynium capitatum*), Lamiaceae (*Gomphostemma microcalyx*), Liliaceae (*Pleomele angustifolia*), Chloranthaceae (*Sarcandra glabra*), Gesneriaceae (*Cyrtandra pilosa*) and Zingiberaceae (*Amomum*, *Globba*, *Riedelia*), and a few rare Poaceae (*Oplismenus compositus*).

Lianoid species are similar to those at lower altitudes, and few seem to be restricted to submontane regions (*Ziziphus horsfieldii*, *Uncaria elliptica*, *Chilocarpus costatus*, *Tetrastigma lanceolata*, *T. papillosum*, *Salacia* sp., *Smilax* spp.). Rattans, which are often abundant, include *Calamus heteroideus* at the South of the island, and *Daemonorops singalana* in the Center. This zone is sometimes remarkably rich in tree ferns, mainly represented by *Cyathea hymenodes* and *C. alderwereltii* in enclosed ravines. The epiphytes form often large populations, but our collections of these life form were insufficient.

Variations in facies. Studies carried out by Wiriadinata et al. (1979) and Laumonier (1981) in the Ranau region have confirmed the remarks made by Van Steenis (1933, 1972) and Grubb (1974) according to which the physiognomy and structure in medium altitude mountain ranges observed towards 1000 m are those of a mountain forest, while the flora still comprises many

Talamau 1100m. Submontane Forest Mt. Talamau, Pasaman

Fig. 79

Eugenia sp. (14,45,60), Eugenia sp. (2 24,14,16), Alseodaphne (3,58), Eugenia sp. (3 6,48), Ficus fistulosa (13,43), Mallotus cf. laevigatus (33,28), Calophyllum venulosum (18,15), Payena acuminata (54,57), Canarium (56,41), CELASTRACEAE indet (47), Radermachera pinnata (31, 30), Engelhardtia serrata (25, 55), Endiandra (2), Cyathocalyx sp (1 7), Lithocarpus elegans (8), Garcinia lateriflora (9), Xanthophyllum griffithii (10), Meliosma (11), Prunus polystachya (12), CELASTRACEAE indet (5), Prismatomeris (32), LAURACEAE indet (22), Cyathocalyx sp (36), Drypetes minahassae (27), ROSACEAE indet (35), Eugenia (17), Sarcosperma paniculatum (20), LAURACEAE indet (26), Castanopsis cf. schefferiana (34), EUPHORBIACEAE indet (37), Quercus oidocarpa (52), Glochidion cf. pubicapsa (46), Litsea (42), Mangifera (51), Flacourtia rukam (44), Nephelium lappaceum (40), RUTACEAE indet (53), ANNONACEAE indet (54), Ilex (39), LAURACEAE indet (49), Neonauclea lanceolata (38), Uncaria elliptica (23), Garcinia sp (38).

Fig. 79. Floristic composition of a submontane forest plot at Mount Talamau, alt. 1100 m. As often noticed during the present survey, submontane forests in Sumatra are not especially rich in members of the Lauraceae family. Most abundantly represented are Myrtaceae, Clusiaceae and Euphorbiaceae, while from the dominance standpoint, the main families are Fagaceae, Myrtaceae, Moraceae and Clusiaceae.

megathermic elements (Anacardiaceae, Annonaceae, Bombacaceae, Meliaceae, Myristicaceae, Sapindaceae). It is important to distinguish between forests on medium altitude ranges (1400–1800 m) and those on higher massifs. South of the Barisan, where the relief is on average more moderate, the 'altitudinal floristic limit of 1000 m', the lower limit of submontane forests, is often raised to much greater heights (1300–1500 m), while the physiognomy of the forest is more typical of high altitude formations.

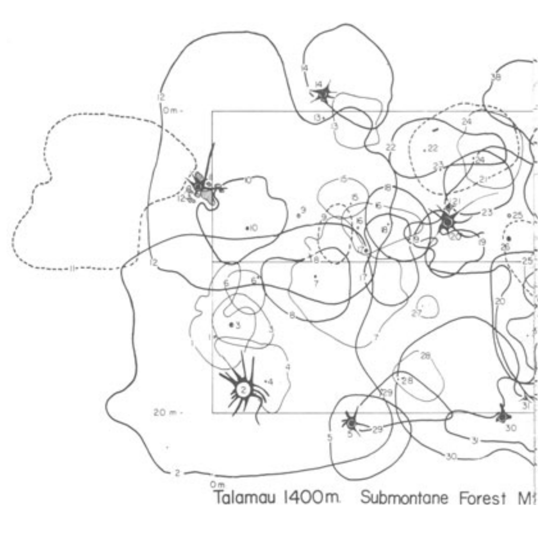
Between 1400 and 1500 m on the crests of the Bukit Pelelawan west of Lake Ranau, one passes abruptly from a high forest of *Altingia excelsa*, *Quercus* and *Eugenia* into a very low (10 m) elfin forest at 1500 m. Two structural levels can still be distinguished, occupied by *Acronychia*, *Litsea*, *Elaeocarpus*, *Eugenia* and *Ixora*. This type of physiognomy only appears on the narrow ridges of Mt Pesagi above 1800 m altitude.

Apart from these facies on medium altitude ridges, these altitudes are sometimes the habitat of bamboo forests (*Schizostachyum* sp.) mainly occupying certain valleys at 800 to 1200 m in the South of the island. The forests we encountered seemed to be natural, often associated with elephant paths.

Lastly, a few medium elevation swamp forests exist. The largest of these, currently being taken over by paddi fields, are located North-east of the Kayu Aro tea plantation, South-east of Mount Kerinci. Little is known about this low forest: Jacobs (1958) mentions *Antidesma tetrandrum*, *Symplocos cochinchinensis*, *Celtis timorensis* and *Lithocarpus hystrix*. Other swamps remain to be explored North-West of Mount Kerinci.

Secondary types

The first stage in the recolonization of these forest types after cultivation through clear felling and burning begins with almost impenetrable *Eupatorium inulifolium* or *Clibadium surinamense* thickets. Where time permits natural succession, Euphorbiaceae species establish themselves such as *Mallotus* cf. *laevigatus*, *Macaranga curtisii*, *M. semiglobosa*, *Homalanthus populneus*, *Breynia microphylla*, Saurauiaceae *Saurauia distasosa*, *S. nudiflora*, Urticaceae, *Debregeasia longifolia*, *Elatostema* sp., *Leucosyke*, Moraceae *Ficus grossularioides*, *Ficus* spp., and Ulmaceae *Trema orientalis*. The latter often form pure populations which are characteristic of old secondary forests at these altitudes. In the most disturbed places (landslides, areas which have been repeatedly burnt), more intensely degraded stages are represented either by Gleicheniaceae (*Gleichenia hirta*, *G. hispida*, *G. microphylla*), *Pteridium*



Talamau 1400m. Submontane Forest M

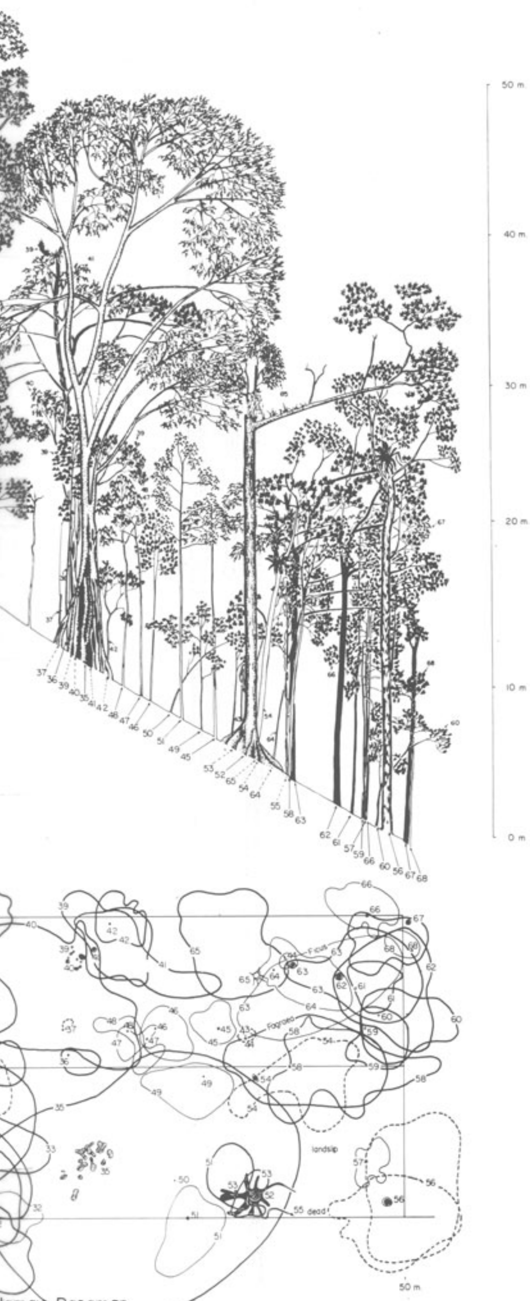

50 m
40 m
30 m
20 m
10 m
0 m
Ficus
Fagraea
landslip
dead
50 m
lamau, Pasaman

Fig. 80a.

Garcinia (8,38,61,64,46,66,57), Eugenia3 (32,37,39,47,34,31,87), Urophyllum (23,33,60,53,50,42), ? MYRTACEAE (31,32,44,34,8), Drypetes rhacodiskos (24,49,19), Ardisia (15,36), Drypetes minahassae (63,30), Eugenia1 (1,26), Ficus sp (40,35), Horsfieldia macrothyrsa (10,29), Mastixia (6,7), Palaquium (27,68), Quercus (20,2), ANNONACEAE indet (45), Aglaia aspera (16), Antidesma cf cuspidatum (22), Beilschmiedia sp (43), Castanopsis cf tungurrut (52), Chionanthus (21), Cryptocarya sp (65), Elaeocarpus obtusus (28, 67), Endiandra rubescens (48), Eugenia2 (5), Eugenia4 (14), Eugenia5 (56, Ficus cf binnendykii (12), Garcinia sp (4) Gordonia (17), Palaquium sp (25), Palaquium sp (62), Palaquium sp (3), Polyosma (51), Quercus oidocarpa (11), SAPOTACEAE indet (41), Sterculia (54).

Fig. 80. Floristic composition of a submontane forest plot at Mount Talamau, West Sumatra, alt. 1400 m. The forest is strongly dominated by *Eugenia* spp., *Urophyllum*, *Garcinia* and several Fagaceae. The presence of *Aglaia*, *Mastixia*, one Annonaceae and several Sapotaceae indicates that one has not yet reached the montane zone *sensu stricto*.

Table 20. Abundance and dominance of the ten most represented families in submontane forests.

Abundance	Dominance (Basal area)	Dominance (Crown surface)
Myrtaceae	Fagaceae	Fagaceae
Guttiferae	Myrtaceae	Moraceae
Euphorbiaceae	Moraceae	Myrtaceae
Rubiaceae	Clusiaceae	Clusiaceae
Lauraceae	Euphorbiaceae	Euphorbiaceae
Fagaceae	Sapotaceae	Sapotaceae
Sapotaceae	Rosaceae	Rubiaceae
Moraceae	Sarcospermaceae	Lauraceae
Annonaceae	Anacardiaceae	Cornaceae

Montane forests (1400–1900 *m*)

The primary forest

Structure and floristics. Different forest physiognomies are observed depending on the size of the mountain ranges.

On the Pesagi near Lake Ranau, the forest gradually diminishes in size at 1600 m, before the slope even begins to get steeper. Rattans are still encountered, represented by large *Plectocomia* which are particularly abundant between 1500 and 1800 m. The number of treefall gaps is higher than that of forests on the submontane level. The

Table 21. Most abundant species in the lower canopy in submontane forests.

Myrtaceae		Rutaceae	
	Acmena acuminatissima		Acronychia laurifolia
	Decaspermum sp.	Daphniphyllaceae	
	Eugenia spp.		Daphniphyllum glaucescens
Meliaceae		Fagaceae	
	Aglaia malaccensis		Lithocarpus javensis
	A. sp. aff. eximia	Rosaceae	
	A. aspera		Prunus polystachyus
	A. elliptica	Araliaceae	
	A. odoratissima		Arthrophyllum javanicum
	Dysoxylum cauliflorum	Theaceae	
	D. cf macrocarpum		Gordonia excelsa
Sapindaceae		Magnoliaceae	
	Nephelium juglandifolium		Magnolia macklottii
	N.lappaceum	Cornaceae	
Icacinaceae			Mastixia rostrata
	Platea latifolia	Myristicaceae	
Clusiaceae			Knema glauca
	Calophyllum venulosum		K. sumatrana
	Garcinia spp.		Horsfieldia cf. macilenta
Euphorbiaceae			H. cf. macrothyrsa
	Drypetes rhacodiskos	Sabiaceae	
Lauraceae			Meliosma pinnata
	Beilschmiedia gemmiflora	Styracaceae	
	Endiandra macrophylla		Styrax paralleloneurum
	E. rubescens	Rubiaceae	
	Litsea angulata		Neonauclea lanceolata
	L. meijerii		Canthium glabrum
	L. resinosa		Urophyllum sp.
	Lindera subumbelliflora	Theaceae	
	Cryptocarya ferrea		Adinandra acuminata
Tiliaceae			Eurya acuminata
	Pentace polyantha		

importance of epiphytes and mosses increases in correlation with the high atmospheric humidity due to the fact that clouds often stagnate at this level. Ground litter becomes thicker as the decomposition process slows down with the drop in temperature. Analysis of plots generally reveals two arborescent structural groups at respective heights of 25 to 30 m and 10 to 20 m, and a shrub layer 5 to 10 m above the ground (Fig. 81). Fagaceae (*Lithocarpus pallidus*, *Quercus gemelliflora*, *Castanopsis*), Lauraceae (*Litsea* cf. *tuberculata*), Myrtaceae (three species of *Eugenia* sp.), some Theaceae (*Haemocharis buxifolia*, *Schima wallichii*), and a number of Sapotaceae (*Payena*, *Madhuca*) constitute the upper level of the canopy.

Below this, one again encounters *Eugenia longiflora*, less abundant than at 1000 m, *Magnolia macklottii*, Clusiaceae (*Garcinia spp.*, *Garcinia gaudichaudii*), Lauraceae (*Actinodaphne glomerulata*, *Cinnamomum subavenium*, *Cryptocarya densiflora*, *Lindera subumbelliflora*, *Notaphoebe umbelliflora*), Rubiaceae (*Urophyllum corymbosum*, *U. arboreum*), Elaeocarpaceae

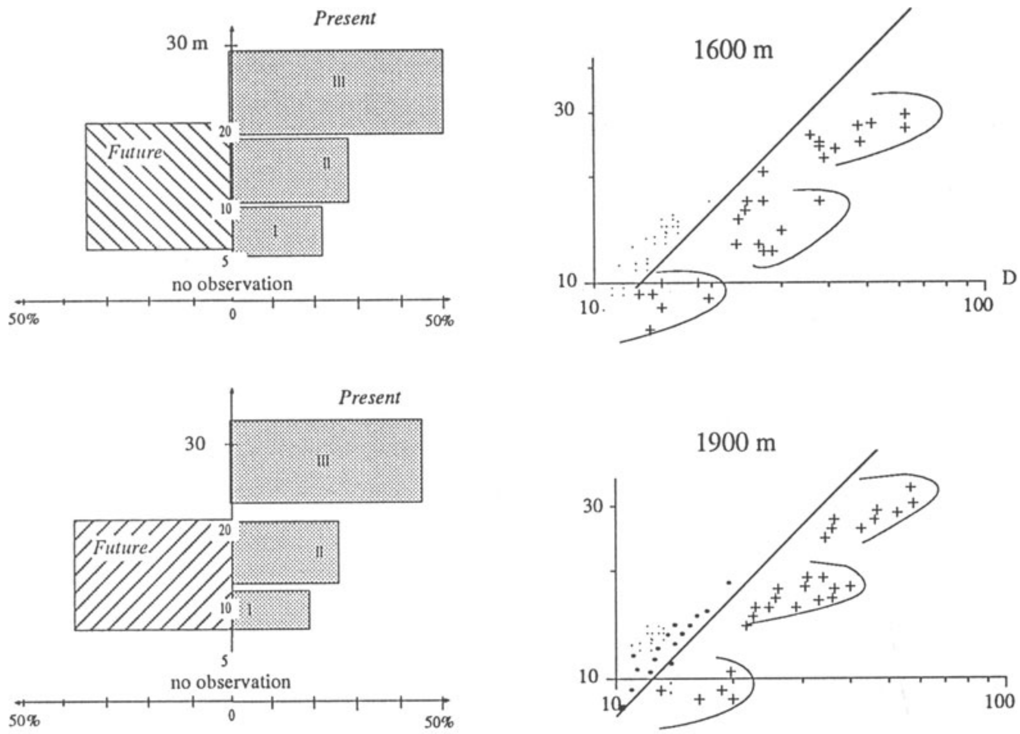


Fig. 81. Height-diameter relationship, stratification, number and coverage of architectural ensembles for lower montane forest types (1400–1900 m). Three structural sets remain for the trees of the present. In terms of tree architecture, it is sometimes difficult to classify trees; the set of the future could be underestimated. The minimal limit of 10 cm for diameter measurements is not suitable anymore for such forest types. It was lowered to 7 cm.

(*Elaeocarpus mastersii*, *E. obtusus*), Euphorbiaceae (*Drypetes subsymetrica*), Hamamelidaceae (*Distylium stellare*), Melastomataceae (*Memecylon oleifolium*), Moraceae (*Ficus involucrata*, *F. lanata*, *F. vasculosa*), Oleaceae (*Chionanthus oxycarpus*).

The undergrowth is particularly rich in Myrsinaceae (*Ardisia korthalsiana*, *A. marginata*, *A. zollingerii*) and Rubiaceae (*Hypobathrum microcarpum*, *Ixora grandifolia*, *Lasianthus chrysotrichus*, *L. purpureus*, *Litosanthes biflora*, *Psychotria viridiflora*). The author collected also *Daphniphyllum glaucescens* (Daphniphylleaceae), a shrub which is at its upper altitudinal limit here, *Glochidion rubrum* (Euphorbiaceae), a few lianas, such as an Olacaceae (*Erythropalum scandens*), a Vitaceae (*Ampelocissus thyrsiflora*), a Fabaceae (*Dalbergia subalternifolia*), Lobeliaceae (*Lobelia montana*), and a fern *Teratophyllum aculeatum* var. *montanum*.

The herb layer includes mainly Rubiaceae (*Ophiorrhyza sanguinea*), Gesneriaceae (*Cyrtandra anisophylla*) and Liliaceae (*Dianella ensifolia*, *Ophiopogon caulescens*). We also collected Melastomataceae (*Parasonerila heterophylla*), Polygalaceae (*Polygala venenosa*), a few Cyperaceae (*Carex*, *Hypolytrum*, *Scleria*) and Poaceae (*Lophatherum gracile*, *Joinvillea borneensis*), Selaginellas (*Selaginella intermedia*), and ferns such as *Diplazium cordifolium*, *D.* cf. *pallidum*, *Itenigraphis* sp..

On the majority of volcanos we climbed in the course of this study, 1800–1900 (2000) m is a relatively clear-cut altitudinal limit where changes in structure are conspicuous. On medium altitude peaks (Tanggamus 2000 m, Pesagi 2200 m), the forests show only two distinct structural groups. The proportion of microphyllous plants in the leaf mass increases considerably, and the forest becomes less dense. The rattans disappear.

On either side of the narrow rocky ridges at 1800 m on the Pesagi, one still encounters *Dacrydium pectinatum* and *Podocarpus* sp., emergent trees 25 m high, associated with *Quercus oido-*

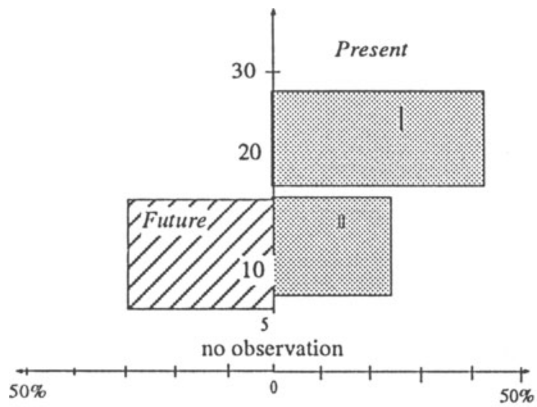


Fig. 82. Structural ensembles coverage in upper montane forest types (1900–2500 m). Only two layers remain. Future ensemble is somewhat less dense.

carpa, *Vernonia arborea*, *Acronodia punctata*, *Symingtonia populnea*, *Drypetes subsymetrica*, *Haemocharis buxifolia*, *Weinmannia blumei* and *Polyosma integrifolia*, all abundantly covered with mosses and other epiphytes. They constitute a fairly dense canopy 15 to 20 m overhead. The trunks are twisted, crowns are wide but the leaf mass sparser. At a height of 5 to 10 m, *Olea javanica*, *Archidendron clypearia*, *Platea excelsa*, *Lithocarpus pseudomoluccus*, *Myrsine hasseltii* are characteristic. Here, *Ficus hirta* is the main colonizer of treefalls and landslides. In the undergrowth, Rutaceae, Polygalaceae and a few herbs such as *Argostemma uniflorum*, *Sonerila tenuifolia*, and *Cyrtandra anisophylla* mix with ferns such as *Dipteris conjugata* and *Cheiropleura bicuspis*.

On the Dempo (3150 m), the Talamau (2912 m) and Mount Kerinci (3800 m), the forest observed at 1800 m is still relatively high and comprises three distinct structural groups (Fig. 82). On the Talamau at 1900 m (Fig. 83), the canopy is situated 25 to 30 m overhead and is occupied by *Castanopsis* cf. *rhamnifolia*, *Elaeocarpus*, *Haemocharis*, *Lithocarpus*.

The lower architectural ensembles from 15 to 20 m are moss covered. They are made up of *Lithocarpus suffruticosus*, *Drypetes talamauensis*, *Eugenia* sp., *Symplocos* sp, *Manglietia glauca*, *Beilschmiedia* sp., *Euonymus* cf. *javanicus*. At heights of 5 to 10 m, *Garcinia lateriflora* is often extremely abundant, associated with *Chionanthus oxycarpus*, *Dysoxylum cyrtobotryum*, *Ficus ribes*, *Drypetes rhacodiskos*, *Ardisia laevigata*, *Neolitsea cassiaefolia*, *Lithocarpus urceolaris*.

Secondary types

The effects of human activity are not so evident, (except in the mountain valleys such as that of Sungaipenuh or Toba plateau region). Secondary growths are mainly observed on old landslides. The colonizing species are chiefly Gleicheniaceae, *Pandanus*, and many other species also found on the submontane zone, such as *Macaranga winkleri*, *Ficus hirta*, *Vernonia arborea*, *Wendlandia glabrata*, *Villebrunea rubescens*.

Upper montane forests (1900–2500 *m*)

The cloud layer is relatively constant at these altitudes with abundant bryophytes. On the Talamau, a belt of *Pandanus* cf. *sumatranus* is encountered, similar to that described by Stein (1974) further North (Mt Sinabung). *Symingtonia populnea*, *Vernonia arborea*, *Acronodia punctata*, *Lithocarpus suffruticosus* are very abundant in the canopy, as is the case of *Saurauia micrantha*, *Weinmannia blumei*, *Michelia salicifolia*, *Viburnum* cf. *coriaceum*, *Symplocos robinsonii*, *Myrsine* cf. *hasseltii* characterizing the underlying layers. *Vaccinium*, *Rhododendron* and *Schefflera* epiphytes become more abundant. On the ridge joining the pass at 2800 m, we traversed a vast growth of Gleicheniaceae, the origin of which is hard to determine as the adjacent ridges are covered in forest at the same altitude. Very likely it could be due to recolonization after burning.

At an altitude of 2300 m on Mount Kerinci, as is the case on the Pangrango in West Java (Yamada 1976), two arborescent structural ensembles are distinguishable (Fig. 84).

The upper structural group 15 to 25 m above the ground is very open, with small crowns shaped by the prevailing winds. Gaps represent up to 60% of plot surface area. Bryophytes cover all individual trees and the branches are often covered in *Usnea*. One of the rare species to still reach 1 m in diameter for a total height of 20 m is *Symingtonia populnea*, a Hamamelidaceae. Only *Manglietia calophylla* and *Symplocos* sometimes

Fig. 83

Garcinia lateriflora (3,7,9,25,34,14,11,18,19,25,26,27,57,41, 44,47,62,71), Eugenia (30,13,15,16,33,21,55,42,45,50,53,60,64,69), Ardisia laevigata (4,17,24,31,51,72,67), Castanopsis cf. rhamnifolia (39,29,38,58,40), Symplocos (10,35,36,46,36), Lithocarpus sp (1,2,5), Beilschmiedia sp (6,22), Litsea (8,65), Elaeocarpus cf. pierrei (37,52), Ilex (30,35), Litsea cf. diversifolia (65,8), Acer caesium (73), LAURACEAE *(43), Chionanthus (54), Drypetes rhacodiskos (12), Euomymus javanicus (70), Eurya sp (20),* FAGACEAE *indet (32), Ficus ribes (48), Helicia sp (68), Lithocarpus sp (23), Litsea (49), Neolitsea cassiaefolia (59),* THEACEAE *unidentified (61).*

Fig. 83. Floristic composition of a montane forest plot at Mont Talamau, West Sumatra, alt. 1900 m. The forest is typically dominated by *Garcinia lateriflora*, *Eugenia* sp., *Castanopsis rhamnifolia*, several *Symplocos* sp. and *Ardisia laevigata*.

reach this size. There are other noteworthy species in the canopy such as *Lithocarpus oreophilus*, *Quercus* cf. *steenisii* and *Glochidion lutescens*.

At 10 to 15 m above the ground, the lower structural group is not very dense. It consist of *Symplocos* sp, *S. cochinchinensis* var. *sessilifolia*, *Acronodia punctata*, *Castanopsis argentea*, *Polyosma integrifolia*, *P. ilicifolia*, *Neolitsea cassiaefolia*, and *Ficus ribes*.

The shrub layer is mainly composed of *Ardisia javanica* associated with *Casearia tuberculata*, *Macropanax dispermus*, *Myrica javanica*, *Schima wallichii*, *Saurauia micrantha*, *Meliosma lanceolata*, *Neolitsea javanica*, *Ostodes paniculata*, *Ilex triflora*, *Viburnum lutescens* and the tree fern *Cyathea trachypoda*. Epiphytes and hemi-epiphytes such as *Schefflera scandens* are common, whereas pioneering species are mainly represented by *Weinmannia*, *Vernonia*, *Parasponia*, *Myrica* and *Albizia lophanta.*

Tropical subalpine forests (> 2500 m)

The belt of Gleicheniaceae (*Gleichenia*, *Dicranopteris*) on Mount Kerinci between 2400 and 2700 m has also not been fully explained (cf. Jacobs 1958). Higher up, the trees suddenly become twisted and shorter. At this altitude, *Myrsine*, *Ardisia* and *Vaccinium* are the dominant genera. The forest is only fifteen meters high at this point and has two vegetation layers. On Mt. Dempo, Ericaceae are very dominant, which is not true of Mt Kerinci. At 2800 m (Fig. 85) the slope is very steep and many trunks first grow out horizontally before bending upwards orthotropically. Trees are twisted and moss-covered, with small microphyllous crowns. Stem density is very high, and most species are multi-stemmed.

The upper structural group at 10–15 m is dominated by *Symplocos cochinchinensis* var. *sessilifolia* and *Ilex pleiobrachiata* (= *I. cymosa*). The second, at 5 to 10 m is composed of *Myrsine affinis*, *Ardisia laevigata*, *Meliosma lanceolata*, *Cyathea trachypoda*.

The ground is covered by a fern *Plagiogyria pycnophylla* (0.5 to 1.5 m high), and brambles such as *Rubus elongatus* and *R. alpestris*. Higher up, the forest is even lower, and at 3000 m all that remains is a very dense thicket 3 to 6 meters high, dominated by Ericaceae *Rhododendron retusum*, *Vaccinium miquelii*, *Gaultheria nummularioides*, Symplocaceae *Symplocos cochinchinensis*. The daisy *Anaphalis javanica* (Asteraceae) is abundant.

At an altitude of 2800 m on Mount Talamau, one reaches a plateau of *Lycopodium* (*L. cernuum*, *L. clavatum*, *L. complanatum*), Cyperaceae (*Gahnia javanica*) and sparsely growing shrubs (*Vaccinium*, *Rhododendron*, *Gaultheria*, *Sorbus granulosa*) before reaching the summit which is colonized by shrubs. At the same elevation the mossy forest around the small lake on the Singgalang is particularly beautiful, with its large *Leptospermum javanicum* (Fig. 86).

Vegetation disappears above 3400 m on Mount Kerinci due to volcanic activity, and one reaches the crater after crossing screes.

The flora of the tropical subalpine zone was thoroughly studied by the Dutch botanists. The best known species are given in Table 22.

Agroforestry formations

This overview of the vegetation of Sumatra would not be complete without discussing agroforestry

Table 22. Main characteristic species of the tropical subalpine zone in Sumatra (Ericaceae after Sleumer, 1960).

ELAEOCARPACEAE
Acronodia punctata

ERICACEAE
Diplycosia apiculifera
Diplycosia atjehensis
Diplycosia brachyantha
Diplycosia glauciflora
Diplycosia sumatrensis
Gaultheria abbreviata
Gaultheria acroleia
Gaultheria atjehensis
Gaultheria dialypetala
Gaultheria kemiriensis
Gaultheria leucocarpa
Gaultheria losirensis
Gaultheria nummulariodes
Gaultheria punctata
Pyrola sumatrana
Rhododendron acehense
Rhododendron adinophyllum
Rhododendron aequabile
Rhododendron sumatranum
Vaccinium bartlettii
Vaccinium laurifolium
Vaccinium miquelii
Vaccinium varingiaefolium

FAGACEAE
Lithocarpus atjehensis
Lithocarpus oreophilus
Quercus stenisii

MYRSINACEAE
Ardisia laevigata
Myrsine affinis

ROSACEAE
Sorbus granulosa

LILIACEAE
Aletris foliolosa

SABIACEAE
Meliosma lanceolata f. nervosa

SYMPLOCACEAE
Symplocos atjehensis
Symplocos robinsonii
Symplocos sessilifolia
Symplocos sumatrana

CYPERACEAE
Gahnia javanica

CYATHEACEAE
Cyathea junghuhniana
Cyathea trachypoda

GLEICHENIACEAE
Gleichenia vestita
Gleichenia volubilis
Gleichenia vulcanica

AQUIFOLIACEAE
Ilex pleiobrachiata

ARALIACEAE
Schefflera sp. aff. rugosa

DAPHNIPHYLLACEAE
Daphniphyllum woodsonianum

EUPHORBIACEAE
Glochidion alticola

MYRTACEAE
Leptospermum flavescens
Leptospermum javanicum

THEACEAE
Gordonia vulcanica

ASTERACEAE
Anaphalis javanica

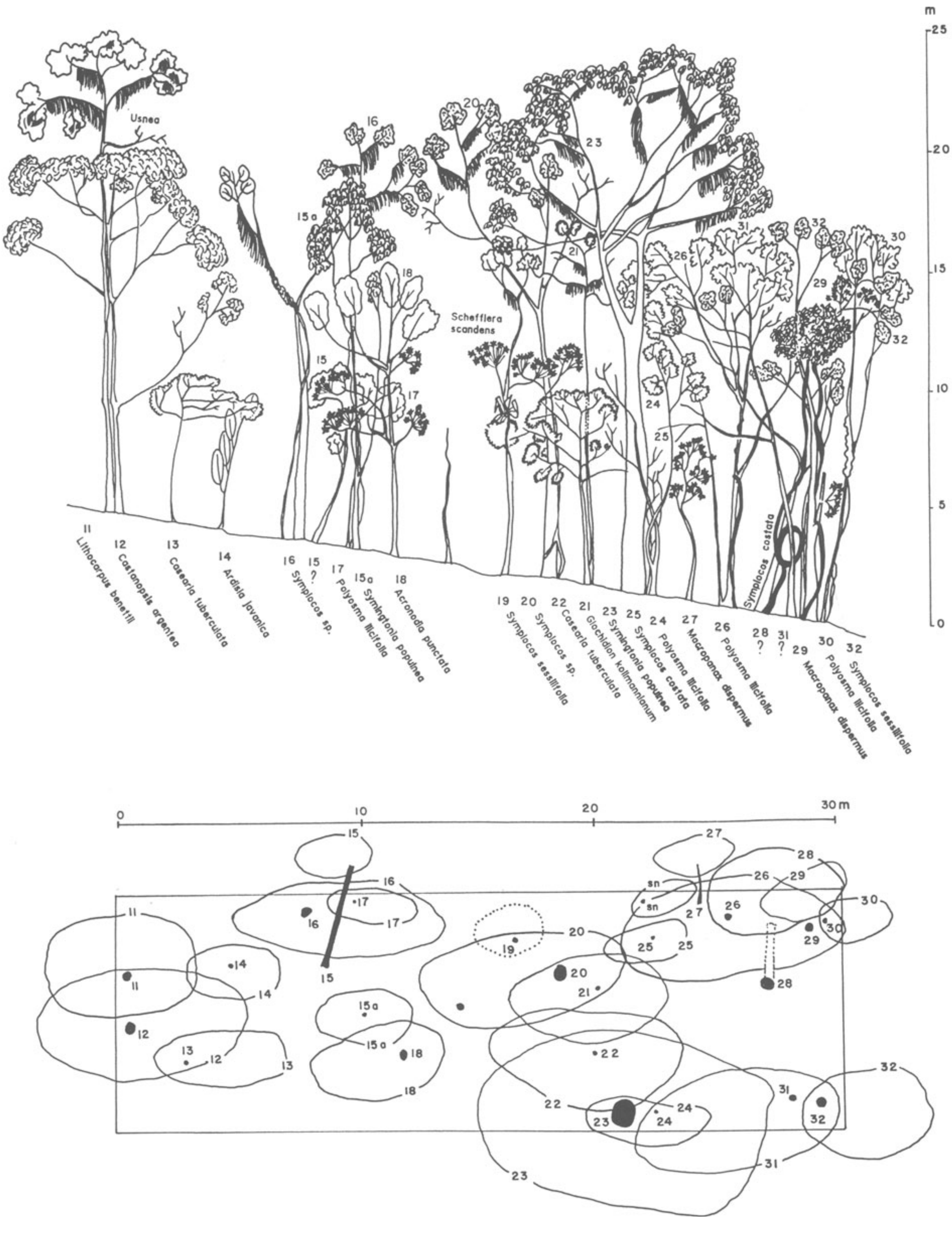


Fig. 84. Upper montane forest type. Mount Kerinci, alt. 2300 m.

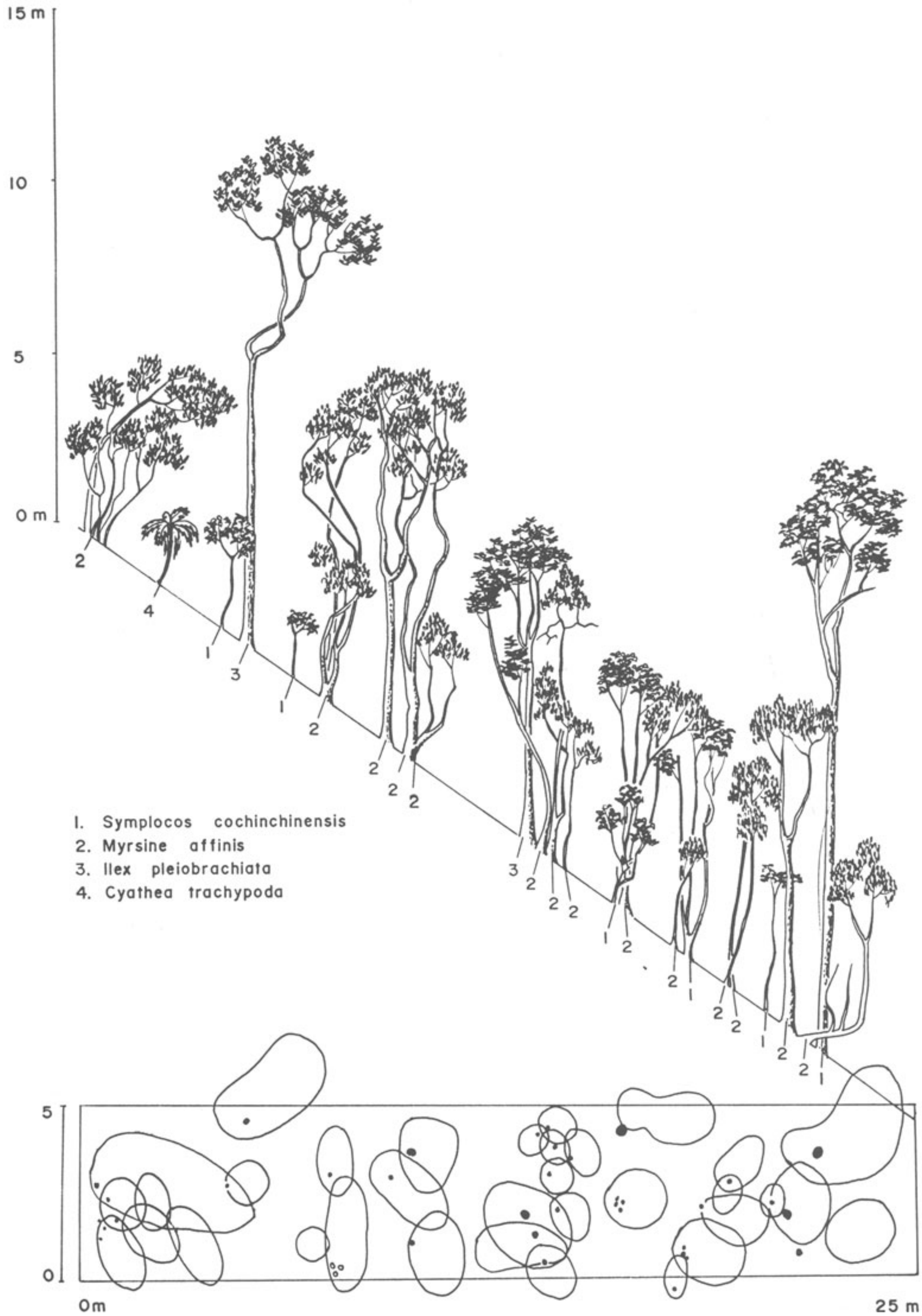


Fig. 85. Tropical subalpine forest type. Mount Kerinci, alt. 2800 m. At that elevation on Kerinci peak, the Ericaceae family is not dominant, a rather unusual fact.

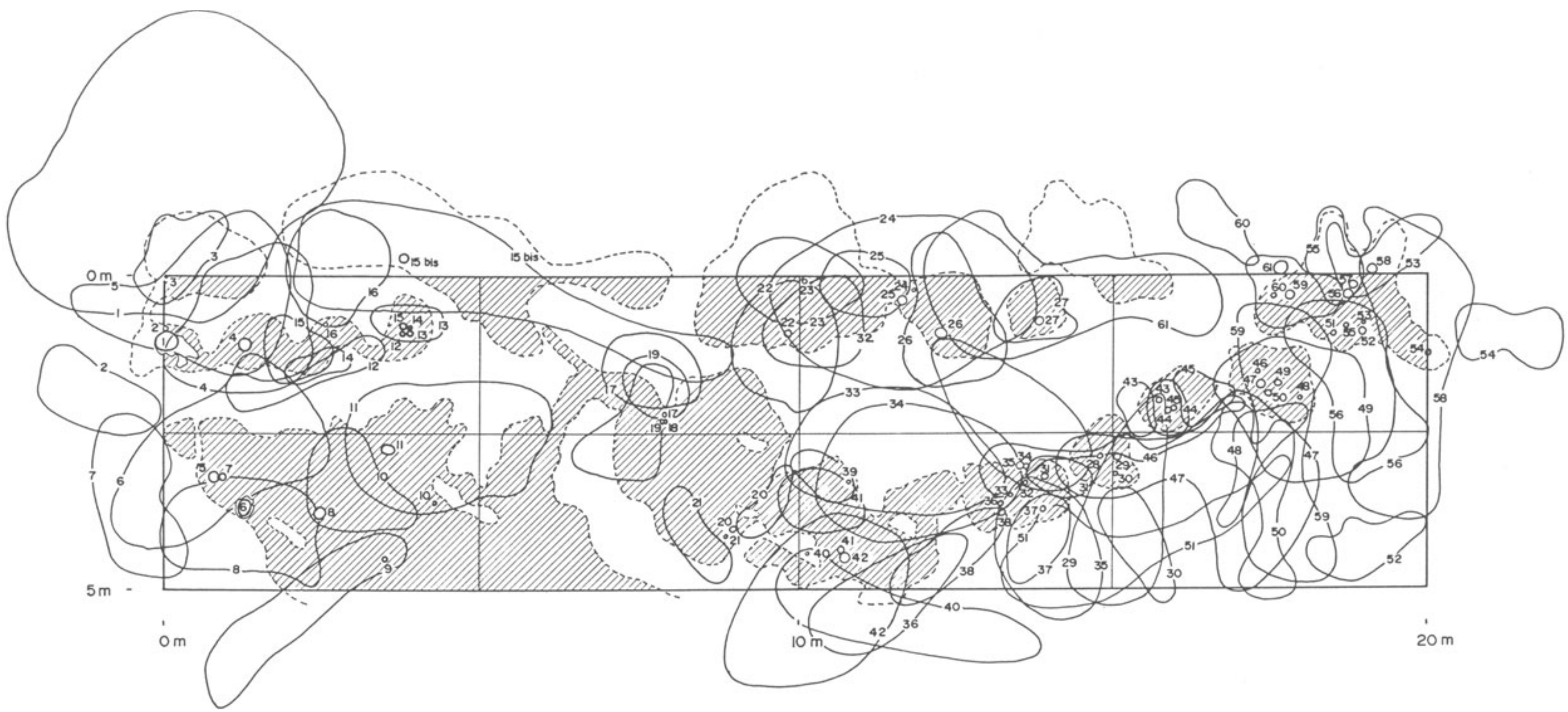


Fig. 86. Tropical subalpine forest type. Mount Singgalang, alt. 2800 m, flat area. This "elfin" forest is dense and mossy. It is also one of the tallest seen in Sumatra with almost pure stands of large *Leptospermum javanicum* in the canopy. Even the ground is covered with mosses.

formations, which take up such large areas on the map. The following descriptions are borrowed from the works of Michon (1985), Michon and Bompard (1987), Michon and de Foresta (1992), Gouyon et al. (1993).

Sumatra is too often considered to be an island dominated by extensive food crop agriculture, where the 'ladang', or plot of cleared forest, burnt and farmed for a year or two and then left to natural regrowth for a long time, is the only real element of the agricultural system.

Today, this form of agriculture exists only as an exclusive production method for a few distinctive ethnic groups (the Orang Talang Mamaq in the Riau region, for instance), or briefly for certain migrant groups without land or other facilities. Only 14% of the rice produced in Sumatra is cultivated in the traditional way in ladangs (Scholz 1983). Everywhere else, the ladang is only a minor component of an agricultural system which also comprises 'sawahs', or permanent irrigated rice fields, which account for 76% of all cultivated rice producing land in Sumatra, 'tegalans', dry fields of seasonal crops like rice, manioc, maize, etc., and 'kebuns', perennial plant gardens.

The importance of perennial crops in the island's agricultural system cannot be over-emphasized: while the large plantations (*Hevea* and oil palm, mainly concentrated in the northern sector of the island) only just cover 10% of all arable land, family-operated 'plantations' of *Hevea*, coconut palm, coffee, fruit, clove and cinnamon trees cover over three million hectares i.e. 55% of arable land.

Another noteworthy feature of Sumatra's arboriculture is the form it takes. The term 'garden' is more appropriate than 'plantation', which refers to the monocultural 'estates', when describing these farming systems. Over 70% of the *Hevea* rubber harvested in Sumatra is produced in what is commonly called 'jungle rubber gardens' which are infinitely more like secondary forests than conventional plantations.

Indeed, a whole part of Indonesian agriculture is built around the natural forest. These 'kebun' systems were originally based on the principle whereby various types of crop trees are combined to form a typically forest-like vegetation: after clearing, the most useful local forest species such as fruit, spice and fiber-producing trees, rattans, bamboos, palms, shrubs, lianas and grasses are gradually reintroduced into these complex 'gardens', which are so totally different to the western concept of a plantation and which form a genuine agroforestry system. Originally food producing (fruit, vegetables, spices and condiments) or useful (natural materials for building and crafts, medicinal plants), these agroforestry gardens soon changed. For centuries, the 'jungle farmers' of Sumatra, inland populations living of crops grown in burnt clearings and products of the forest, played an active part in the traditional 'export' product trade (resins, exotic woods, lacquers, etc.). The development of trade with the West and over-exploitation of forest products rapidly gave rise to plantations of the main products. Thus the benzoin and cinnamon, both natural forest trees, found their place in the jungle garden system as from the 16th century (Marsden 1783).

With the development of colonial crops, the Sumatrian peasants naturally adopted new species which were ecologically well adapted to their agroforestry system: the pepper tree, coffee, and above all the *Hevea*, all of which are forest species, were soon integrated into the jungle gardens. The pepper tree was adopted in the 17th century, coffee at the beginning of the 18th century, and *Hevea* towards 1900 (Pelzer 1948). These introductions have been multiplied by means of the ladang since the boom of colonial crops: more than three quarters of the ladangs made in the forests are transformed into kebuns during the second year by planting young saplings with the second crop of rice.

The introduction of these new crops has not changed the traditional form of the jungle garden to any great extent and it still with us today: the dominant crop is often combined with other useful plants, all trees are not of the same age, the spontaneous element (the 'weed' equivalent in western agriculture) is not systematically fought against but either put to use or left alone if harmless (Michon et al. 1986).

Main agroforest types and structure

The agroforestry systems encountered in Sumatra are varied, the most widely used being the *Hevea* system in the piedmonts and peneplains of the east where perennial plants cover more than 70% of cultivated land. This system accounts for 90% of all jungle gardens. Over the entire island, small family-run *Hevea* gardens are estimated as 2 to 2.5 million ha (Michon & de Foresta 1992), while industrial plantations only cover 280 000 ha (Scholz 1983).

The young *Hevea* are planted in the ladang and receive the care given to other food crops for one or two years. The plantation is then left to nature and the trees grow with the secondary vegetation which establishes itself spontaneously. The plot is partially and selectively cleared when rubber production starts. The species growing with the *Hevea* thus depend more on random natural dispersion than on a deliberate choice of the planter. Concentrations of fruit trees generally indicate where the old ladang house once stood, and it is mainly the characteristics of the local forest or ground flora, as well as the proximity of forest masses which affect the make up and structure of these jungle gardens.

Structurally, *Hevea* plantations are similar to secondary forests (belukars), with which they are often confused, both at ground level and on aerial photographs. The canopy over *Hevea* plantations is generally low (18–25 m), with a few emergent trees reaching heights of 30–35 m (in the Lahat region there are systems incorporating dipterocarps cultivated for wood, H. De Foresta, pers. comm.). The density of small stems is high. The structure is not well defined as these plantations rarely reach a sufficient degree of maturity: they are often entirely reworked after 70–80 years.

Fruit orchard systems are found around nearly all villages on the island. Depending on the ethnic group, the environment and the state of access roads, these vary in size and importance. In the central peneplains where riverways and roadways date from ancient times, orchards have been established on alluvial terraces along the Batanghari at Jambi. Under a high canopy of durians (*Durio zibethinus*) the orchards along the banks of the Enim, Komerin, Ogan rivers in South Sumatra shelter duku (*Lansium domesticum*) and rambutan (*Nephelium lappaceum*) cultivated for the urban market, and species of lesser importance such as *Baccaurea*, *Eugenia*, and *Pithecellobium* for family and local use. These orchards, which also contain trees for wood only, bamboos and medicinal plants, are very similar to the Javanese 'home-gardens' described by Soemarwotto (1975).

More complex and original systems have developed in the forests bordering the Barisan mountain range. In certain regions, these systems form a transition belt between agriculture and the natural forest. In the Lampung, Bengkulu, and South Sumatra provinces, a system based on a resin-producing dipterocarp, *Shorea javanica*, was developed at the beginning of the century. In these original systems, which were studied by Rappart (1937), Torquebiau (1984) and Michon et al. (1992), the plant biomass, tree population density, vertical structure and leaf coverage have a similar value to those of the nearby natural ecosystem. The canopy is high (40–45 m), dominated by forest tree genera (*Durio*, *Mangifera*, *Shorea*), density varies between 400 and 600 trees with a diameter greater than 10 cm per hectare, which corresponds to the values found in the primary forest (Fig. 87).

Floristics

The agroforestry garden of Sumatra is a complex world of forest and agricultural elements. The cinnamon tree (*Cinnamomum burmanii*) and the *Hevea*, the island's commercial pillars, have always been and will remain forest trees, even as far as their behaviour in the jungle gardens is concerned. In the fruit-producing region of Palembang, the 'rambutan' designates both the grafted clones of *Nephelium lappaceum* and the forest varieties of *Nephelium*, carefully maintained in the *Hevea* gardens.

Wherever dominant crops are surrounded by large forest trees or shrubs common to secondary vegetation other than the species directly cultivated or controlled (export products, fruit, wood), the agroforestry systems comprise a 'spontaneous' component which, like in certain *Hevea* gardens in Jambi province, can represent over 50% of the tree population. Thanks to their structure and the agricultural practices applied to them, the jungle gardens maintain many species of forest trees. Near Padang in West Sumatra, one of the richest and most densely populated areas of Sumatra, the low altitude forest was replaced ages ago by jungle gardens commonly comprising over 30 farmed species and several hundred spontaneously growing species, which are themselves often used.

In the spontaneous component, the proportion of species originating in the primary forest or secondary vegetation depends mainly on the age

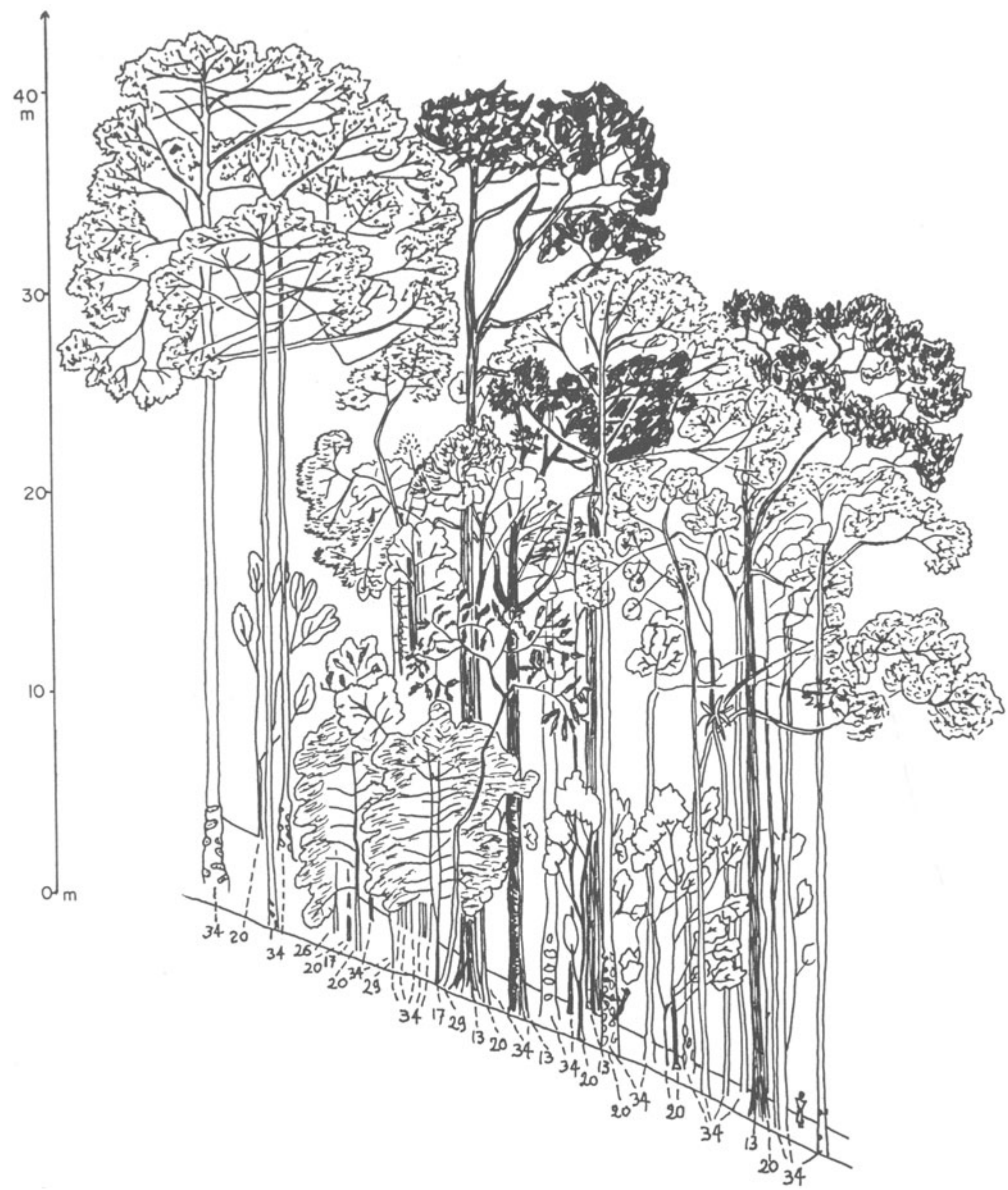


Fig. 87. Agroforest with *Shorea javanica*, Krui, West Lampung (after Michon et al., 1986). *Shorea javanica 34; Lansium domesticum 20, Nephelium lappaceum 26, Garcinia mangostana 17, Parkia speciosa 29, Durio zibethinus 13.*

of the garden, the way the dominant crops are rotated and on the distance from natural forests.

The most frequently encountered trees are from the canopy (*Durio*, *Shorea*, *Mangifera*, *Parkia*) or undergrowth (*Garcinia*, *Nephelium*, *Cinnamomum*, *Pithecellobium*, *Eugenia*) of natural forests, but large heliophilous plants are also present (*Artocarpus*, *Ficus*, *Terminalia*, *Octomeles*, *Alstonia*, *Pterospermum*) as well as the species typical of pioneer formations: *Macaranga*, *Mallotus*, *Vitex*, *Commersonia*, *Peronema*. The combination of shade-tolerant and sun-loving species as also found in the undergrowth where shade plants characteristic of forest environments (many Ferns and *Selaginella*, Araceae, Begoniaceae, Gesneriaceae, Leeaceae, Marantaceae, Rubiaceae, Urticaceae, Zingiberaceae) grow with species typical of degraded ruderal or savanna vegetation: *Chromolaena odorata*, *Lantana camara*, *Piper aduncum*, *Eupatorium inuli-*

folium, *Clibadium surinamense*. The specific variety of the agroforestry flora is complemented by lianas, rattans, and epiphytes (many Orchidaceae, ferns, Melastomataceae, Rubiaceae), which are more numerous when the garden is still close to forest.

The importance of these agroforestry systems, which cover nearly 10% of Sumatra's surface area, should not be underestimated. They maintain a part of the original floristic diversity on the land cleared by peasants, represent an important reservoir of the genetic resources of the forest, which are currently threatened, and allow for reforestation of a considerable amount of land. The part they play in planning for the regions under development should be more systematically taken into account, particularly their conservation potential for soil and forest resources in agricultural zones. They are also valuable for controlling land surrounding the natural forest reserves as buffer zones.