THAI FOR. BULL. (BOT.) 25: 102–123. 1997.

GEOGRAPHICAL AND ECOLOGICAL DISTRIBUTIONS OF THE TWO TROPICAL PINES, PINUS KESIYA AND PINUS MERKUSII, IN SOUTHEAST ASIA

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ABSTRACT

Geographical and ecological distributions of the two tropical pines, *Pinus kesiya* and *P. merkusii* in Southeast Asia are clarified and illustrated. The taxonomic confusions of the species complex, *P. kesiya* and *P. yunnanensis* are briefly discussed. *Pinus kesiya* illustrates a northerly distribution pattern whereas *P. merkusii* can be encountered as far south as in central Sumatra, the only place where the genus Pinus occurs naturally south of the Equator. In Thailand *P. kesiya* is mainly associated with lower montane pine-oak forest whilst *P. merkusii* is a characteristic species of pine-deciduous dipterocarp forest and pine-oak savanna. Occasionally, *P. kesiya* is locally found co-dominant with *P. merkusii* in the moister areas of pine-deciduous dipterocarp forest. The optimal altitudinal range of *P. kesiya* is recorded at above 1,000 m.a.s.l. In northern Thailand the pine-oak association is reduced considerably above 1,500 m.a.s.l., and pine trees (*P. kesiya*) here are rather sporadic in occurrence. However, in the higher mountain ranges north of the Thai territory (i.e. Assam, Yunnan), *P. kesiya* (including *P. yunnanensis*) proliferates at the altitudinal zone from 1,500 to 2,900 m.a.s.l. *Pinus merkusii* usually reaches its best development at below 1,000 m.a.s.l. in the pine-deciduous dipterocarp forest or the savanna-like pine-deciduous dipterocarp vegetation. The lowest altitudinal distributions of the tropical pines are represented by *P. merkusii* in Thailand (at ca 70 m.a.s.l.) and the Philippines (at ca 60 m.a.s.l.).

INTRODUCTION

The indigenous pines in Thailand are represented by two tropical Pinus, *P. kesiya* Royle ex Gordon (Son sam bai-literally, 3-needled pine) and *P. merkusii* Jungh. & de Vriese (Son song bai-literally, 2-needled pine) (Phengklai 1972; Santisuk 1988; Werner 1993). Both are found mainly in the zone of lower montane forests (900–1,400 meter above sea level) in the mountains of the north and northeast. *Pinus merkusii*, however, can grow in the zone of lowland deciduous forests at elevations about 70–400 m.a.s.l. in the eastern and central Thailand, and as low as 60 m.a.s.l. in the Philippines (Mirov 1967).

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Botanically the distinctions between *Pinus kesiya* and *P. merkusii* are clear-cut, especially in the number of needles in each bundle (Figs. 7 & 23). More botanical informations on these two pines are available in the Flora of Thailand (Phengklai 1972). However, infraspecific variations can be expected in certain geographical variants of *P. kesiya*. Hence, nomenclatural confusions with *P. kesiya* are inevitable. The specific name *P. insularis* Endl., for example, has long been known in the Philippines for the 3-needled pine or "benguet pine" (e.g. Mirov 1967; Laubenfels 1978). *Pinus yunnanensis* Franchet occurring on the high plateaus of southwestern China (Yunnan) is, in general appearance, similar to *P. kesiya* (Figs. 6 & 7). The recognition of *P. yunnanensis* as separable from P. kesiya by certain authors is based on variable vegetative characters (i.e. length of needles) and the chemical components of the oleoresin. *Pinus yunnanensis* is therefore considered to be conspecific with *P. kesiya* (*P. insularis*) by Wu (1956). Ecologically, *P. yunnanensis* grows from 1,900 to 2,900 m.a.s.l. on the excessively eroded slopes and ridges of the mountains of Yunnan where it forms extensive pine forests (Figs. 8 & 9). In the west its area merges into that of *P. kesiya* (Fig. 2). Both taxa possess the similar colonizing habit on the extreme sites of the non-calcareous mountains.

The aim of this study is to clarify the geographical ranges and ecological zones between *P. kesiya* and *P. merkusii* in Southeast Asia, with particular emphasis on the populations in Thailand. This work is a result of innumerable botanical surveys in the pine vegetation in Thailand (from 1977 onwards), Laos (February 1993, October 1994) and Yunnan, Southwestern China (February-March 1992, November 1993, February-March 1995).

GEOGRAPHICAL DISTRIBUTION OF THE TWO TROPICAL PINES

The two tropical pines, *P. kesiya* and *P. merkusii* are restricted to seasonnally dry climatic regions of Southeast Asia, mainly in the zone of montane forests, occurring naturally on extreme sites and with their range expanded by man-made disturbance. They are more widespread in the mainland Southeast Asia (Figs. 2 & 3.)

Geographical distribution of *Pinus kesiya*

Pinus kesiya has a more northerly distribution (Fig. 2) extending from the Khasi Hills in India, northeastward through the Naga Hills of Assam and farther, towards southeastern Sikang and Yunnan, merging gradually into the *P. yunnanensis* (*P. kesiya* in a broad sense) area. To the southeast of the Khasi Hills it extends to the mountains of upper Burma (the Chin Hills), the mountains of Karen State, and the highlands of Shan State (the Shan Hills). It continues southward to adjacent parts of northern and northeastern Thailand. Then it reappears in the mountains in the vicinity of Luang Prabang and east of Chiang Khouang in northern Laos, and the Bolovens Plateau around Attopeu of southern Laos. In Vietnam it occurs in Lao Kai, a northern province near Yunnan border, and the Langbian Plateau around Dalat in southern Vietnam. *Pinus kesiya* has never been recorded from Cambodia (Armitage & Burley 1980).

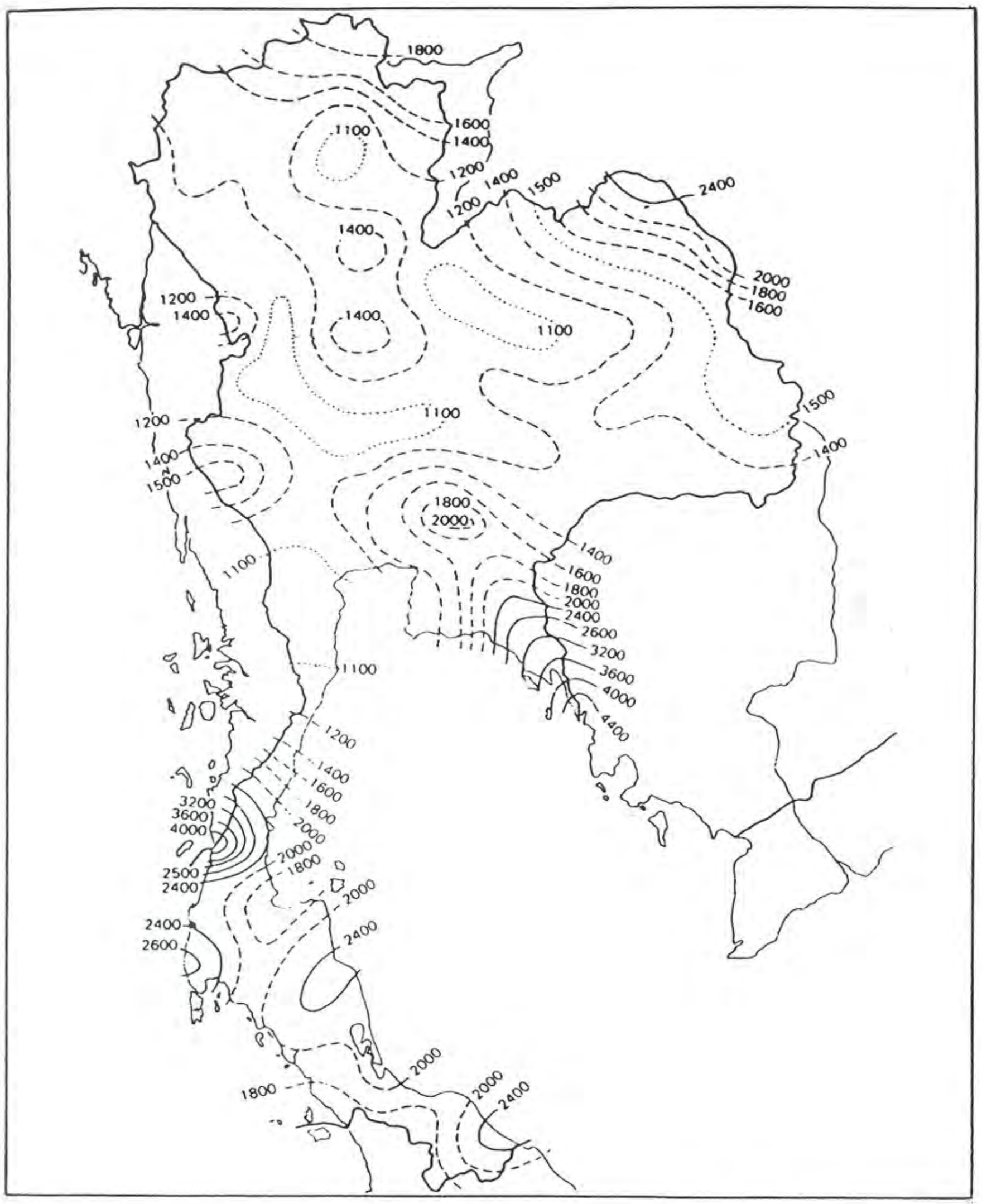

Figure 1. Thailand: isohyets with average mean annual precipitation (30 year-period, 1951-1980). Source: Meteorological Department, Bangkok (1982).

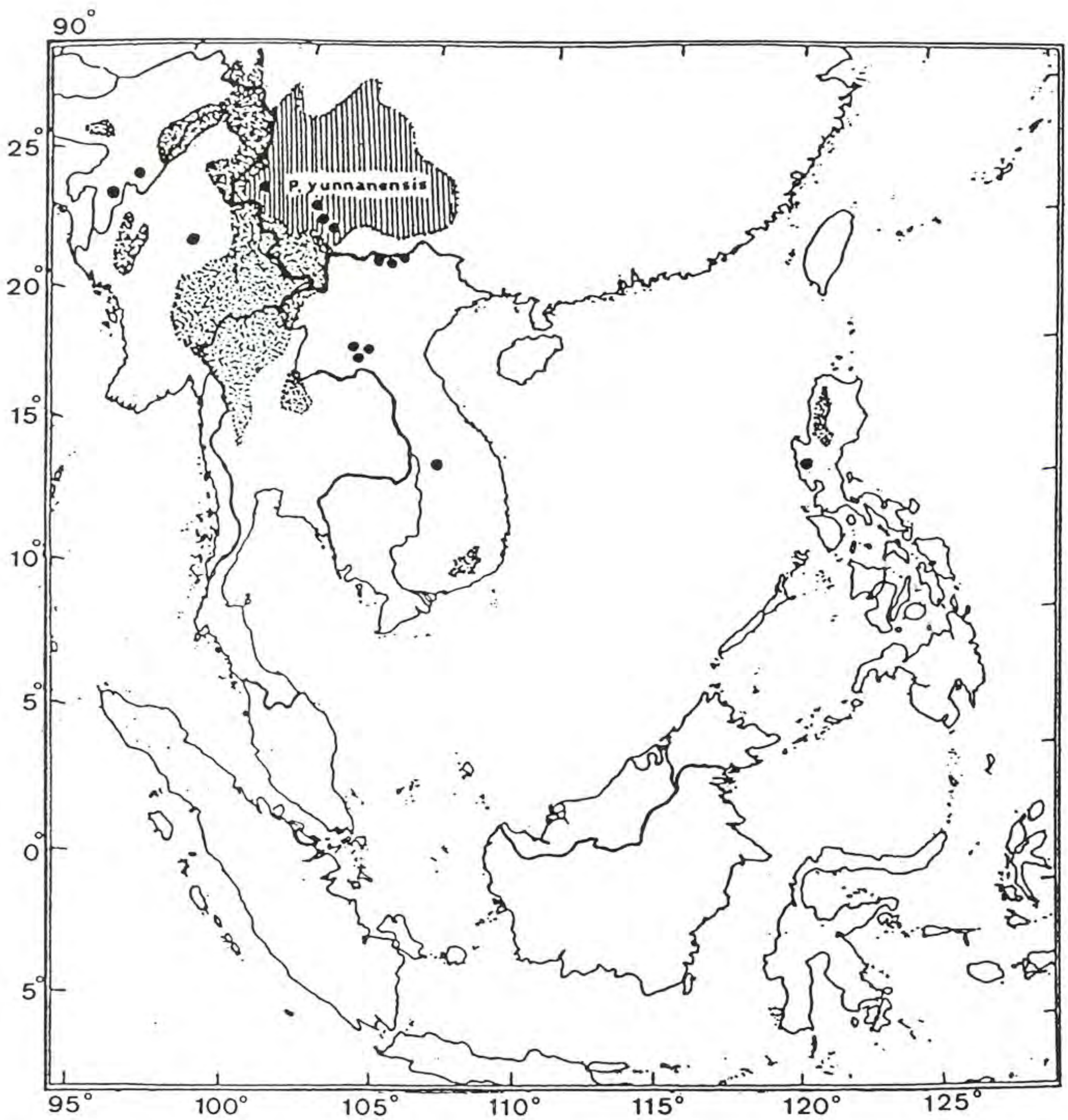

Figure 2. Geographical distribution of *Pinus kesiya* ■ & ● and *P. yunnanensis* ▥ in Southeast Asia.

To the east *P.kesiya* reaches as far as the Central Cordillera and Zambales mountains of northern Luzon in the Philippines, where it occurs at elevations between 1,000 and 2,700 m.a.s.l. (Farjon 1984). It came to Luzon from mainland Southeast Asia either at the end of the Tertiary or, most likely, much later, during the cool periods at the time of the Ice Age in the northern hemisphere (Mirov 1967).

Geographical distribution of *Pinus merkusii*

Pinus merkusii, in comparison with *P. kesiya*, has a more southerly distribution (Fig. 3). The northernmost limit of *P. merkusii* is located around Lao Kai in northern Vietnam close to the border of Yunnan, and in Muang Ou Nua, a northernmost province of Laos (about 22°–23° N) (Mirov 1967; Cooling 1968). It occurs in the southern Shan Hills of Burma, extending south into the adjacent western mountains of northern Thailand. *Pinus merkusii* is also found in sporadic patches in northeastern, eastern, and central Thailand. *P. merkusii* grows in the highlands of Chiang Khouang and Vientiane in northern and central Laos, the low plateaus of Khammouane and Savannakhet Provinces (e.g. Phu Phiang Nakai at the elevation ca 500 m.a.s.l.), and Paksong in southern Laos. In Cambodia, *P. merkusii* grows scatteredly in association with deciduous dipterocarps in the south of the Phanom Dongrak Range at elevations from 100 to 300 m.a.s.l., and farther south in Phanom Khla, Siem Reap, Kampong Thom, Tonle Sap, Pursat, Mondulkiri, and the Kirirom Plateau (Legris & Blasco 1972). In Vietnam, *P. merkusii* occurs extensively on the plateaus of Kontum, Dalat, Blao, and Lang Hanh at elevations of between 500–1,200 m.a.s.l. (Cooling 1968).

Pinus merkusii is also found in two areas in the Philippines, one on the island of Mindoro and the other in the Zambales mountains of western Luzon from 600 m.a.s.l. downwards. Surprisingly, *P. merkusii* on Mindoro can grow as low as ca 60 m. above sea level (Mirov 1967).

In the south, *P. merkusii* reappears again in the northern part of Sumatra where pines occur in the savanna-like terrain (about 800–2,000 m.a.s.l.) regularly disturbed by forest fire. *Pinus merkusii* is found south of the Equator in the Barisan Range of Sumatra at about 1° 41' to 2° 6' south, this being the only place where the genus Pinus occurs naturally south of the Equator (Stein 1978; Blasco et al. 1983).

ECOLOGICAL DISTRIBUTION OF THE TROPICAL PINES IN THAILAND

The two tropical pines *P. kesiya* and *P. merkusii* grow exclusively in the seasonally dry climatic zone of Thailand, characterized by the remarkable alternation of the hot dry (November-April) and rainy (May-October) season. Frequent mist at higher elevations (above ca 1,800 m.a.s.l.) (Fig. 4) and high annual precipitation more or less distributed throughout the year as encountered in the southeastern (Chanthaburi-Trad) region and peninsular Thailand throughout the Malay Peninsula (Fig. 1) are decisive factors in discouraging the growth and development of pines in Thailand, in addition to other edaphic and biotic parameters (Santisuk 1988).

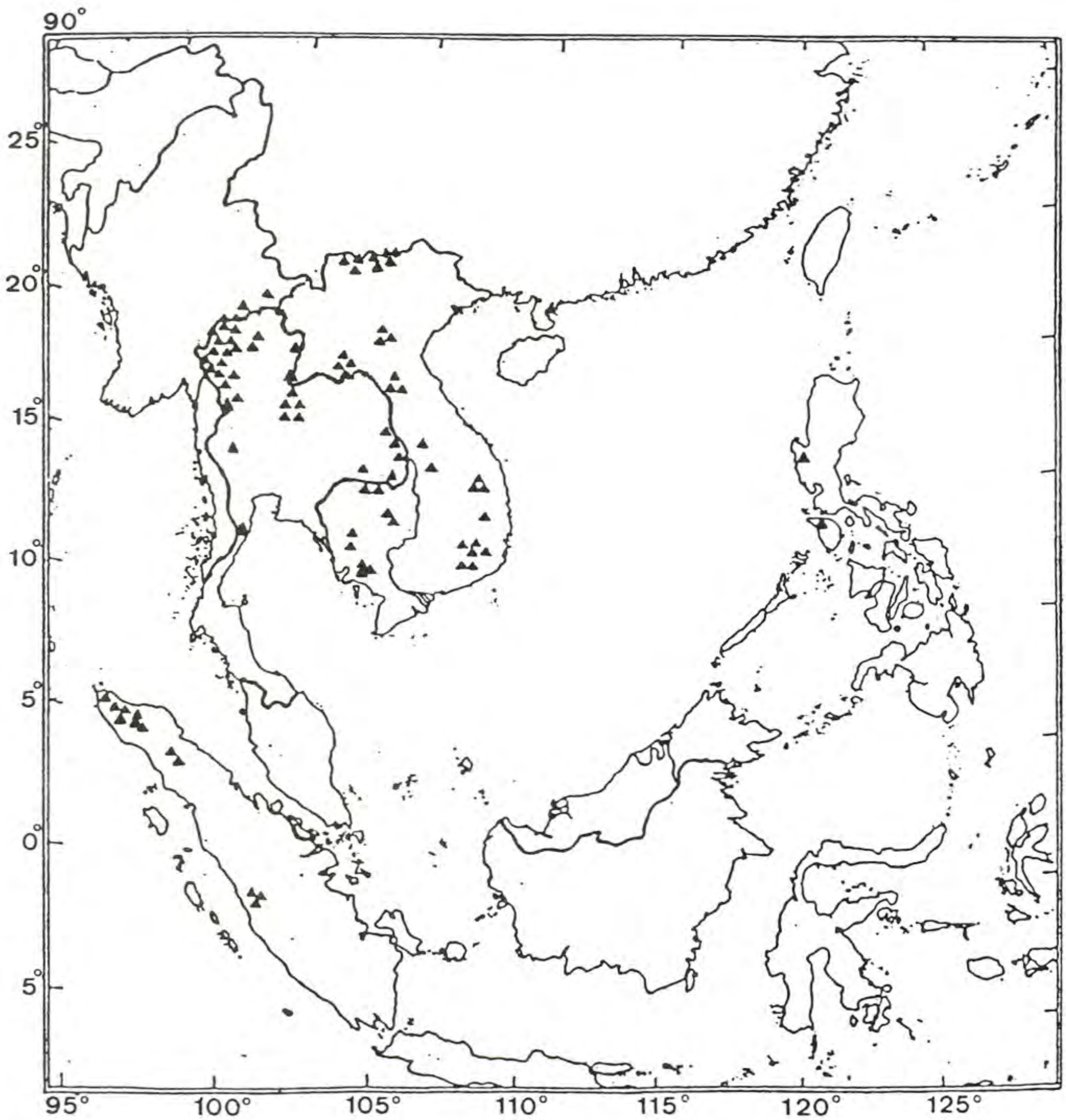

Figure 3. Geographical distribution of *Pinus merkusii* ▲

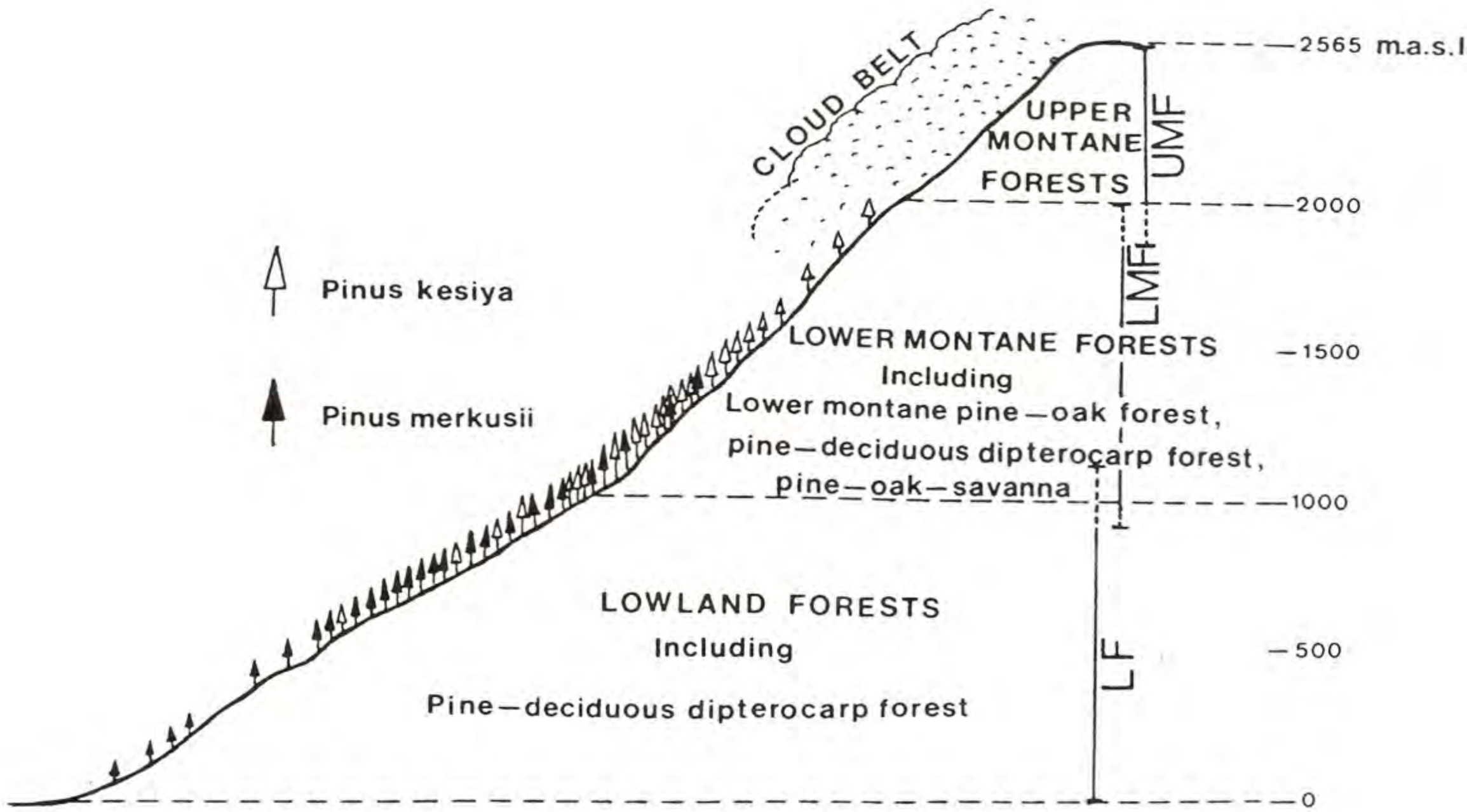

Figure 4. Diagram of the mountainous areas (except the southeast and peninsula) in Thailand up to the highest peak of Doi Inthanon (2,565 m.a.s.l.) showing the vertical or altitudinal distribution of the two tropical pines, *Pinus kesiya* and *P. merkusii*. Three ecological zones are recognized : lowland forest (LF), lower montane forest (LMF) and upper montane forest (UMF). Deciduous dipterocarp forest advancing at higher elevations into the zone of lower montane forests is characterized by an inclusion of the native pine trees, hence the name, "**pine-deciduous dipterocarp forest**". Furthermore, pine trees may be seen in association with the dominant components of the lower montane forests such as oaks from which the name "**lower montane pine-oak**" is derived. Pine-oak-savanna, characterized by an extensive undergrowth layer of grasses and sedges interspersed with scattered stands of pine trees, is usually confined to the flat-topped sandstone mountain at ca 1,000–1,800 m.a.s.l. in northern and northeastern Thailand (i.e. Phu Soidao, Phu Kradung and Phu Luang).

Pine vegetation in Thailand is often conveniently referred to as "coniferous forest" or "pine forest" under the evergreen forest category, by virtue of the evergreen habit of the pine trees, in several publications. In reality *P. kesiya* and *P. merkusii* seem to prefer different sites, occurring in association with other broad-leaved hardwood species of distinct forest formations of both deciduous and evergreen categories, namely pine-deciduous dipterocarp forest (deciduous type), lower montane pine-oak forest (evergreen type) and pine-oak savanna (Fig. 5). With the exception of pine-oak savanna in the level-topped sandstone mountains in northern and northeastern Thailand, pine forests similar to those of temperate regions never occur in Thailand. Hence, pine forests in Thailand are, in fact, lower montane pine-oak forest, pine-deciduous dipterocarp forest or pine-oak savanna in which *P. kesiya* and *P. merkusii* are scattered as one of the main canopy trees in association with other broad-leaved members of Fagaceae (*Castanopsis, Lithocarpus, Quercus*), Lauraceae (*Beilschmiedia*, *Litsea*, etc.), Theaceae (*Anneslea fragrans*, *Eurya*, *Schima wallichii*, etc.), and Dipterocarpaceae (*Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtusa* and *S. siamensis*) (Figs. 14, 15 & 22).

Pines in northern Thailand (Chiangrai-Chiangmai-Phayao-Maehongson-Lamphun-Lampang-Phrae-Nan-Uttaradit-Tak-Kamphaengphet-Phitsanulok)

Northern Thailand, characterized by hilly and mountainous landscape at elevations from about 200 to 2,565 m.a.s.l. (Doi Inthanon), supports varied types of forests which are very rich in species. With respect to altitudinal sequence, the vegetation zones of the north can be classified into the lowland zone [200–800(–900) m.a.s.l.)], the lower montane zone [(900–)1,000–1,800(–2,000) m.a.s.l.] and the upper montane zone [(1,800–)2,000–2,565 m.a.s.l.] (Santisuk 1988). The optimal growth and development of the two indigenous pines in the north are usually encountered in the lower montane zone at elevations from 900–1,300 m.a.s.l. However, a few individual pine trees may descend down slopes to about 400 m.a.s.l. (P. merkusii), or ascend up slopes to about 1,850 m.a.s.l. (P. kesiya) (Fig. 4). Pines in northern Thailand occur naturally in three distinct forest formations namely, lower montane pine-oak forest, pine-deciduous dipterocarp forest and pine-oak savanna.

Lower montane pine-oak forest (Figs. 5, 11, 12 & 13)

Floristically this vegetation type is similar to lower montane oak forest, but differs from it by the inclusion of a native, three-needled pine, *P. kesiya*, ranging from a few scattered trees to a dense stand. Lower montane pine-oak forest may be considered as a severe destruction stage of lower montane oak forest which is regularly or periodically interfered by biotic (burning, cutting, grazing) or edaphic (e.g. soil erosion) factors. Lower montane pine-oak forest is best developed on ridges, moderate to steep slopes at elevations from 950–1,400 m.a.s.l. Here pine trees are associated mainly with fagaceous (*Castanopsis, Lithocarpus, Quercus*), lauraceous (*Litsea*) and theaceous (*Anneslea fragrans, Eurya, Schima wallichii*) trees (for more details on floristic composition see Santisuk 1988). The lofty pine stands, up to 30–40 m high are more remarkable on the exposed ridges and steep slopes on which the red to yellow granitic soils are excessively eroded, and become too xeric to support the growth of other broad-leaved trees (Fig. 11).

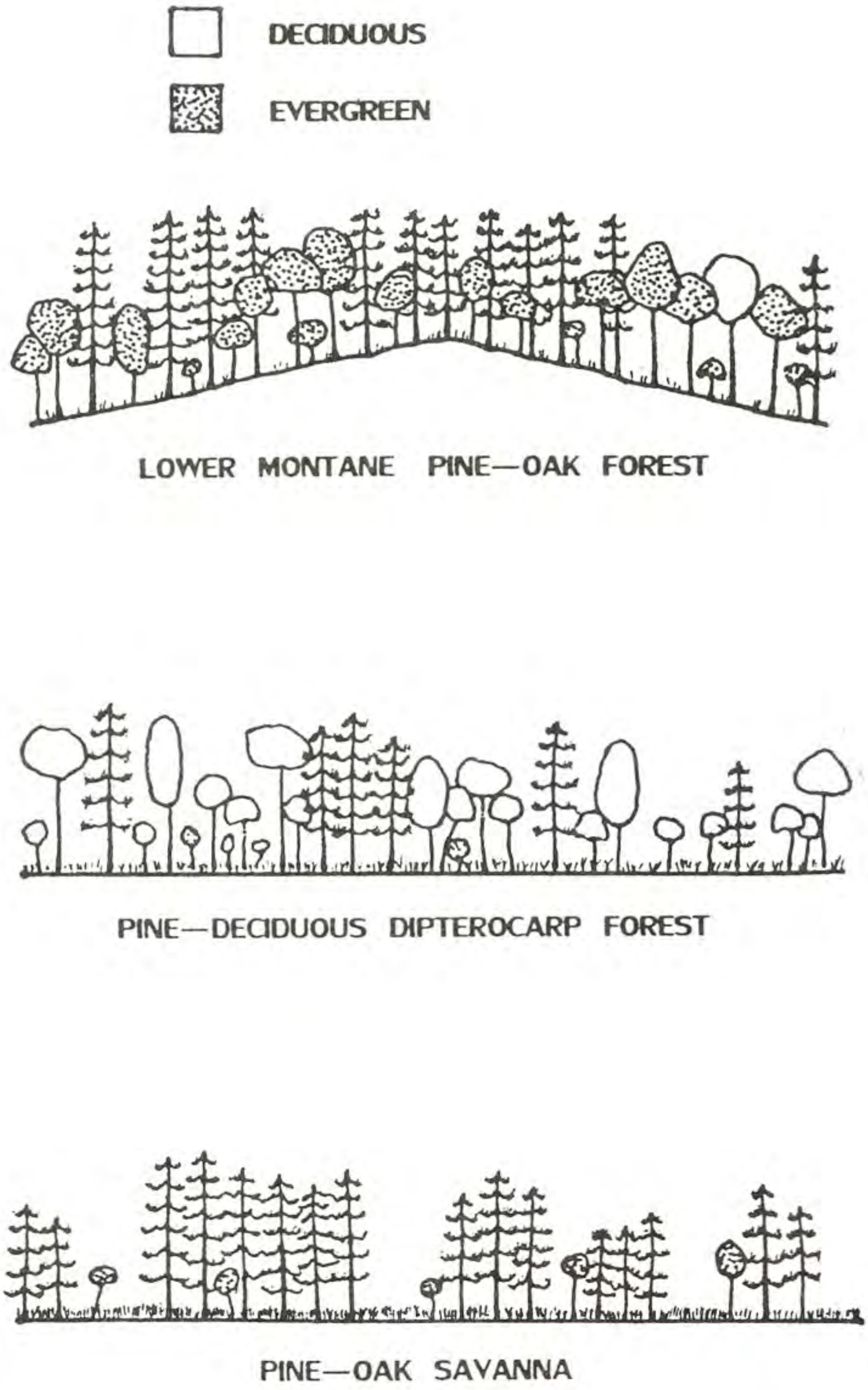

Figure 5. Schematic profiles of lower montane pine-oak forest, pine-deciduous dipterocarp forest and pine-oak savanna in Thailand.

Regular or periodical burning in the cool dry season (December-February) is a common phenomenon in lower montane pine-oak forest as surface fire can readily sweep over the forest floor with thickly-accumulated dry needles. The more regular the forest fire, the less chance for the broad-leaved trees to compete with pine seedlings and saplings. The Royal Forest Department's pine (*P. kesiya*) plantations in Doi Inthanon National Park have shown, that the number of species is increasing, once fire has been prevented for several years. For the rehabilitation of lower montane forests, fire protection is essential (Stott et al. 1990). To prevent surface run-off and soil erosion in the watershed areas of northern Thailand, the abandoned, degraded fields are planted with *P. kesiya* by the Royal Forest Department. Once fire is effectively prevented for at least 5–10 years, these pine plantations or other patches of the natural pine stands are sooner or later replaced by the broad-leaved species of lower montane oak forest and hence forming "lower montane pine-oak forest".

Lower montane pine-oak forest is a common landscape in the mountainous areas of northern Thailand (Figs. 11, 12 & 13) with the exception in the eastern range in Nan Province. Surprisingly, natural groves of *P. kesiya* in the eastern mountains of the north, especially Doi Phu Kha (ca 200–1,980 m.a.s.l.) have never been in existence despite the extensive development of lower montane oak forests more or less disturbed by human influences. However, the limestone rock formations are not uncommon along the Doi Phu Kha Range even at the higher elevations (i.e. Doi Phu Wae -ca 1,840 m.a.s.l.) and may discourage the growth and development of both pine species. Only a few small patches of *P. merkusii* in association with pine-deciduous dipterocarp forest on the non-calcareous soils are occasionally encountered at lower elevations along the Laos border (i.e. Districts of Mae Charim and Bo Klua).

It is not uncommon that lower montane pine-oak forest descends down slopes to approximately 700 m.a.s.l. An individual tree of *Pinus kesiya* is rarely recorded below 600 m.a.s.l. in northern Thailand. The pine-oak association is reduced considerably above 1,500 m.a.s.l., and pine trees are rather sporadic in occurrence (Fig. 4). The disturbed ridged-top of Doi Langka in Lampang (1,850 m.a.s.l.) seems to mark the highest limit of a small patch of pine-oak association. The prevailing mist belt above ca 1,800 m.a.s.l. is possibly one of the decisive factors discouraging the growth and development of pine trees in the upper montane zone. Another higher altitudinal record of an individual *P. kesiya* tree at approximately 1,800 m.a.s.l. on the open scree of the limestone mountain of Doi Chiang Dao in Chiang Mai (cf. Smitinand 1966 as *P. insularis*) is obviously an accidental case. A few isolated, misshapen and stunted pine trees are found thriving in the crevices of rocky limestone slopes devoid of surface soil, but some accumulated organic matter and humus apparently render an acidic growth medium for the pine trees as in the case of *Rhododendron ludwigianum* Hoss (Ericaceae), an endemic species confined to Doi Chiangdao (Santisuk 1988). The two native pine species, *P. kesiya* and *P. merkusii*, elsewhere in Thailand always exhibit calcifuge habit, where the trees are totally absent from the calcareous or limestone soils. In the greater mountain ranges north of the Thai territory, *P. kesiya* trees are often found at higher elevations than those in northern Thailand. According to Bor (1938), *P. kesiya* reaches its best development at the altitudinal zone from 1,500 to 2,200 m.s.a.l. in the Khasi Hills of India, the type locality from which the specific epithet of *P. kesiya* is derived.

The lower montane pine-oak forest and pine-deciduous dipterocarp forest represent two discrete edaphic types on different soil types. *Pinus kesiya*, the only pine species of lower montane pine-oak forest in northernThailand, thrives well on mountain ridges and on moderate to steep slopes mostly characterized by a red to yellow granitic soil type. On the other hand, *P. merkusii* is closely associated with pine-deciduous dipterocarp forest in the rolling hills or on the gentle slopes dominated by grayish sandy, brownish gravelly, or lateritic soils with varying degrees of stoniness.

Pine-deciduous dipterocarp forest (Figs. 5, 14, 15, 21 & 22)

This vegetation type with the notable inclusion of two native pine species, *P. kesiya* and *P. merkusii*, in fact, represents the advance of the lowland deciduous dipterocarp forest into the lower montane zone, which is readily promoted by man-induced fire in the cool dry season (December-February). The two-needled pine, *P. merkusii* accompanied by some fagaceous (*Castanopsis, Lithocarpus, Quercus*), lauraceous (*Beilschmiedia, Litsea*) and theaceous (*Anneslea fragrans, Eurya, Schima wallichii*) tree species make their infiltration into deciduous dipterocarp forest generally at elevations of approximately 550 m.a.s.l. and are more abundant from 700–1,200 m.a.s.l. (for more details on floristic composition see Santisuk 1988). The highest altitudinal record of *P. merkusii* in the pine-deciduous dipterocarp forest in Thailand is at about 1,350 m.a.s.l. in Doi Inthanon National Park in Chiangmai. Another three-needled pine, *P. kesiya* is locally found co-dominant with *P. merkusii*, but nowhere in a dense stand. In northern Thailand *P. kesiya* is commonly associated with lower montane pine-oak forest whilst *P. merkusii* is confined to pine-deciduous dipterocarp forest. Besides the topographic and edaphic factors that limit the distribution of *P. kesiya* in pine-deciduous dipterocarp forest, frequent and more severe forest fires in the forest (often caused through turpentine harvesting) (Fig. 25) are likely to favour *P. merkusii* which is characteristically more fire resistant than *P. kesiya* (Bhanijbatana 1978). Due to high relative humidity and regular cool breeze the upper branches of all big pine trees are often, to varying degrees, loaded with epiphytic lichens, mosses and orchids, and profusely festooned with beard lichens (*Usnea* ssp.) (Fig. 14).

In northern Thailand pine-deciduous dipterocarp forest is most extensively developed in the plateau-like rolling hills of Bo Luang-Mae Sanam-Omkoi areas, southwest of Chiang Mai Province at elevations ranging from 800–1,200 m.a.s.l. Along the northern periphery of this area (Nong Krating, near Bo Luang, ca 1,000–1,150 m.a.s.l.) some remarkable stands of *P. kesiya* in association with *Dipterocarpus obtusifolius*, *D. tuberculatus* and *Gluta usitata* are locally encountered on the moister and more fertile, moderate slopes of broad stream basins. However, *P. kesiya* is usually sporadic in occurrence or mostly replaced entirely by *P. merkusii* in the greater area of these plateau-like hills. At present, the pine-deciduous dipterocarp forests of Bo Luang plateau have, somehow, lost their characteristics through commercial felling of mature pine trees undertaken in 1986. Around the plateau-like areas of Ban Watjan, Samoeng District of Chiangmai (ca 1000 m.a.s.l.) extensive stands of *P. kesiya* in association with *Dipterocarpus obtusifolius* and *D. tuberculatus* are quite remarkable (Fig.15). The other extensive areas of pine (only *P. merkusii*)-deciduous dipterocarp forest also occur

in the rolling terrain of the western mountains close to the Burmese border along Khun Yuam-Maehongson Route (ca 600–800 m.a.s.l.) (Fig.14). *Pinus merkusii* may descend down slopes to approximately 400 m.a.s.l. in the province of Tak, the southern margin of northern Thailand, where it thrives on the old river terraces. This is a xeric phase of pine-deciduous dipterocarp forest exhibiting a rather poor form often with misshapen pine tree interspersed between the other crooked trees of deciduous dipterocarp species.

In Phitsanulok, the southernmost province of northern Thailand, locates a plateau-like sandstone mountain. Here the savanna-like pine-deciduous dipterocarp vegetation dominated by scattered stands of *P. merkusii* interspersed with a few deciduous dipterocarp and fagaceous trees is a common landscape, especially in the southern part (Thung Nang Phrayaa -ca 800 m.a.s.l.) of Thung Salaeng Luang National Park. Surprisingly, as a consequence of past succession, quite a few gigantic pine trees are found scatteredly in the adjacent evergreen forests (Fig. 24). In this locality *P. merkusii* trees often reach the biggest size ever reported from Thailand (45–50 m in height, and 100–130 cm dbh.).

Pine-oak savanna

This vegetation type is locally found in the plateau-like sandstone mountains above 1,000 m.a.s.l. in northern and more common in northeastern Thailand. Here the tree savanna-like vegetation with scattered more or less dense stands of *P. merkusii* or *P. kesiya* is developed in response to the surface fire in the dry season (January-March). Another highest record of pine (*P. kesiya*)-oak formation in Thailand is locally found in the level-topped sandstone mountain of Phu Soidao National Park (ca 1,800 m.a.s.l.) bordering Thai-Laos territory in Nampad District of Uttaradit Province. This is the highest occurrence of the natural pine-oak savanna dominated by dense stands of *P. kesiya*. A few fagaceous, lauraceous and theaceous trees are sparsely interspersed in between pine trees. The deciduous dipterocarp species are totally absent in the pine-oak savanna. However, the highest peak of Phu Soidao (ca 2,010 m.a.s.l.) adjoining the pine-oak savanna is devoid of pine trees, but some other conifers such as *Dacrycarpus imbricatus*, *Dacrydium elatum*, *Podocarpus* spp. (Podocarpaceae) and *Cephalotaxus griffithii* (Cephalotaxaceae) in the dense montane forest.

Pines in northeastern Thailand (Loei-Phetchabun-Chaiyaphum-Khon Kaen)

In the level-topped sandstone montains of Phu Kradung, Phu Rua and Phu Luang (1,000–1,400 m.a.s.l.) occur the extensive pine-oak savannas in which almost pure stands of *P. merkusii* and *P. kesiya* are found in scattered patches with continuous layers of sedge and graminoid undergrowth. Here the pine forests (or more precisely, pine savannas) are luxuriantly developed in the soils with peaty top layers of mosses under savanna. Along the fringe of lower montane oak forest in ravines some scattered single trees or small patches of *P. kesiya* are often encountered.

In contrary to the pine-deciduous dipterocarp forest in northern Thailand mainly dominated by *P. merkusii*, pine-deciduous dipterocarp forest with *P. kesiya* is a common

landscape of open habitat in the level-topped sandstone mountain of Nam Nao National Park, Phetchabun Province (Fig. 22) and Phu Khieo Wildlife Sancturay, Chaiyaphum Province (ca 750–900 m.a.s.l.).

Pines in eastern Thailand (Surin-Sri Saket-Ubol Ratchathani)

The lowland pine stands in Buntarik, Khong Chiam, and Trakan Phuthon Districts of Ubol Ratchathani Province are different again. At elevations about 120–150 m.a.s.l., only *P. merkusii* occurs in mixed stands associated with deciduous dipterocarps (pine-deciduous dipterocarp forest), mainly *Dipterocarpus intricatus* and *D. obtusifolius* (Fig. 21). Some sizeable pine trees occur in the adjacent evergreen forests as well, possible relics of past succession. Near Surin (Nong Khu) only small, degraded stands of pine (*P. merkusii*)-deciduous dipterocarp occur. Stands of *P. merkusii* in the provincial areas of Sri Saket have almost been wiped out.

Pines in central Thailand (Uthaithani-Kanchanaburi-Suphanburi-Phetchaburi)

Small groves of *P. merkusii* in association with deciduous dipterocarps (pine-deciduous dipterocarp forest) are encountered scatteredly along the exposed, non-calcareous ridges of the Tenasserim (Ta Naosri) Range in Suphanburi and Kanchanaburi at elevations below 500 m.a.s.l. The most xeric site of pine-deciduous dipterocarp forests dominated by *Shorea siamensis* occurs on the slopes and ridges of Khao Son and Khao Maa Lai (ca 400 m.a.s.l.) around the Kaeng Krachan Dam, Phetchaburi. The southernmost limit of *P. merkusii* in Thailand is found on the level ground of Paa Chum Chon at elevations of about 70 m.a.s.l. (the lowest elevation of *P. merkusii* in Thailand) near the eastern coast of Cha-am District of Phetchaburi Province. About 300 pine trees are still in existence, but the annual increment is very poor.

Pinus kesiya and *P. merkusii* do not exist in the western mountain range (Tenasserim or Tanaosri) of Kanchanaburi Province (i.e. Thungyai Naresuan Wildlife Sanctuary) on account of the extensive karst formations and layer of soils derived from limestones.

The southernmost record of *P. kesiya* in Thailand is represented by small groves of lower montane pine-oak forest along the open, granitic ridges (ca 900–1,000 m.a.s.l.) in Huay Kha Khaeng Wildlife Sanctuary, Uthaithani Province.

CONCLUSION

The two tropical pines, *Pinus kesiya* and *P.merkusii* are sympatric species in the mountainous areas in Southeast Asia. *Pinus kesiya* exhibits a northerly distribution to approximately at 29° N latitude, whereas the northernmost limit of *P. merkusii* is recorded at about 23° N latitude. The southernmost distributions of *P. kesiya* and *P. merkusii* are recorded at about 10° N latitude in southern Vietnam and 2° S latitude in Sumatra respectively. The optimal ecological amplitude of *P. kesiya* is usually recorded at above 1,000 m.a.s.l., whilst *P. merkusii* is well developed at below 1,000 m.a.s.l. The highest altitudinal record of *P. kesiya* (including a geographical variant, *P. yunnanensis*)

is above 3,000 m.a.s.l. in Yunnan, whereas *P. merkusii* is rarely found above 1,400 m.a.s.l. The most luxuriant and healthy stands of *P. merkusii* in association with pine-deciduous dipterocarp forest are encountered in the plateau-like sandstone range at the elevations of 300–600 m.a.s.l. in central and southern Laos.

The occurrence of native pines in Thailand was hitherto known or conveniently referred to as "coniferous forest" or "pine forest" (literally in Thai - Pa Sonkhao). In reality, both pine species occupy different forest formations namely, lower montane pine-oak forest, pine-deciduous dipteroarp forest and pine-oak savanna representing three distinct edaphic types on different soil types. *Pinus kesiya* the only pine species of lower montane pine-oak forest in Thailand, thrives well on mountain ridges and on moderate to steep slopes mostly characterized by red to yellow granitic soil types. On the other hand, *P. merkusii* is closely associated with pine-deciduous dipterocarp forest in the undulating hills on the gentle slopes dominated by grayish sandy, brownish gravelly, or lateritic soils with varying degrees of stoniness. Hence, both pine species exhibit calcifuge habit, thriving well on the non-calcareous soils. Occasionally, *P. kesiya* is locally developed in association with pine-deciduous dipterocarp forest on the plateau-like rolling hill, i.e. Thung Salaengluang National Park, Phitsanulok Province; Ban Watjan, Samoeng District and Nongkrating, Omkoi District of Chiangmai Province. Pine-oak savanna in the level-topped sandstone mountain in the north and northeast is associated with *P. merkusii* and/or *P. kesiya*. Three distinct vegetation types with associated pine species mentioned are more or less maintained by surface fire mainly induced by man in the dry season (January-March). Because of its colonizing habit, *P. kesiya* is considered as one of the most appropriate species for forest rehabilitation program in the watershed areas in northern Thailand.

ACKNOWLEDGEMENTS

My sincere appreciation is expressed towards the directors, keepers and staff members of Kunming Institute of Botany and Xishuangbanna Tropical Botanical Garden, Yunnan, China, for herbarium investigations and for their efficient arrangements of the Joint Chinese-Thai Botanical Excursions in Yunnan, China, in 1992, 1993 and 1995.

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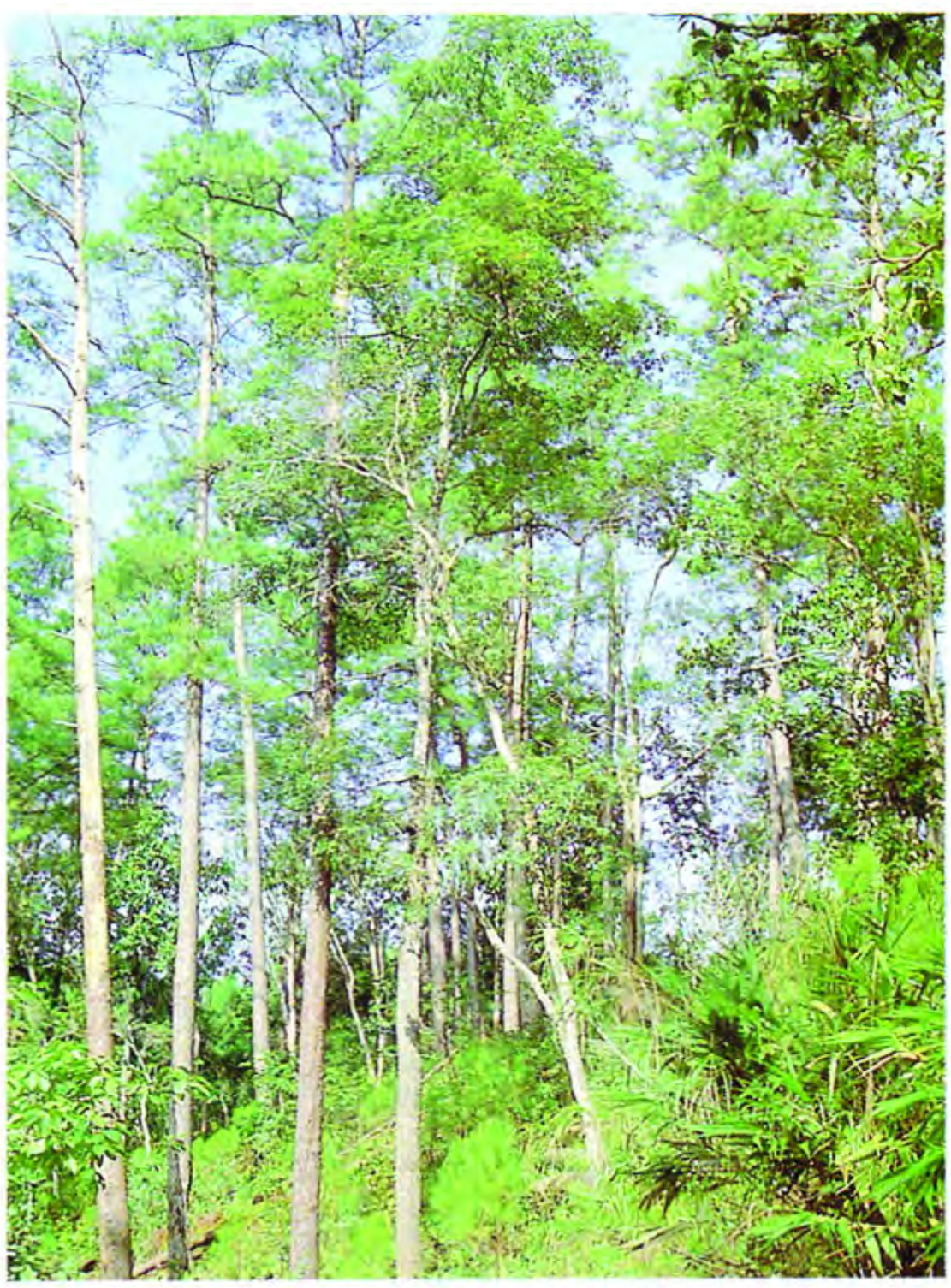
Figures 6 & 7.: *Pinus yunnanensis* (above) from Chuxiong, Yunnan, with old female cones and *P. kesiya* from Phu Kradung National Park, Thailand, with withering male cones and young fruiting cones. *P. yunnanensis* possesses longer needles than those of *P. kesiya*.

Figure 8. A natural stand of *Pinus yunnanensis* on the much eroded slopes (ca 2,100 m.a.s.l.) in central Yunnan, China.

Figure 9. Stunted *Pinus yunnanensis* trees in association with oak trees on an exposed, eroded ridge (ca 1,950 m.a.s.l). Chuxiong town, Yunnan, in the background.

Figure 10. (Left) Colonizing habit of *P. kesiya* along the main road in Doi Inthanon National Park, Chiangmai (ca 1,000 m.a.s.l.)

Figure 11. (Right) Lower montane pine-oak forest in Doi Inthanon dominated by *P. kesiya* stands (ca 1,000 m.a.s.l.)



Figures 12 & 13. Profiles of lower montane pine (*P. kesiya*)-oak forest in Doi Inthanon (ca 1,000 m.a.s.l.) (left), and in the watershed area of Chiangdao District of Chiangmai (ca 1,300 m.a.s.l.) (right).

Figure 14. Typical pine (*P. merkusii*)-deciduous dipterocarp forest along Mae Sariang-Khunyuam route in Maehongson (ca 800 m.a.s.l.). Deciduous dipterocarp, *Dipterocarpus tuberculatus* in the foreground.

Figure 15. Pine (*P. kesiya*)-deciduous dipterocarp forest in Ban Watjan, Samoeng District of Chiangmai (ca 1,000 m.a.s.l.). *Dipterocarpus tuberculatus* in the foreground.

Figure 16. (Left) A typical level-topped sandstone mountain of Phu Phajit in northeastern Thailand as seen from a sandstone cliff of Phu Kradung National Park, Loei Province, with *P. merkusii* in the foreground (ca 1,300 m.a.s.l.)

Figure 17. (Right) Flushes of the undergrowth in the pine (*P. merkusii*)-oak savanna in Phukhadung following the surface fire in April. *Curcuma aeruginosa*, a herbaceous ginger, proliferating on the ground floor (ca 1,300 m.a.s.l.).

Figure 18. (Left) Pine-oak savanna near a sandstone cliff of Phu Luang Wildlife Sanctuary, Loei Province (ca 1,350 m.a.s.l.).

Figure 19. (Right) A profile of pine-oak savanna in the level-topped of sandstone mountain of Phu Luang dominated by stands of *P. kesiya* (ca 1,350 m.a.s.l.).

Figure 20. Pine-oak savanna in Phukradung sandstone mountain dominated by stands of *P. merkusii* (ca 1,300 m.a.s.l.).

Figure 21. Almost wiped out pine-deciduous dipterocarp forest in Buntarik District of Ubol Ratchathani Province. A few standing *P. merkusii* trees are rarely seen (ca 130 m.a.s.l.).

Figure 22. (Above left): Profile of pine-deciduous dipterocarp forest in the level-topped sandstone mountain of Nam Nao National Park, Phetchabun Province, dominated by *P. kesiya*. Broad-leaved trees in the foreground are *Dipterocarpus obtusifolius* (ca 870 m.a.s.l.).

Figure 23. (Above right): Young male cones of *P. merkusii* in pine-deciduous dipterocarp forest in Maehongson province (ca 700 m.a.s.l.).

Figure 24. (Below left): A remnant, gigantic *P. merkusii* tree along the edge of evergreen forest in Thung Salaeng Luang National Park (ca 800 m.a.s.l.).

Figure 25. (Below right): Turpentine tapping of *P. merkusii* in Khun Yuam, Maehongson (ca 700 m.a.s.l.).