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A TRANSECT SURVEY OF MONSOON FOREST IN DOI SUTHEP-PUI NATIONAL PARK

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ABSTRACT

A transect survey (0.828 ha) of monsoon forest was carried out in Doi Suthep-Pui National Park, Northern Thailand. Tree species richness was 90 species per hectare for trees of diameter at breast height of 10 cm or more, which ranks Doi Suthep as the most species-rich dry tropical forest currently known. Wide variations in topography, soils and microclimate are thought to be responsible for the high tree species richness. Most of the tree species were rare, 59.4% of them being represented on the transect by 3 individuals or less. The canopy had a simple structure with no clearly defined strata.

Cluster analysis divided the transect into two main associations: a deciduous (D) association, in which 88.2% of the trees were deciduous, and a mixed evergreen-deciduous (M) association in which 49.6% of trees were deciduous and 43% evergreen. The M association occurred on the more mesic parts of the transect at higher elevations or along seasonal streams at lower elevations. The D association occurred mostly on xeric sites at lower elevations or along ridges at higher elevations.

Doi Suthep is not only an area of exceptional biodiversity but is also home to many endangered species and it is a study site for scientific research and education. However, the mountain is threatened by a multitude of detrimental development projects. Unless such development is controlled, the value of the park for conservation and tourism will be considerably reduced.

INTRODUCTION

According to Holdridge's system of life zone classification (HOLDRIDGE, 1967) dry tropical and subtropical forests and woodlands occur in frost-free areas where the mean annual biotemperature is higher than 17°C, where mean annual rainfall is 250 – 2000 mm and where the mean annual evapotranspiration (PET) to precipitation (P) ratio exceeds unity. Within these climatic conditions exists a wide range of different forest types including monsoon forest which SCHIMPER (1898) in his classic work *Plant Geography* described as: "...more or less leafless during the dry season especially towards the end, usually less tall than rainforest, rich in woody lianas, rich in herbs but poor in woody epiphytes..."

Monsoon forest is the natural vegetation of much of Northern Thailand, where average annual precipitation is 1,000 – 2,000 mm and a dry season extends

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from November to April. Compared with tropical rainforest, monsoon forest has received little attention from ecologists. This may be because monsoon forest is considered to lack the high species diversity, characteristic of tropical rainforest and is therefore less attractive to researchers. Such forests are thought to contain only about one-third to one-half the number of tree species of tropical rainforest (HUBBELL, 1979; MURPHY & LUGO, 1986).

Despite Thailand's fairly large expanse of monsoon forest, there have been few studies of its species diversity or structure. In 1961 OGAWA *et al.* published a preliminary survey of the vegetation of Thailand. They classified the deciduous forests of Northern Thailand into three major categories: "dipterocarp savanna", "mixed savanna" and "tall deciduous forest". They recorded 23 tree species with diameter at breast height (dbh) ≥ 10 cm in a 0.25 ha quadrat of "dipterocarp savanna" near Doi Inthanon and 17 species in a 0.1 ha quadrat of "mixed savanna" near Tak. In a later study OGAWA *et al.* (1965) recorded 15, 17, and 22 tree species (dbh ≥ 10 cm) in 0.16 ha of "dipterocarp savanna," "monsoon forest-savanna forest ecotone" and "monsoon forest," respectively. BUNYAVEJCHEWIN (1983) divided the deciduous forests of Northern Thailand into two major dominance types: the *Tectona grandis*-type and the *Lagerstroemia calyculata*-type, which averaged 17.6 and 23.1 tree species (dbh ≥ 10 cm) per 0.2 ha plot, respectively. SANTISUK (1988) provides the most recent account of the forest types of Northern Thailand.

There is an urgent need for more baseline information about dry tropical forests, since as with most other forms of tropical forest, it is fast disappearing. For example, in Chiang Mai Province the area of deforested land doubled in the 10 years 1975-85 from 323,458 ha to 651,302 ha (GRID, 1988). In Northern Thailand, forest is usually felled to provide timber and land for cultivation, but the soil often becomes unproductive after a few years, especially on steep slopes. Fire and soil erosion prevent forest regeneration and tree seedlings cannot compete with fast-growing grasses such as *Imperata cylindrica* (L.) P. Beauv., *Thysanolaena maxima* (Roxb.) O.K. and *Phragmites karka* (Retz.) Trin. ex Steud. which invade such areas. Attempts to restore forest to these degraded sites will only succeed through a better understanding of the ecology of remaining undisturbed forest areas.

In this paper we suggest that the tree species richness of forest in Doi Suthep-Pui National Park may be the highest currently known for dry tropical forest, approaching or exceeding that of some tropical rainforests. We discuss the implications of this result concerning the value of Doi Suthep for wildlife conservation and outline some of the major threats to the forest.

STUDY SITE

Doi Suthep lies a few km west of Chiang Mai City in Northern Thailand. Rising to 1,685 m above sea level, it forms the western side of the Ping River valley. The eastern side of the mountain is heavily dissected into a series of steep gullies and narrow ridges running approximately west-east. Base rocks are mostly granitic but shale occurs in some places. Soils are generally deep and highly weathered, ranging from coarse grey sands on ridges to red-brown loams in gullies. Annual rainfall varies considerably with elevation, ranging from about 1,000 mm near the base of the mountain to just over 2,000 mm near the summit. There is a marked dry season and from December through March there is usually little or no rain. Temperatures also vary with elevation, ranging from 5.0 °C (Jan) to 35.5 °C (Mar) at 1,400 m above sea level and from 9.2 °C (Nov) to 40.3 °C (Mar) at 312 m above sea level (data from the Meteorological Department, Bangkok).

Undisturbed forest survives only on the eastern side of the mountain, most of that on the other sides having been destroyed by shifting cultivation and fire. In 1981 the area was designated a national park covering 261 km^2. It is an important tourist attraction and is the 4th most heavily visited national park in the country. In 1988, 440, 891 tourists visited the park, generating an income of 1,296,487 baht for the Forest Department. The proximity of the park to Chiang Mai City and the presence of hill tribe settlements within its boundaries has led to the elimination of most large mammal and several bird species (ROUND, 1984). However, a wide variety of plants, invertebrates, amphibians, reptiles, birds and small mammals can still be found within the remaining forest patches.

Preliminary descriptions of the vegetation of Doi Suthep were provided by HOSSEUS (1908), KERR (1911), COCKERELL (1929), and later KUCHLER & SAWYER (1967) compiled a vegetation map of the mountain. They divided the forest into 10 different phytocenoses based on physical characteristics (e.g. life forms, leaf shape, etc.). BEAVER & JINOROSE (1974) established 30 × 30 m plots on Doi Suthep in "hill evergreen," "evergreen gallery," "dry dipterocarp" and "mixed deciduous" forests and measured all trees of gbh (girth at breast height) ⩾ 20 cm. They reported 40, 42, 31 and 34 tree species per plot. MAXWELL (1988) has provided the most recent and detailed description of the vegetation. The main distinction made by all previous authors was between the deciduous forest of the lower slopes (up to 850 – 950 m elevation) and the evergreen forest of the upper slopes.

METHODS

A 1.38 km long transect survey of forest on Doi Suthep was carried out using contiguous quadrats 20 m long and 6 m wide, starting just below Prataht Doi Suthep Temple at 960 m elevation (map reference 1:50,000 series, sheet 4746I, 922 788) following a compass bearing of 76° to a point just above Palaht Temple at 670 m elevation. During 112 man-days of field work, 71 quadrats were completed. However, the first two quadrats were subsequently omitted from the sample because they had been cut to provide an unobstructed view of Chiang Mai for a nearby house.

A central line was marked out using a tape measure and all trees and woody climbers of gbh ⩾ 10 cm within 3 m on either side of the tape measure were labelled with metal tags. In each quadrat, the slope, altitude and tree gbh were recorded. Repeated visits were made over about a year to collect flowering and fruiting material for identification. Specimens of all species are deposited at the Herbarium, Faculty of Pharmacy, Chiang Mai University. At various representative points along the transect, profile diagrams were constructed. Tree positions were recorded. Tree heights and lowest branch heights were measured using a clinometer and crown diameter parallel to the transect was measured.

As quadrat positions were determined by a compass bearing, regardless of any physical or biological features of the forest, the sample may be regarded as effectively random (CAUSTON, 1988 p. 16). Mean values for the entire transect may therefore be used as average descriptions of the forest occurring between elevations of 670 m and 960 m. Initial observations suggested that the transect did not pass along a continuum, with species distributions intergrading smoothly, but through several distinct vegetation associations. Fairly clear transitions between associations, often marked by topographic features such as seasonal stream beds, were visible at several points. It was therefore decided to carry out a classification of the data (CAUSTON, 1988, p. 35) in order to test for the existence of associations and to determine the position of the boundaries between them. A cluster analysis was performed (LUDWIG & REYNOLDS, 1988, chap. 16 and accompanying computer program CLUSTER.BAS) using chord distance as a coefficient of dissimilarity between quadrats and the flexible clustering strategy ($\beta = -0.25$).

RESULTS

The mean number of trees (gbh $\geqslant$ 10 cm) per quadrat (120 m^2) was 10.6 (c.l. $\pm$ 1.3, $P < 0.05$). The relationship between cumulative area surveyed (m^2) and cumulative number of trees encountered was expressed by the linear equation:

$$\text{No. of trees} = (0.08311 \times \text{Area}) - 4.546 \qquad (r^2 = 0.9929)$$

which predicts that on average there were 826.5 trees/ha (c.l. $\pm$ 9.1, $P \geqslant 0.05$). There was no clear relationship between tree density and slope or altitude.

Mean gbh of all 729 trees included in the survey was 51.1 cm. Figure 1 shows the frequency histogram of tree gbh, with large numbers of small trees and few large ones. About half (54.2%) had girths within the range 10 – 39.9 cm, whilst only 10% had girths greater than 100 cm. There were fewer trees in the 10 – 19.9 cm girth class (18.8%) than in the 20 – 29.9 cm girth class (20.4%).

In 0.828 ha surveyed, 117 trees species from 84 genera and 48 families were recorded (see appendix). The mean number of species per quadrat was 6.9 (c.l. $\pm$ 0.7, $P < 0.05$) and the mean number of individuals per species was 6.2. Most species were rare, more than half (59.4%) being represented on the transect by three individuals or less (34.9% by a single individual), whilst only a quarter (27.8%) were represented by five individuals or more (Fig. 2.)

A species-area curve (Fig. 3) was constructed by selecting quadrats at random

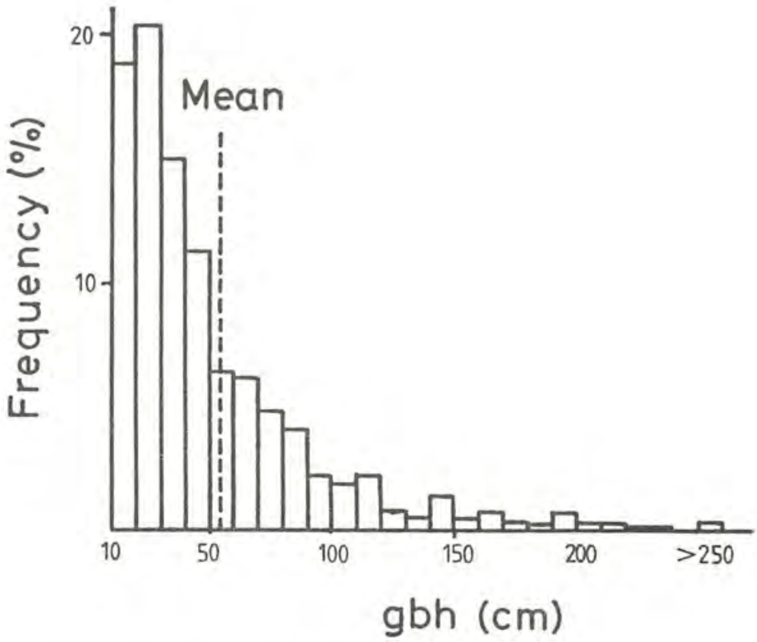

Figure 1. Frequency histogram of girth at breast height for 729 trees on a transect through monsoon forest in Doi Suthep-Pui National Park.

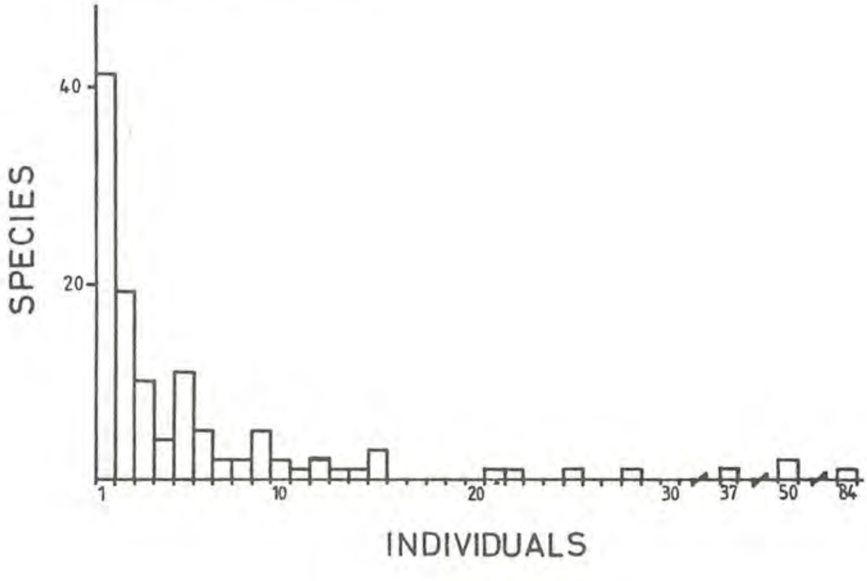

Figure 2. Number of tree species represented on the transect by 1, 2, 3....etc. individuals.

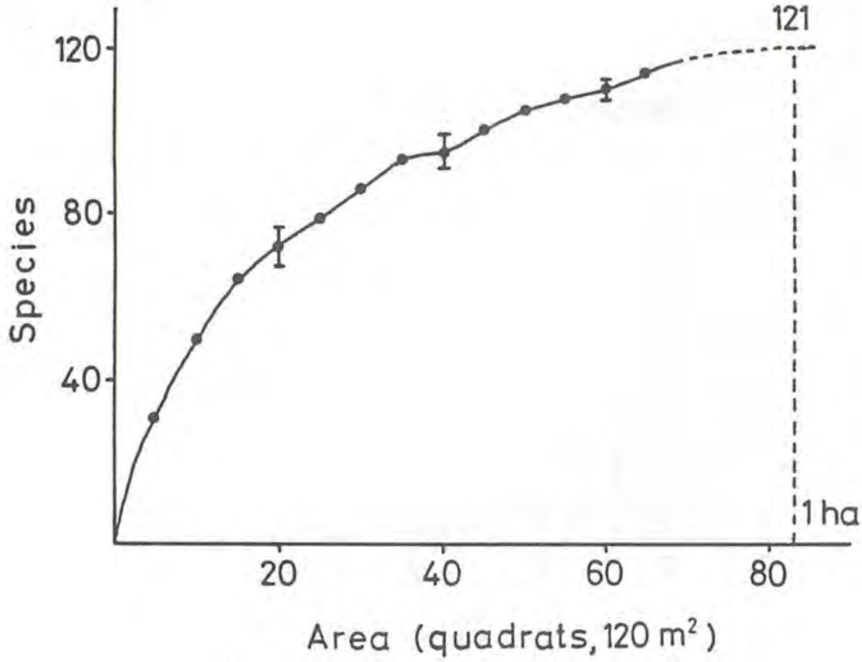

Figure 3. Species-area relationship of quadrats selected at random (bars indicate standard deviations, n = 5).

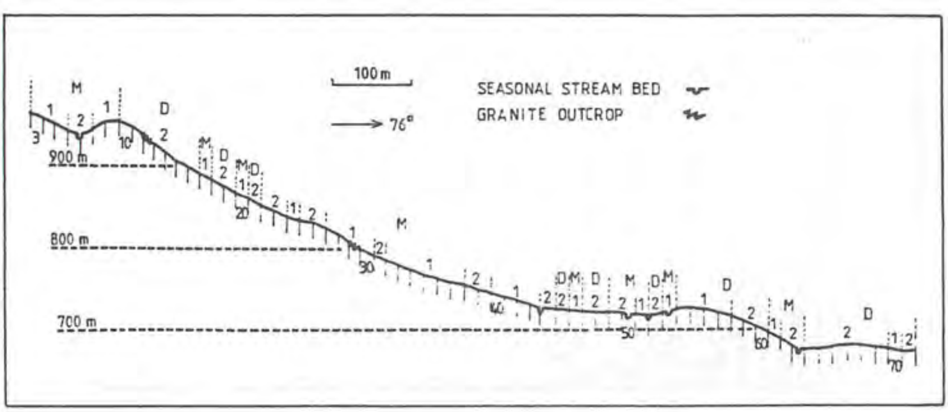

Figure 4. Distribution of sub-associations identified by cluster analysis. D = deciduous, M = mixed evergreen-deciduous, 1's and 2's above the transect refer to sub-associations. Numbers below the transect indicate quadrat numbers referred to in the text.

and adding the number of newly encountered species cumulatively to the number of previously encountered species. This was repeated five times and mean numbers of species for each area were used to produce a smoothed curve. Extrapolating the curve indicated that there were about 121 tree species/ha (gbh $\geqslant$ 10 cm) and that this was probably near the maximum for the whole forest within the elevation range of the transect (670 – 960 m).

Most of the trees (68.6%) on the transect were deciduous. Only 26.2% were evergreen and the rest were tropophyllous i.e. intermediate between deciduous and evergreen. For a discussion of the term tropophyllous see KUCHLER & SAWYER (1967).

Cluster analysis clearly distinguished two main associations (at a cluster level of 2.8) with possibly two sub-associations within each main association (at a cluster level of 1.8). The main distinction between the two main associations was in the relative proportions of evergreen and deciduous trees. In one main association 88.2% of the trees were deciduous and this association was therefore named the D association. The other main association contained a fairly equal mixture of deciduous and evergreen trees (49.6% and 43.0% respectively) and this association was therefore named the M (mixed evergreen-deciduous) association. Subscripts are used to distinguish between sub-associations i. e. D_1, D_2, M_1, M_2. Of the 4 sub-associations, D_1 was the most deciduous followed by D_2, M_1, and M_2.

Table 1 summarizes the characteristics of the associations. M covered a greater area (40 quadrats) than D (29 quadrats) but the tree population was split almost equally between the two associations (363 in D and 366 in M). It therefore follows that tree density was higher in D than in M (means of 12.5 and 9.1 trees/quadrat respectively, significantly different at $P < 0.01$, t-test). Trees were larger on average in M than in D (mean gbh 56.6 and 45.5 cm respectively).

M contained more tree species than D (99 and 58 respectively). This would be expected since M covered a greater area, but when species richness was expressed per unit area, M still exceeded D (means of 7.1 and 6.6 species/quadrat respectively), although the difference was statistically insignificant (t-test, $P > 0.10$). Individuals were more evenly spread between the species in M than in D. M contained mostly rare species (mean of 3.7 trees/species) whereas D contained several of the more common species (mean of 6.2 trees/species). This was reflected in the eveness index which was much higher for M than for D (0.85 and 0.52 respectively). An eveness index of 1.0 indicates that all species are represented by equal numbers of individuals, whereas a low value indicates a few very common species and many rare ones. The species diversity index, which combines the total number of species (species richness) with their relative abundances (eveness), showed that M was a much more diverse association than D (55.5 and 10.6 respectively). Characteristic species of the associations (those with more than 10 individuals on the whole transect with more than 70% of them restricted to one main or sub-association) are listed in Table 2.

Figure 4 shows the distribution of the associations along the transect and their relationship with topography. The transect began by descending steeply into a

Table 1. Characteristics of the main and sub-associations identified by cluster analysis.

	Sub-Associations				Main Associations		Total
	D_1	D_2	M_1	M_2	D	M	Transect
No. of quadrats	5	24	26	14	29	40	69
No. of trees	95	268	240	126	363	366	729
Mean no. of trees per quadrat (SD)	19.0 (4.3)	11.2 (4.9)	9.2 (4.3)	9.0 (5.1)	12.5 (5.6)	9.1 (4.6)	10.6 (5.3)
Mean gbh (cm)	33.5	49.9	58.5	52.9	45.5	56.6	51.1
Total no. of tree species	15	54	89	48	58	99	117
Mean no. of trees per species	6.2	5.0	2.7	2.6	6.2	3.7	6.2
Mean no. of species per quadrat (SD)	7.4 (2.7)	6.5 (2.4)	7.4 (3.3)	6.5 (3.1)	6.6 (2.4)	7.1 (3.3)	6.9 (2.9)
Species diversity index[1]	5.1	9.7	50.9	25.9	10.6	55.5	29.4
Evenness index[2]	0.60	0.45	0.86	0.80	0.52	0.85	0.54
Evergreen trees (%)	4.3	10.0	33.2	61.9	8.5	43.0	26.2
Tropophyllous trees (%)	3.2	3.3	9.2	4.0	3.3	7.4	5.2
Deciduous trees (%)	92.5	86.7	57.6	34.1	88.2	49.6	68.6

[1] Hill's diversity index $N_I = e^{H'}$ where H' is the Shannon function:

$$H' = -\sum_{i=1}^{s}\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right]$$

Where S is the total number of species, n is the total number of individuals and n_i is the number of individuals belonging to the ith species.

$$E_5 = \frac{(1/\lambda) - 1}{e^{H'} - 1} \text{ where } \lambda \text{ is Simpson's Index } = \sum_{i=1}^{s} p_i$$

p_i is the proportional abundance of the ith species (i.e. n_i/n), see LUDWIG & REYNOLDS (1988, chap. 8).

gulley of a seasonal stream with M_1 occurring in the upper parts of the gulley and the more evergreen M_2 in the more mesic conditions around the stream bed. In addition to the characteristic species listed in Table 2, *Baccaurea ramiflora, Dimocarpus longan, Garcinia cowa, Walsura intermedia, Kydia calycina* and *Lagerstroemia cochinchinensis* occurred uniquely in this gulley. This part of the transect had the highest tree species richness, averaging 9.1 species/quadrat, between quadrats 3 and 9, compared with a mean for all M association quadrats of 7.1 species/quadrat. The gulley was also the most strongly evergreen section of the transect with a more or less closed canopy even during the dry season. The ground flora consisted mainly of herbs and tree seedlings and saplings with the notable occurrence of *Balanophora abbreviata* Bl. (Balanophoraceae), a rare parasitic flowering plant (Fig. 5).

After the stream bed at quadrat 6, the transect climbed steeply to a dry ridge at quadrat 10 where there was a sharp transition to the more open D_2 sub-association. Whilst several of the tree species in this section (quadrats 10 – 16) also occurred in the lower D association quadrats (quadrats 54 – 71) e.g. *Dipterocarpus obtusifolius, Quercus kerrii, Shorea siamensis* and *Tristania rufescens,* other species occurred uniquely here, including *Buchanania glabra, Quercus kingiana, Quercus lanata, Rhus chinensis, Sterculia ornata, Strychnos nux-vomica* and *Vitex canescens.* The canopy was open, allowing the development of a ground layer of sedges and grasses e.g. *Microstegium vagans* (Nees ex Steud.) A. Camus and *Panicum montanum* Roxb.

Between quadrats 17 and 21 there was a gradual transition from D_2 to the M sub-associations, as the transect descended away from a ridge to the south. In addition to the species listed in Table 2., this long section of M association (quadrats 22 – 44) also contained *Cratoxylum cochinchinense, Diospyros pilosanthera, Ilex umbellulata, Schima wallichii* and *Tarenna disperma.* Canopy cover was generally complete, although less dense than that of the uppermost quadrats, with massive *Dipterocarpus costatus* trees as occasional emergents (Fig. 7). The ground flora included 3 bamboos (*Bambusa tulda* Roxb., *Dendrocalamus membranaceus* Munro and *D. nudus* Pilg.), several members of the ginger family (Zingiberaceae) e.g. *Zingiber kerrii* Craib, *Curcumorpha longifolia* (Wall.) Rao & Verma and *Curcuma parviflora* Wall., the sedge *Scleria terrestris* (L.) Fass. (Cyperaceae), the lily *Disporum calcaratum* Wall. ex G. Don var. *rubiflorum* Gagnep. (Liliaceae) and the orchid *Spathoglottis pubescens* Ldl. (Orchidaceae). Several of the ground flora species here were first described from specimens collected from Doi Suthep including *Globba kerrii* Craib, *G. nisbetiana* Craib, *G. reflexa* Craib (Zingiberaceae), *Chlorophytum intermedium* Craib var. *intermedium* (Liliaceae), *Amorphophallus sutepensis* Gagnep. (Araceae) (Fig. 9) and *Cycas micholitzii* Dyer var. *simplicipinna* Smit. (Cycadaceae). Rare species included the herb *Tacca chantrieri* André (Taccaceae), characteristic of evergreen areas, and the shrub *Maoutia puya* (Wall. ex Hk.) Wedd. (Urticaceae). The transect passed obliquely down the north facing side of a seasonal stream gulley crossing the stream bed at quadrat 44.

From quadrat 45 to 53, there was a transition from the M to the D

Table 2. Characteristic species of the main and sub-associations identified by cluster analysis — those with 10 or more individuals on the transect with more than 70% of the individuals restricted to one main or sub-association. Figures in brackets are percentages of each species population found in each main or sub-association.

Main Associations

D		M	
Aporusa villosa	(100%)	*Antidesma acidum*	(100%)
Craibiodendron stellatum	(92%)	*Castanopsis diversifolia*	(100%)
Dipterocarpus obtusifolius	(82%)	*Eugenia albiflora*	(92%)
Quercus kerrii	(92%)	*Metadina trichotoma*	(92%)
Shorea siamensis	(94%)	*Oroxylon indicum*	(80%)
Tristania rufescens	(94%)	*Styrax benzoides*	(87%)
		Terminalia mucronata	(76%)
		Vitex peduncularis	(93%)
		Xylia xylocarpa	(73%)

Sub-Associations

D_1		D_2		M_1		M_2	
Tristania rufescens	(76%)	*Craibiodendron stellatum*	(75%)	*Antidesma acidum*	(80%)	*Castanopsis diversifolia*	(93%)
		Quercus kerrii	(78%)	*Oroxylum indicum*	(70%)	*Metadina trichotoma*	(85%)
		Shorea siamensis	(84%)	*Styrax benzoides*	(73%)		
				Vitex peduncularis	(93%)		
				Xylia xylocarpa	(73%)		

Figure 5. *Balanophora abbreviata* Bl., a rare parasitic flowering plant found in the ground flora of the upper M_1 quadrats.

Figure 6. The flowers of *Metadina trichotoma*, a characteristic tree species of the M_2 sub-association, commonly found by streams.

Figure 7. The M_1 sub-association at quadrat 35. The tree in the centre is *Dipterocarpus costatus* with emergent canopy.

Figure 8. The D_1 sub-association at quadrat 55. The trees in the centre are *Tristania rufescens* and on the left is *Aporusa villosa*.

Figure 9. *Amorphophallus sutepensis* Gagnep. in the ground flora of the M_1 sub-association at quadrat 43; one of many plant species first described from specimens collected on Doi Suthep.

Figure 10. Abrupt transition between the M_2 (background) and D_2 (foreground) sub-associations marked by a seasonal stream bed. The sharpness of the transition may be due to the stream bed acting as a fire break.

Figure 11. The D_2 sub-association at quadrat 71. Note the open canopy and grassy ground layer. The tree in the centre is *Dipterocarpus obtusifolius* var. *obtusifolius*, photographed in November.

Figure 12. The D_2 sub-association photographed five days after a litter burn in April. The grassy ground layer was completely destroyed but recovered soon afterwards. Most of the trees survived.

association, with the M association more or less restricted to seasonal stream banks and the D association occurring on slightly raised areas in between. On the crest of a ridge between quadrats 54 and 57, the sub-association D_1 occurred (Fig. 8). Although this sub-association occupied only 5 quadrats on the entire transect, the cluster analysis identified it as having the greatest dissimilarity compared with the rest of the transect. It was the most xeric of the sub-associations with the highest percentage of deciduous trees (92.5%) and lowest species diversity. It also had the highest tree density and lowest mean tree gbh. It was the only place on the transect where a single tree species approached dominance. *Tristania rufescens* comprised 40.2% of the tree population (between quadrats 54 and 57). In addition, the rarer tree species *Dillenia aurea, Gluta usitata* and *Parinari anamensis* were restricted to this area.

From the ridge top at quadrat 54 to the gulley bottom at quadrat 63, the transect passed through all 4 sub-associations in order of decreasing deciduousness with the seasonal stream banks occupied by M_2, the most evergreen sub-association. Tree species around the streem banks included *Castanopsis diversifolia, Eugenia albiflora, Scleropyrum wallichianum, Memecylon plebejum* and *Metadina trichotoma* (Fig. 6). The ground flora included the sedges *Scleria kerrii* Turr. and *S. terrestris* (L.) Fass. (Cyperaceae), and the fern *Pteris decrescens* Christ (Pteridaceae). The woody climber *Gnetum leptostachyum* Bl. (Gnetaceae) was also present.

After the stream bed there was a sharp transition to the D_2 sub-association at quadrat 64 (Fig. 10). The tree species were similar to those on the dry ridge in quadrats 10 to 16 with the addition of *Anneslea fragrans, Aporusa villosa* and *Dipterocarpus tuberculatus. Dipterocarpus obtusifolius* and *Quercus kerrii,* although present in the upper D_2 quadrats, were much more common in the lower D_2 quadrats. The canopy was open (Figs. 11 and 12), allowing the development of a ground layer, mostly comprising grasses, e.g. *Apluda mutica* L., *Aristida cumingiana* Trin. & Rupr., *Themeda trianda* Forssk. and *Arundinella setosa* Trin. var. *setosa* (Gramineae) and sedges e.g. *Rhynchospora rubra* (Lour.) Mak., *Scleria levis, Carex continua* Cl. Herbs in the ground flora included *Geniosporum coloratum* (D. Don) O.K. (Labiatae), *Globba reflexa* Craib (Zingiberaceae) and the orchid *Liparis sutepensis* Rol. ex Dow. Vascular epiphytes growing on the trees in this section included ferns and orchids e.g. *Cymbidum simulans* Rol., *Dendrobium secundum* (Bl.) Ldl. (both Orchidaceae) and *Drynaria rigidula* (Sw.) Bedd. (Polypodiaceae).

Figures 13 – 16 show representitive profile diagrams for the 4 sub-associations. The main canopy of D_1 between 2 and 8 m comprised mostly *Tristania rufescens* and *Wendlandia tinctoria* crowns, generally narrow and elongated in shape. Occasionally *Dipterocarpus obtusifolius* trees rose above the main canopy as emergents (up to 12 m high) with more rounded crowns. *Aporusa villosa* is shown in Figure 13 in its typical position as an understorey species.

The main canopy of the D_2 sub-association was more discontinuous but higher (at 2 to 12 m) than that of the D_1 sub-association (Fig. 14). *Shorea siamensis* replaced *Tristania rufescens* as the most common main canopy species. Again, large

Dipterocarpus obtusifolius trees formed occasional emergents up to 25 m high. There were also large numbers of saplings *(Dipterocarpus tuberculatus, D. obtusifolius, Quercus kerrii* and *Wendlandia tinctoria)* beneath the main canopy.

The M_1 sub-association had the most complete canopy cover. No single species was common. The broad, rounded crowns of *Phyllanthus emblica, Eugenia albiflora* and *Xylia xylocarpa* formed the upper canopy at 7 – 20 m, beneath which (at 3 – 7 m) a wide variety of small-crowned trees formed a continuous layer. *Antidesma acidum* is shown in its typical position in Figure 15 as an understorey species.

Figure 16 shows the M_2 sub-association on the banks of a seasonal stream as it commonly occurs at lower elevations. Trees were scattered in clumps with no dominant species. Canopy cover was incomplete and canopy shape highly variable.

Crown density histograms showing variations in crown density at different heights above the ground for all four sub-associations are shown in Figure 17. Such diagrams may be used to identify strata within the canopy (OGAWA *et al.* 1965). Gaps between strata are indicated by minima within the histogram where crown density is low at a certain height due to low overlap between adjacent strata. No such minima can be seen in Figure 17 (with the possible exception of 12 – 14 m for sub-association M_2). Canopies of all sub-associations increased in density to a certain height and decreased gradually thereafter. Therefore there is no evidence for the existence of clearly defined strata within the canopies. Both D sub-associations showed a maximum crown density at 4 – 6 m. Maximum crown density occurred at higher levels in the canopies of M sub-associations; 10 – 12 m for M and 6 – 8 m for M_2.

DISCUSSION

Distribution of Forest Associations

The associations identified by cluster analysis corresponded fairly well with two of the "vegetation types" proposed by SANTISUK (1988) for Northern Thailand. The D association was similar to what SANTISUK terms "deciduous dipterocarp forest," whilst the M association corresponded well with what he terms "tropical mixed deciduous forest." SANTISUK (1988, p. 51) states that deciduous dipterocarp forest is "the most xeric type of natural vegetation of Northern Thailand," occurring "in alternation with tropical mixed deciduous forest." This statement is a good description of the situation on the transect on Doi Suthep (see Fig. 4). However, there was very little similarity with KÜCHLER & SAWYER's (1967) "phytocenoses"— units used to compile a vegetation map of Chiang Mai. Quadrats 3 to 9 were within KÜCHLER & SAWYER's phytocenosis 8: "medium tall broadleaf and needleleaf evergreen and tropophyllous trees and shrubs and needleleaf evergreen trees with an open ground cover of graminoids," whilst the whole of the rest of the transect was within phytocenosis 5: "tall and medium tall broadleaf tropophyllous trees with little bamboo."

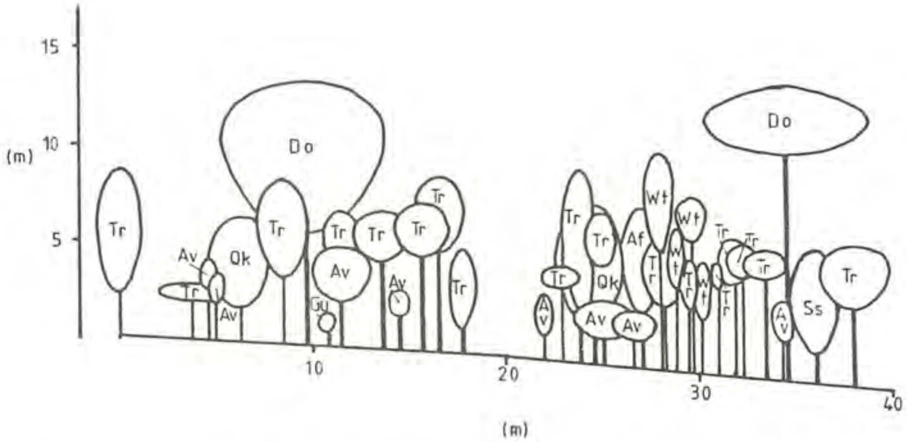

Figure 13. Profile diagram of the D_1 sub-association at quadrats 54 – 55. Af, *Anneslea fragrans; Av, Aporusa villosa;* Do, *Dipterocarpus obtusifolius;* Gu, *Gluta usitata*; Qk, *Quercus kerrii;* Tr, *Tristania rufescens;* Ss, *Shorea siamensis;* Wt, *Wendlandia tinctoria.*

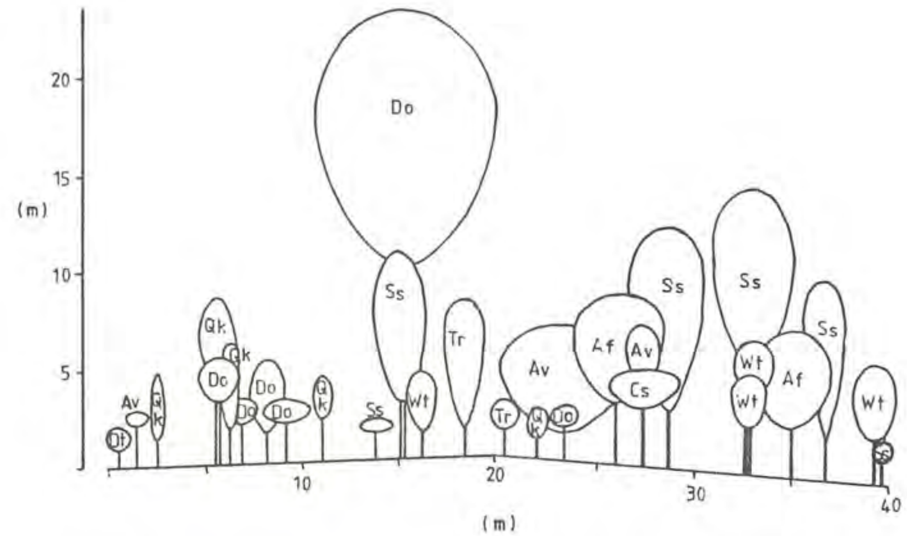

Figure 14. Profile diagram of the D_2 sub-association at quadrats 67 – 68. Af, *Anneslea fragrans;* Av, *Aporusa villosa;* Cs, *Craibiodendron stellatum;* Do, *Dipterocarpus obtusifolius;* Dt, *Dipterocarpus turberculatus;* Qk, *Quercus kerrii;* Ss, *Shorea siamensis;* Tr, *Tristania rufescens;* Wt, *Wendlandia tinctoria.*

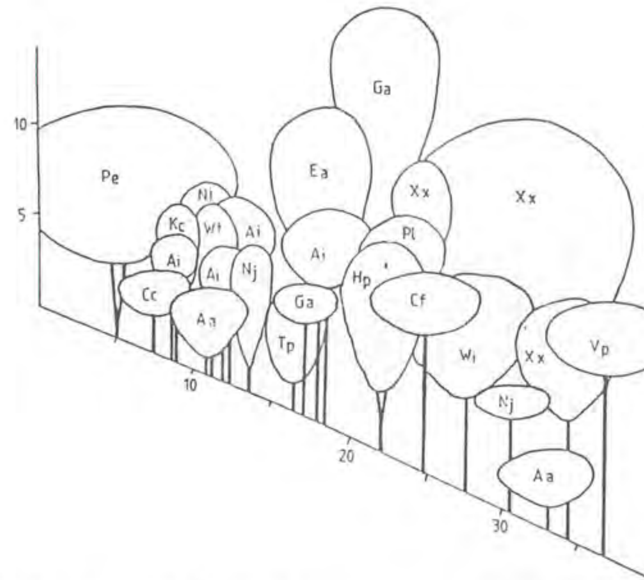

Figure 15. Profile diagram of the M_1 sub-association at quadrats 3 – 4. Aa, *Antidesma acidum;* Ai, *Anacolosa ilicioides;* Cf, *Colona flagrocarpa;* Cr, *Cratoxylum cochinchinensis;* Ea, *Eugenia albiflora;* Ga, *Gmelina arborea;* Hp, *Holarrhena pubescens;* Kc, *Kydia calycina;* Pl, *Phoebe lanceolata;* Nj, *Nyssa javanica;* Pe, *Phyllanthus emblica;* Tp, *Turpinia pomifera;* Vp, *Vitex peduncularis;* Wi *Walsura intermedia;* Wt, *Wendlandia tinctoria*; Xx, *Xylia xylocarpa.*

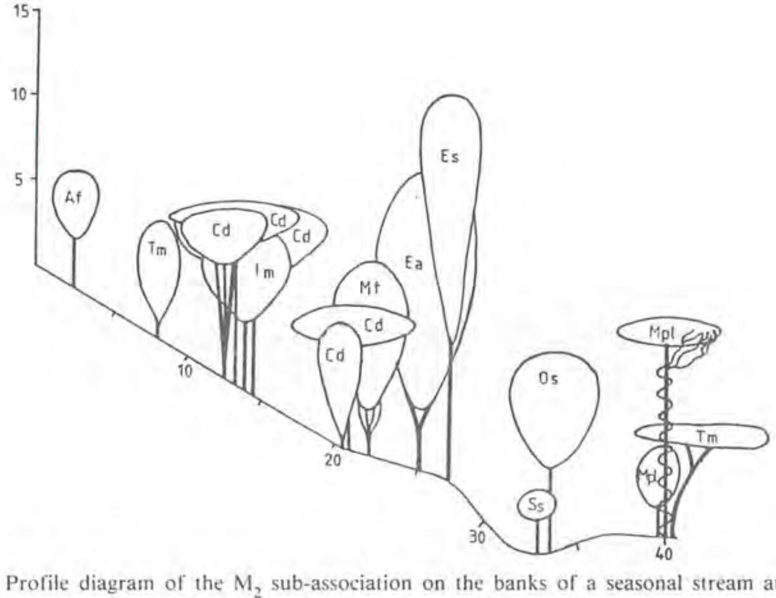

Figure 16. Profile diagram of the M_2 sub-association on the banks of a seasonal stream at quadrats 62 – 63. Af, *Anneslea fragrans;* Cd, *Castanopsis diversifolia;* Ea, *Eugenia albiflora;* Es, *Engelhardia serrata;* Im, *Irvingia malayana;* Mp, *Memecylon plebejum;* Mt, *Metadina trichotoma;* Os, *Olea salicifolia;* Sc, *Semecarpus curitsii;* Tm, *Terminalia mucronata.*

Initial observations suggested that availability of soil moisture during the dry season may be the prime factor determining the distribution of the associations. As elevation increases, temperature and therefore also the rate of evapotranspiration falls and rainfall increases. During December to March when there is very little or no rain, mists sometimes occur at higher elevations and may result in a significant input of moisture into the soil. In general the M association occupied the upper, wetter quadrats, whilst the D association occupied the lower, drier ones. However, superimposed on overall gradients of temperature and rainfall are variations in soil, which are themselves largely dependent upon local topography. On the crests of ridges, soils are extremely coarse sands with little organic matter and low water-holding capacity. Therefore, even at fairly high elevations, the D association could replace the M association near the tops of ridges (quadrats 10 – 16). Soils in gullies tend to be darker loams which stay moist longer during the dry season. So even at low elevations the M association could replace the D association along seasonal stream beds (e.g. quadrats 61 – 63) where water may still be available deep down during the height of the dry season. These are just initial subjective observations. Further research is currently in progress at Chiang Mai University to determine the precise relationship between soil moisture availability during the dry season and the deciduousness of the forest and tree species distributions.

Tree Density and Species Richness

Tree density on Doi Suthep is similar or higher than previously published values for Thai forests. OGAWA *et al.* (1965) reported tree densities of 581, 475 and 494 trees/ha for "dipterocarp savanna forest," "monsoon forest-savanna forest ecotone" and "monsoon forest" respectively at Ping Kong about 80 km north of Doi Suthep. BUNYAVEJCHEWIN (1986) recorded 514 – 562 trees/ha for "tropical semi-evergreen rain forest" in Northeast Thailand and 262 – 395 trees/ha for "tropical dry deciduous forest" in Northern Thailand (BUNYAVEJCHEWIN, 1983). All these figures are for trees of dbh 10 cm (i.e. gbh _ 31.4 cm). The density of trees of such a size in the Doi Suthep sample was 536 trees/ha, much higher than BUNYAVEJCHEWIN's value for deciduous forest and well within the range for semi-evergreen rainforest. In fact, in terms of tree density, Doi Suthep compares quite favourably with tropical rainforests. PAIJMANS (1970) reported that for trees with girths of more than 12 inches (30.4 cm), densities in lowland tropical rainforests are 245 – 740/ha and that for trees with girths of more than 24 inches (60.8 cm) densities are 185 – 420/ha. Comparable figures from the Doi Suthep sample were 536/ha and 249/ha.

Comparing the tree species richness of Doi Suthep with that reported for other tropical forests must be done with caution due to differences in methodology used by different authors. Most estimates of tree species richness in tropical forests are based on quadrats of various shapes ranging from 0.2 – 1.5 ha, usually placed deliberately in areas of forest pre-judged subjectively as being homogenous. The

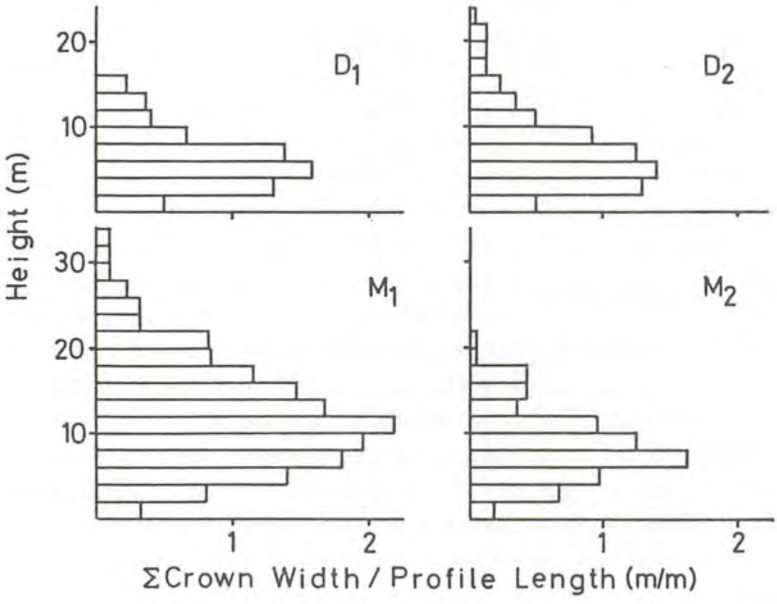

Figure 17. Variation in crown density with height above the ground for the four sub-associations.

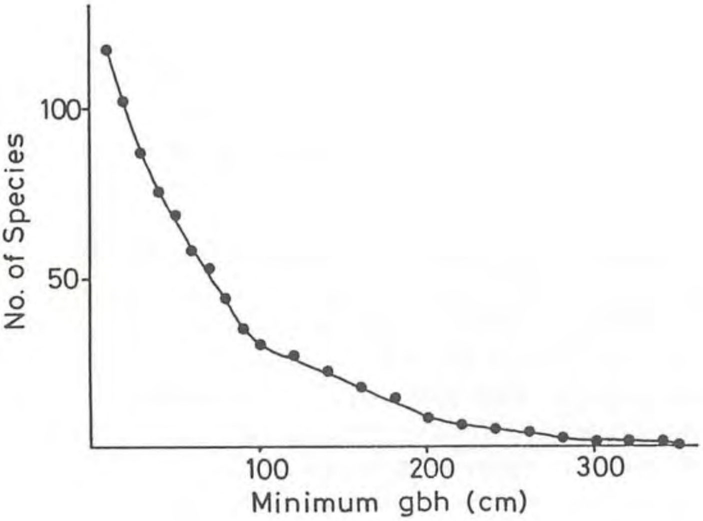

Figure 18. Relationship between total number of species recorded and minimum girth.

transect on Doi Suthep was positioned by means of a compass bearing regardless of any apparent homogeneity of the forest. Furthermore, most previous studies only counted trees with a dbh of ⩾ 10 cm (i.e. a gbh of ⩾ 31.4 cm) whereas for the Doi Suthep transect the size criterion was a minimum gbh of 10 cm. The minimum size criteria used in a forest survey greatly affects the species richness recorded. WHITMORE (1975) noted that the number of tree species recorded increases geometrically as the minimum girth considered is reduced. Figure 18 shows that this was also true of the forest on Doi Suthep.

When the Doi Suthep data were re-analysed ignoring trees of gbh 10 – 31.4 cm, the number of tree species on the transect was reduced to 87 and the estimated number per ha was reduced to about 90. This result ranks Doi Suthep as the most species-rich dry tropical forest currently known. In MURPHY & LUGO's (1986) review of data from 18 dry tropical forest sites, tree species richness varied from 30 up to a maximum of 90, the uppermost figure equalling the value for Doi Suthep. However this figure was based on estimates for 4 ha (at Guanica Forest, Puerto Rico) and included trees as small as dbh 2.5 cm (MURPHY, pers. comm.). HUBBELL (1979) recorded 87 tree species at Guanacaste Province, Costa Rica, but this was also for a much larger area than 1 ha (13.44 ha) and included trees of dbh ⩾ 2.0 cm. The only comparable figures for dry tropical forest in Northern Thailand are provided by OGAWA *et al.* (1961) who reported 35 tree species/ha for "diptercocarp savanna forest" at 300 m above sea level on the lower slopes of Doi Inthanon (about 50 km southwest of Doi Suthep) and 40 tree species/ha for "mixed savanna forest" near Tak (no elevation given), both for trees of dbh ⩾ 10 cm. The figure of 90 tree species (dbh ⩾ 10 cm) per hectare recorded for Doi Suthep is therefore the highest tree species richness known to the authors for any dry tropical forest. Doi Suthep-Pui National Park is therefore one of the most important sites in the world for the conservation of dry tropical forest and the strictest measures should be applied to prevent any degradation of such a unique genetic resource.

Doi Suthep even rivals some tropical rainforests in terms of tree species richness. All the following results are for trees of dbh ⩾ 10 cm. RICHARDS (1952) reported only 35 – 60 tree species in 1 ha plots of various rainforest types in Nigeria and BLACK *et al.* (1950) found only 60 – 80 tree species per hectare in Amazonian rainforest plots. EDWARDS (1989) studied altitudinal zonation of rainforest in Manusela National Park, Seram, Indonesia. In fourteen 0.25 ha plots ranging in elevation from sea level to 2,500 m, 13 to 44 tree species (dbh ⩾ 10 cm) were recorded. On Doi Suthep a 0.25 ha plot anywhere within the elevation range 670 – 960 m would contain on average 55 tree species (c.l. ± 17, $P < 0.05$) of the same size. Only those tropical rainforests widely acknowledged as among the most species-rich in the world exceed the tree species richness of Doi Suthep, including Sulawesi (100 species/ha, WHITMORE & SIDIYASA (1986)), Papua New Guinea (123 – 157 species/ha, PAIJMANS (1970)), Kalimantan (129 – 173 species/ha, KARTAWINATA *et al.* (1981)) and Sumatra (148 species/ha, KARTAWINATA *et al.* (1981)).

Biodiversity of Doi Suthep

Other evidence supports the view that Doi Suthep has exceptionally high overall biodiversity. In just two and a half years of collecting vascular plants on the mountain, MAXWELL (1989) has found at least one completely new species, one new family record, 9 species not previously known from Thailand, and a total of more than 1800 taxa, i.e. about 14% of Thailand's flora. To put this figure in perspective, it is about equal to the entire flora of the United Kingdom (WEBB, 1978), an area 1000 times larger than Doi Suthep. Species of wild animals include at least 320 bird species (ROUND 1984), 500 butterflies (PINRATANA, 1977 – 85) and 300 moths (BÄNZIGER, 1988), 50 mammals, 28 amphibians and 50 reptiles (NABHITABHATA, 1987), all in a park which covers just 261 km^2. For comparison, at Khao Yai National Park, which is ten times larger than Doi Suthep and is covered mostly with tropical rainforest, "only" 206 butterfly (BÄNZIGER, 1988) and 318 bird species (CONSERVATION DATA CENTRE, 1989) have so far been recorded.

The high biological diversity of Doi Suthep-Pui National Park may be due in part to its geographical location. Its position on the boundary of the Himalayan and Indo-Malesian biogeographical realms means that its flora and fauna contain representitives of both: temperate species from the north e.g. *Saurauia nepaulensis* DC. (Saurauiaceae) and *Cyathea chinensis* Copel. (Cyatheaceae) and equatorial species from the south e.g. *Catunaregam tomentosa* (Bl. ex DC.) Tirv. (Rubiaceae) and *Diospyros pilosanthera* Blanco (Ebenaceae). The wide range of elevation found in the park (350 – 1685 m) imposes an overall gradient in climate from cool and wet near the summit to hot and dry at the base of the mountain. The somewhat severe topography also creates a wide range of niches, varying in exposure to sun and wind, in a relatively small area and it is hardly surprising that a wide variety of organisms is present to fill them.

The Value of Doi Suthep as a National Park

Such high biodiversity is potentially of great economic value. In particular, the high tree species richness could play an important role in forest restoration projects. Compared with other regions of Thailand, the North has suffered least from deforestation. Even so, between 1961 – 1985 the region lost 28% of its forest (TDRI, 1987) and at this rate, there will be little left outside protected areas in 60 – 70 years. A quick solution to the problem of deforestation has been the rapid establishment of large-scale eucalyptus and pine plantations. Although such plantation trees grow very quickly, they have proved to be socially unacceptable in areas where villagers rely on native forests for products such as bamboo shoots, mushrooms and medicinal plants etc. which do not grow in monocultures of exotic tree species (ELLIOTT, 1989). Native tree species would be far more appropriate for reafforestation, especially in degraded national parks or wildlife sanctuaries where conservation and aesthetic considerations are paramount. Such species may not grow as fast as eucalyptus or pines but they are genetically suited to grow in the range of soil and climatic conditions of Northern Thailand and can provide a wide range of other forest products. Doi Suthep with its wide range of different tree species and varieties, each suited to particular soil and climate conditions, could provide a valuable seed source in the search for native trees of potential value for reafforestation projects. As well as timber, many of the tree species on the transect produce edible fruit (e.g. *Phyllanthus emblica, Castanopsis* spp., *Baccaurea ramiflora* etc.) whilst others are currently the subject of pharmacological research (e.g. *Holarrhena pubescens*). The forest also produces an abundant supply of bamboo shoots and mushrooms during the rainy season.

The high biodiversity of Doi Suthep fully justifies its status as a national park, but diversity is just one factor determining the value of a protected area. Another is the presence of rare or endemic species and Doi Suthep has many. Fifty of the 250 or so species of orchids which grow in the park (SEIDENFADEN & SMITINAND, 1959–65) are classified by the International Union for the Conservation of Nature (IUCN) as endangered, threatened or rare, 7 being found nowhere else in the world (BÄNZIGER, 1988). The bird fauna also includes several rare or endangered species such as the silver pheasant (*Lophura nycthemera*), Hume's pheasant (*Syrmaticus humiae*) and the wedge-tailed green pigeon (*Treron spenura*) among others (BAIN & HUMPHREY, 1982; ROUND, 1984).

Another attribute which greatly enhances the value of a protected area, is a long history of scientific research. COCKERELL (1929) described the mountain as "a veritable paradise for botanists". Doi Suthep has long been known as a study site for plant ecology and taxonomy (HOSSEUS, 1908; KERR, 1911; COCKERELL, 1929; OGAWA *et al.*, 1961; KÜCHLER & SAWYER, 1967; SAWYER & CHERMSIRIVATHANA, 1969; BEAVER & JINOROSE, 1974; CHEKE *et al.*, 1979; MAXWELL, 1988; BÄNZIGER, 1989) and is the type locality for at least 250 plant and 60 animal species (BÄNZIGER, 1988). Animal taxonomists and ecologists have also been attracted (DEIGNAN, 1945; DICKINSON & CHAIYAPHUN, 1967; ROUND, 1984; BEAVER & SRITASUWAN 1985; NABHITABHATA, 1987). Such a long history of scientific study is of immense value in providing base-line data against which long term change, whether man-made or natural, in similar ecosystems may be compared. As the remaining forest in Northern Thailand rapidly disappears, Doi Suthep will become increasingly more important as an area where ecologists can carry out the essential research that will be needed if native forest is to be restored to degraded areas. In addition, the park serves as a classroom for the two universities and many schools of Chiang Mai City. For biology majors at Chiang Mai University for example, field trips to Doi Suthep are an essential part of their courses.

Threats to Biodiversity

However, despite its status as a national park, Doi Suthep is constantly threatened by encroachment and a multitude of destructive development projects. Each one considered in isolation appears insignificant, but together they are causing the gradual deterioration of the forest. In a forest where most tree species are represented by very few individuals, the felling of just a few trees can have serious consequences for the local survival of the species as a whole. The continual expansion of tourist facilities, the upgrading of dirt tracks into surfaced roads, the construction of television transmitters and the continuation of slash and burn agriculture within the park have all taken their toll on the forest. More than 500 hilltribe families living within the park have encroached upon more than 800 ha, whilst agricultural research stations, run by various government agencies, cover a similar area (KASETSART UNIVERSITY, 1989) (Fig. 19). Plans to build a cable car system to Prataht Doi Suthep Temple would also involve further loss of forest.

Even where the forest habitats remain, wildlife is in serious danger from people who live in or near the park, gathering firewood, felling trees to obtain honey from bees hives (Fig. 20), collecting butterflies, large spiders and scorpions for the tourist trade, capturing birds and squirrels as pets and kil''ng birds of prey considered to be pests (Fig. 21). Such activities have probably been carried out for centuries without destroying the ecosystem, but now the number of people entering the park for these purposes has grown so high that loss of species seems inevitable.

Large mammals such as sambar deer (*Cervus unicolor*) and bear (*Selenarctos thibetanus*) disappeared many years ago. The largest mammal on Doi Suthep today is the barking deer (*Muntiacus muntjak*) which survives in very small numbers in the remotest areas (BANZIGER, pers. com.). Of particular concern has been the loss of all primates (*Hylobates lar, Presbytis phayrei* and *Nycticebus coucang* were common until recently) and all 5 hornbill species (DEIGNAN, 1945; ROUND, 1984). Many tree species may have relied on such animals for seed dispersal. Such trees may decline or disappear over the long term, as mature individuals die and are not replaced by seedlings. Research currently underway at Chiang Mai University is attempting to determine how many tree species may be affected.

Another worry is the annual occurrence of fires during the dry season. Such fires are all man made. They are started by villagers to clear land for agriculture, to flush out small mammals and birds for hunting and supposedly to increase the yield of wild mushrooms. Much of the forest below 950 m is burnt every year and fires often penetrate deep into the evergreen forest at higher altitudes. The Bhuping Forest Fire Control Project, responsible for fire surpression in the national park, lacks sufficient resources and manpower to adequately protect the remaining forest areas from frequent burnings (Fig. 22). Fire is a natural part of the ecology of dry deciduous forests in Southeast Asia (STOTT, 1986) and most mature trees are protected from fire by having very thick bark. However evergreen trees at higher elevations are not so protected. Even at lower elevations, the unnaturally high frequency of fires on Doi Suthep may by a cause for concern, since small seedlings are susceptible to fire until they have become large enough to grow thick bark. Repeated

Figure 19. In the foreground, strawberries are grown inside Doi Suthep-Pui National Park by an agricultural research station. Behind, the slopes have been completely denuded of forest by Hmong villagers.

Figure 20. A large *Dipterocarpus obtusifolius* tree felled near the transect by local people to obtain honey from a bees' hive.

Figure 21. The corpse of an eagle, shot, dismembered and hung in a tree just outside the grounds of Prataht Doi Suthep Temple to scare away other birds of prey which might be tempted by villagers' hens.

Figure 22. Understaffed and underfunded, the Bhuping Forest Fire Control Project tackles a fire in deciduous dipterocarp forest in February using their most sophisticated piece of equipment, a four-wheel drive water truck which carries up to 500 litres.

burnings every year may therefore lead to a decrease in the number of very young trees. Evidence that this may be happening on Doi Suthep is shown in Figure 1. The lack of trees in the 10 – 19.9 cm girth class compared with the 20 – 29.9cm girth class may indicate an increase in mortality of the young tree population or failure of seed germination in recent years. Further investigation is needed to determine whether this is due to fire or some other factor. At Chiang Mai University the effects of fire on seed germination are currently being investigated.

In conclusion, Doi Suthep-Pui National Park has exceptionally high biodiversity for a dry tropical forest and matches that of some tropical rainforests, but unless a greater effort is made to protect the forest and to do essential research, that biodiversity will be eroded and the value of the park for conservation, for biological sciences and for tourism will be considerably diminished.

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Appendix.
List of trees and lianas of girth at breast height of 10 cm or more occurring on a transect 1.38 km long and 6 m wide in Doi Suthep-Pui National Park, Chiang Mai Province, Thailand. Abbreviations: TT = topotype, D = deciduous, E = evergreen, TP = tropophyllous (see KUCHLER & SAWYER, 1967)

Species	Family	Leafing Pheno-logy	No. of individuals					Mean girth (cm)
			Total	D_1	D_2	M_1	M_2	
Acacia megaladena Desv. var. *megaladena*	Leguminosae, Mimosoideae	E	1	0	0	1	0	36.8
Albizia odoratissima (L.f.) Bth.	Leguminosae, Mimosoideae	D	8	0	2	5	1	57.9
Anacolosa ilicoides Mast.	Olacaceae	E	8	0	0	8	0	47.3
Anneslea fragrans Wall.	Theaceae	T	9	3	4	1	1	34.8
Antidesma acidum Retz.	Euphorbiaceae	E	10	0	0	8	2	16.6
Antidesma bunius (L.) Spreng.	Euphorbiaceae	E	1	0	0	0	1	67.0
Antidesma montanum Bl.	Euphorbiaceae	E	1	0	0	1	0	24.0
Antidesma sootepense Craib (TT)	Euphorbiaceae	E	1	0	0	1	0	18.4
Aporusa villosa (Lindl.) Baill.	Euphorbiaceae	D	22	13	9	0	0	23.6
Aporusa wallichii Hk.f.	Euphorbiaceae	D	9	1	0	4	4	39.0
Artocarpus gomezianus Wall. ex Trec.	Moraceae	E	2	0	1	1	0	57.5
Baccaurea ramiflora Lour.	Euphorbiaceae	E	1	0	0	0	1	50.0
Bauhinia variegata L.	Leguminosae, Caesalpinioideae	D	1	0	0	0	1	19.5
Bombax kerrii Craib (TT)	Bombacaceae	D	2	0	0	2	0	25.0
Bombax malabarica DC.	Bombacaceae	D	2	0	2	0	0	32.7
Buchanania glabra Wall. ex Hk. f.	Anacardiaceae	D	1	0	1	0	0	36.0
Buchanania latifolia Roxb.	Anacardiaceae	D	1	0	1	0	0	52.5
Canarium subulatum Guill.	Burseraceae	D	3	0	1	0	2	27.2

Species	Family	Leafing Pheno-logy	No.of individuals					Mean girth (cm)
			Total	D_1	D_2	M_1	M_2	
Canthium umbellatum Wight	Rubiaceae	E	1	0	0	1	0	27.0
Cassia bakeriana Craib (TT)	Leguminosae, Caesalpinioideae	D	1	0	0	1	0	54.0
Castanopsis diversifolia King	Fagaceae	E	15	0	0	1	14	40.9
Castanopsis indica (Roxb.) A.DC.	Fagaceae	T	1	0	1	0	0	53.0
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	E	9	0	2	1	6	83.7
Catunaregam tomentosa (Bl. ex DC.) Tirv.	Rubiaceae	D	5	0	3	2	0	50.4
Celastrus paniculatus Willd.	Celastraceae	D	2	0	0	1	1	25.2
Colona floribunda (Kurz) Craib	Tiliaceae	D	5	0	2	2	1	35.8
Colona flagrocarpa (Cl.) Craib	Tiliaceae	D	9	0	5	4	0	44.9
Craibiodendron stellatum (Pierre) W.W. Sm.	Ericaceae	E	12	2	9	1	0	27.3
Cratoxylum cochinchinense (Lour.) Bl.	Hyperiaceae	D	4	0	0	4	0	34.2
Croton robustus Kurz	Euphorbiaceae	T	1	0	0	1	0	10.0
Dalbergia sp.	Leguminosae, Papilionoideae	D	1	0	0	0	1	30.0
Dalbergia dongnaiensis Pierre	Leguminosae, Papilionoideae	D	5	0	2	2	1	101.7
Dalbergia fusca Pierre	Leguminosae, Papilionoideae	D	11	0	5	6	0	39.6
Dillenia aurea Sm. var. *aurea*	Dilleniaceae	D	3	2	1	0	0	14.3
Dimocarpus longan Lour. ssp. *longan* var. *longan*	Sapindaceae	E	1	0	0	0	1	28.0
Diospyros ehretioides Wall. ex G. Don	Ebenaceae	E	2	0	1	0	1	36.2
Diospyros ferrea (Willd.) Bakh. var. *littorea* (R.Br.) Bakh.	Ebenaceae	E	1	0	0	1	0	16.5
Diospyros pilosanthera Blanco	Ebenaceae	E	3	0	0	1	2	60.6
Dipterocarpus costatus Gaerth. f.	Dipterocarpaceae	E	2	0	0	2	0	279.1

Species	Family	Leafing Pheno-logy	No.of individuals					Mean girth (cm)
			Total	D_1	D_2	M_1	M_2	
Dipterocarpus obtusifolius Teijsm. ex Miq. var. *obtusifolius*	Dipterocarpaceae	D	50	8	33	6	3	70.7
Dipterocarpus tuberculatus Roxb. var. *tuberculatus*	Dipterocarpaceae	D	5	0	4	0	1	19.8
Engelhardia serrata Bl.	Juglandaceae	D	6	0	2	1	3	29.3
Engelhardia spicata Lechen. ex Bl. var. *spicata*	Juglandaceae	D	1	0	0	1	0	75.0
Eugenia albiflora Duth. ex Kurz	Myrtaceae	E	12	0	1	5	6	79.2
Ficus benjamina L. var. *benjamina*	Moraceae	E	1	0	0	1	0	17.8
Ficus fistulosa Reinw. ex Bl. var. *fistulosa*	Moraceae	E	2	0	0	1	1	24.5
Ficus hispida L.f. var. *hispida*	Moraceae	E	1	0	0	1	0	16.0
Flacourtia indica (Burm. f.) Merr.	Flacourtiaceae	D	1	0	0	1	0	25.0
Garcinia cowa Roxb.	Guttiferae	D	1	0	0	1	0	14.0
Gardenia sootepensis Hutch. (TT)	Rubiaceae	E	5	0	3	2	0	39.8
Gluta usitata (Wall.) Hou	Anacardiaceae	D	2	2	0	0	0	15.3
Gmelina arborea Roxb.	Verbenaceae	D	2	0	0	2	0	110.2
Grewia eriocarpa Juss.	Tiliaceae	D	1	0	0	1	0	73.0
Holarrhena pubescens (B. -H.) Wall. ex G. Don.	Apocynaceae	D	3	0	0	3	0	30.8
Ilex umbellulata (Wall.) Loesn.	Aquifoliaceae	E	6	0	0	4	2	69.4
Irvingia malayana Oliv. ex Benn.	Irvingiaceae	E	3	0	0	1	2	58.7
Kydia calycina Roxb.	Malvaceae	D	1	0	0	1	0	23.0

Species	Family	Leafing Pheno-logy	No.of individuals					Mean girth (cm)
			Total	D_1	D_2	M_1	M_2	
Lagerstroemia cochinchinensis Gagnep. var. *ovalifolia* Furt. & Mont.	Lythraceae	D	1	0	0	0	1	83.0
Lagerstroemia macrocarpa Kurz var. *macrocarpa*	Lythraceae	D	4	0	2	2	0	13.9
Lithocarpus harmandii (Hick. & A. Camus) A. Camus	Fagaceae	E	2	0	1	1	0	77.7
Lithocarpus lindleyanus (Wall.) A. Camus	Fagaceae	E	2	0	2	0	0	63.5
Lithocarpus sootepensis (Craib) A. Camus (TT)	Fagaceae	E	25	4	4	4	13	48.0
Lithocarpus spicatus (Sm.) Rehd. & Wils.	Fagaceae	E	2	0	0	1	1	108.7
Lophopetalum wallichii Kurz	Celastraceae	D	1	0	0	1	0	23.0
Mangifera caloneura Kurz	Anacardiaceae	E	1	0	0	1	0	300.0
Memecylon plebejum Kurz var. *siamense* Craib (TT)	Melastomataceae	D	5	0	0	1	4	24.7
Memecylon scutellatum (Lour.) Naud.	Melastomataceae	D	1	0	0	1	0	18.0
Metadina trichotoma (Z. & M.) Naud.	Rubiaceae	E	13	0	1	1	11	81.1
Michelia champaca L.	Magnoliaceae	E	1	0	0	1	0	51.8
Millettia extensa Bth. ex Baker	Leguminosae, Papilionoideae	D	2	0	2	0	0	22.0
Mitragyna hirsuta Hav.	Rubiaceae	D	1	0	1	0	0	41.0
Nyssa javanica (Bl.) Wang.	Nyssaceae	E	4	0	0	4	0	38.1
Olea salicifolia Wall. ex G. Don	Oleaceae	E	5	0	0	1	4	78.0
Oroxylum indicum (L.) Vent.	Bignoniaceae	D	10	0	2	7	1	23.5
Parinari anamensis Hance	Rosaceae	D	1	1	0	0	0	85.9

Species	Family	Leafing Phenology	No.of individuals: Total	D_1	D_2	M_1	M_2	Mean girth (cm)
Pavetta petiolaris Wall. ex Craib	Rubiaceae	D	2	0	0	1	1	13.7
Phoebe lanceolata (Nees) Nees	Lauraceae	E	7	0	2	2	3	77.8
Phyllanthus emblica L.	Euphorbiaceae	D	2	0	0	2	1	70.8
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae	D	6	0	0	5	1	18.4
Pterocarpus macrocarpus Kurz	Leguminosae, Papilionoideae	D	1	0	1	0	0	20.6
Quercus brandisiana Kurz	Fagaceae	D	2	0	1	1	0	55.5
Quercus kerrii Craib var. *kerrii* (TT)	Fagaceae	D	37	5	29	3	0	41.2
Quercus kingiana Craib (TT)	Fagaceae	D	3	0	0	3	0	247.7
Quercus lanata J. Smith	Fagaceae	D	1	0	1	0	0	197.0
Randia sootepensis Craib (TT)	Rubiaceae	E	9	0	0	8	1	45.9
Rapanea neriifolia (Sieb. & Zucc.) Mez var. *yunnanensis* (Mez) Walk.	Myrsinaceae	E	2	0	0	1	1	51.0
Rhus chinensis Mill.	Anacardiaceae	D	1	0	1	0	0	23.0
Schima wallichii (DC.) Korth.	Theaceae	T	6	0	0	4	2	176.3
Scleropyrym wallichianum Arn. var. *siamensis* H. Lec. (TT)	Santalaceae	E	2	0	0	1	1	51.0
Semecarpus curtisii King	Anacardiaceae	D	3	0	1	2	0	59.2
Shorea obtusa Wall. ex Bl.	Dipterocarpaceae	D	1	0	0	1	0	120.0
Shorea roxburghii G. Don	Dipterocarpaceae	D	6	0	0	2	4	46.1
Shorea siamensis Miq. var. *siamensis*	Dipterocarpaceae	D	84	8	71	3	2	54.8
Spatholobus parviflorus (Roxb.) O.K.	Leguminosae, Papilionoideae	T	5	0	1	4	0	44.8
Spondias axillaris Roxb.	Anacardiaceae	E	1	0	0	1	0	11.6
Sterculia angustifolia Roxb.	Sterculiaceae	D	2	0	0	0	2	48.0

Species	Family	Leafing Pheno-logy	No.of individuals					Mean girth (cm)
			Total	D_1	D_2	M_1	M_2	
Sterculia ornata Wall. ex Kurz	Sterculiaceae	D	1	0	1	0	0	39.5
Stereospermum colais (B. -H. ex Dillw.) Mabb.	Bignoniaceae	D	3	0	2	1	0	114.1
Stereospermum neuranthum Kurz	Bignoniaceae	D	5	0	4	1	0	52.7
Strychnos nux-vomica L.	Loganiaceae	D	1	0	1	0	0	31.0
Styrax benzoides Craib (TT)	Styracaceae	T	15	0	2	11	2	37.2
Tarenna disperma (Hk.f.) Pit.	Rubiaceae	E	7	0	0	6	1	82.4
Tectona grandis L.f.	Verbenaceae	D	5	0	4	1	0	87.2
Terminalia mucronata Craib & Hutch. (TT)	Combretaceae	D	21	0	5	14	2	61.4
Tetrastigma serrulatum (Roxb.) Pl.	Vitaceae	E	1	0	0	1	0	11.7
Trema orientalis (L.) Bl.	Ulmaceae	T	1	0	0	1	0	22.0
Tristania rufescens Hance	Myrtaceae	D	50	38	11	1	0	28.2
Turpinia pomifera (Roxb.) Wall. ex DC.	Staphyleaceae	E	5	0	0	2	3	64.4
Vaccinium sprengelii (D. Don) Sleum.	Ericaceae	D	4	1	2	1	0	23.2
Viburnum inopinatum Craib (TT)	Caprifoliaceae	D	3	0	0	1	2	19.2
Vitex canescens Kurz	Verbenaceae	D	1	0	1	0	0	48.0
Vitex limoniifolia Wall. ex Kurz	Verbenaceae	D	2	0	1	1	0	16.2
Vitex peduncularis Wall. ex Schauer	Verbenaceae	D	14	0	1	13	0	76.2
Walsura intermedia Craib	Meliaceae	E	1	0	0	1	0	46.0
Wendlandia tinctoria DC. var. *floribunda* (Craib) Cowan (TT)	Rubiaceae	D	28	6	11	8	3	32.9
Xylia xylocarpa (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Niels. (TT)	Leguminosae, Mimosoideae	D	15	0	4	11	0	79.2
Ziziphus rugosa Lmk. var. *rugosa*	Rhamnaceae	D	1	0	1	0	0	17.2