Vegetation and Vascular Flora of Doi Sutep–Pui National Park, Northern Thailand

J. F. Maxwell and Stephen Elliott

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FOREWORD

"Biodiversity" has become the catchphrase and rallying point for conservation and the environment during the last ten years, and it promises to remain so well into the next century. This is because ecologists and conservation biologists have come to the view that loss of species, their genes (through decline in population size), and their habitats is the most serious environmental problem facing us. Loss of species is irreversible over the time scale of our own species, and loss of many habitats is irreversible over our own lifetimes. Species will disappear fastest from limited, insular, or fragmented areas. The remaining natural forest areas in Thailand are highly fragmented. Surveying current species diversity in natural habitats, especially forests, and monitoring the rates of species loss over the next century are high priorities for conservation, because we need to determine which areas are most at risk and which offer the most promise.

There are few areas of significant size in Thailand for which we have a near complete list of vascular plants. Thanks to the authors of this volume, we now have such a list for Doi Sutep–Pui National Park, a forest island of about 261 km^2. There is no other forest area of comparable size in Thailand that is so well studied botanically, or which has such a high list of species. Incredibly, this relatively small park contains approximately 20 percent of the vascular plant species of Thailand. The secret to its high biodiversity probably lies in the broad range of elevation zones and habitats present, spanning the deciduous lowland forest to the moist subtropical to the cool, nearly temperate climate of the mountain tops. Nevertheless, one wonders how many species would be recorded in other areas if every knoll, ravine, and seep were so closely inspected for plants with the sustained, steadfast determination that Maxwell has applied to Doi Sutep–Pui.

J. F. Maxwell started his botanical career in Thailand in January of 1969, first botanizing more as a hobby, then a year later as a professional activity. Most of his career, his intense interest in collecting and learning about different species has been his prime motivation, often in spite of the need to also make a living. During 1970–75 he worked in the Herbarium, Department of Agriculture, Bangkok (BK). After nearly a year at FAO (with the TigerPaper), he became a student in botany at the University of Singapore, earning a master's degree. During 1980–84 he served as a curator of the Herbarium, Botanic Gardens of Singapore (SING). He returned to Thailand in mid-1984 to develop the herbarium at Prince of Songkla University (PSU), Hat Yai, the largest university in South Thailand. From there he moved to Chiang Mai University in July of 1987 where he established the CMU herbaria. Maxwell's publications have been profuse and continuous throughout his career and his well-known collections have been numerous and meticulous.

Stephen Elliott, another long-term resident of Thailand, obtained his Ph.D. degree from the Department of Forestry and Natural Resources of Edinburgh University in 1985, specializing in the ecology of plant-animal interactions. Following postdoctoral research projects on ethnobotany and forest ecology in Indonesia and Africa, he joined the Biology Department of Chiang Mai University where he has been teaching ecology and conservation biology. Recognizing deforestation as one of the most serious problems in northern Thailand, he has focused his research on developing techniques of restoring deforested or degraded areas. To achieve this aim, he co-founded, with Dr. Vilaiwan Anusarnsunthorn, the Forest Restoration Research Unit (FORRU), whose main work site is situated on the mountain at the national park headquarters. There, a team of workers and students work with Forest Department authorities

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Cover: *Dipterocarpus costatus* Gaertn. f. (Dipterocarpaceae) is one of the most obvious and spectacular indicator species of mixed evergreen + deciduous, seasonal, hardwood forest in northern Thailand. In Doi Sutep-Pui National Park it is found from 500 to 1150 m elevation, flowers from December to February, fruits during May-August, and is evergreen. Photo: Warren Brockelman, east side of Doi Sutep, along the road to Montatahn Falls, *c*. 700 m, April 1997.

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and local tribal people to germinate and plant seedlings of native species of trees. In this respect, the FORRU effort really deserves to be called reforestation much more than the widespread planting of monocultures of pines or non-native eucalypts.

Elliott's main contribution to the flora enumeration has been collaboration with Maxwell on forest transects on the mountain and construction of the database in which are stored species names, habit, habitat, phenology, and other useful information about each species. Without such a database the compilation would have been difficult if not impossible to complete and to publish.

The forest vegetation classification set forth by the authors offers some important differences from the one (or ones) presently in wide use in Thailand. It seems destined to raise some eyebrows and cause controversy. I have reviewed it carefully and have urged Maxwell to explain specifically in what ways his system differs from the current ones, so that further discussion can focus on productive issues. In some instances it just involves some new terminology, but in others it challenges the distinctions between the currently recognized associations. One of the important recommendations that arise is that vegetation types should be based on analysis of the entire assemblage of species and not on just a few dominant tree species important to commerce.

Ecologists in Thailand have become complacent about the current forest classification system and do not seem to care whether it makes any biological sense, is consistent, or is supported by any quantitative analysis. In fact, it was created primarily by (or for) foresters with some floristic knowledge, but no analytical tools for ecological classification, primarily for the convenience of recognizing harvestible timber. Maxwell has raised some important issues that should be discussed. I fully support his attempt to challenge the status quo, and he has plenty of field experience to justify it. But it is clear that our forest classification systems cannot be improved much without much additional analysis and better definition of the criteria used.

This landmark floristic inventory provides the most powerful argument for implementing measures for protecting the forests of Doi Sutep–Pui from continued degradation and abuse. This national park is somewhat unusual in that settlement and destruction were increasing apace when it was created; hence the existence of so many enclaves of human activity within its borders. In a sense we should be thankful that any forest at all was preserved so close to the largest city in the North. The authors have pointed out many vegetational changes and losses of species that have occurred during the last hundred years or more. Nevertheless, the biodiversity present is still outstanding in species richness and luxuriance, and most of it can be saved if we make the effort. Its proximity to Chiang Mai greatly enhances its value.

Warren Y. Brockelman
August 2001

The upland weed collections of Roswita Wehner and Liane Chamsai have been very useful by providing us with us with much supplementary information which we are grateful to have.

Dr. Warren Brockelman, a friend and collaborator of ours for many years, is especially thanked for not only encouraging the production of this opus, but also critically reviewing and editing several of its drafts. Part I could not have been satisfactorily completed without his constant assistance.

Rungtiwa Panyayod, our computer typist, is gratefully thanked for her skill and patience in dealing with our numerous additions, changes, corrections, *etc.* of the manuscript. Janice Kerby is thanked for proof reading our plus Rungtiwa's work.

We would like to thank John Milne for his tremendous job in editing and vastly improving the final version of the manuscript.

Final type setting and organization of this work was professionally done by Urai Toobhawm. We are grateful for her expertise and cooperation.

It has been our pleasure to supervise various botanical and ecological research projects in Doi Sutep–Pui National Park from which we were able to study certain areas in detail. The details of these projects are:

Adhikari, B. P. 1996. Relationship Between Forest Regeneration and Ground Flora Diversity in Deforested Gaps in Doi Suthep–Pui National Park, Northern Thailand. M.Sc. thesis, Graduate School, Chiang Mai University; 111 pp.

Hiranramdej, S. and J .F. Maxwell. 1991. Research Book of Study and Herbarium of Medicinal Vascular Flora of Doi Suthep–Pui. Faculty of Pharmacy, Chiang Mai University (in Thai); 229 pp.

Kafle, S. K. 1997. Effects of Forest Fire Protection On Plant Diversity, Tree Phenology, and Soil Nutrients in a Deciduous Dipterocarp–Oak Forest in Doi Suthep–Pui National Park. M. Sc. thesis, Graduate School, Chiang Mai University; 92 pp.

Kopachon, S. 1995. Seed Germination and Seedling Development of Dry Tropical Forest Trees: A Comparison Between Dry Season Fruiting and Rainy Season Fruiting Species. M. Sc. thesis, Graduate School, Chiang Mai Uniersity; 86 pp.

La Karimuna. 1995. A Comparison of Ground Flora Diversity Between Forest and Plantations in Doi Suthep–Pui National Park. M. Sc. thesis, Graduate School, Chiang Mai University; 107 pp.

Meng, M. 1997. Effects of Forest Fire Protection on Seed Dispersal, Seed Bank, and Tree Seedling Establishment in a Deciduous Dipterocarp–Oak Forest in Doi Suthep–Pui National Park. M.Sc. thesis, Graduate School, Chiang Mai University; 89 pp.

Pakkad, G. 1997. Morphological Database of Fruits and Seeds of Trees in Doi Suthep–Pui National Park. M. Sc. thesis, Graduate School, Chiang Mai University; 204 pp.

Phuakam, A. 1994. A Survey of Herbaceous Ground Flora on the Eastern Side of Doi Suthep, Altitude 670–750 Meters. M. Sc. thesis, Graduate School, Chiang Mai University; 2 volumes, 478 pp.

Sharp, A. 1995. Seed Dispersal and Predation in Primary Forest and Gap on Doi Suthep. M. Sc. thesis, Graduate School, Chiang Mai University; 81 pp.

Sopsop, G. 1996. Effect of Land Use Patterns on Soil–Inhabiting Arthropods in Doi Suthep–Pui National Park. M. Sc. thesis, Graduate School, Chiang Mai University; 72 pp.

THAI STUDIES IN BIODIVERSITY

No. 1 **(1997) T. Radanachaless and J. F. Maxwell.** ***List of Weeds Reported in Thailand***
No. 2 **(1998) P. Poonswad (ed.).** ***The Asian Hornbills: Ecology and Conservation***
No. 3 **(1998) Y. Chaimanee.** ***Plio-Pleistocene Rodents of Thailand***
No. 4 **(2001) C. Swennen, R. G. Moolenbeek, N. Ruttanadakul, H. Hobbelink, H. Dekker and S. Hajisamae.** ***The Molluscs of the Southern Gulf of Thailand***
No. 5 **(2001) J. F. Maxwell and Stephen Elliott.** ***Vegetation and Vascular Flora of Doi Sutep–Pui National Park, Northern Thailand***

PREFACE

This monograph on the vegetation and vascular flora of Doi Sutep–Pui National Park is the result of a collaborative effort which started in July 1987. Both myself and Dr. Elliott were new to Chiang Mai University and northern Thailand at this time and Doi Sutep–Pui was the closest and most interesting place for us to begin learning about the vegetation of the region. We were surprised to find out that a proper flora of Doi Sutep–Pui had never been written, although it was the first place in northern Thailand to be studied botanically and had also been a very popular collecting locale for both Thai and foreign botanists since the 1950's. We also quickly realized that there was no conclusive vegetational analysis of this mountain or, in fact, for the entire kingdom. In late 1988 I published a paper on the vegetation of this mountain which differed significantly from all previous papers on this subject. A series of short papers of botanical notes on plants collected on Doi Sutep–Pui and other areas in northern Thailand was started in 1989. Our first joint paper about a transect survey in the lower elevations of Doi Sutep was published in 1989. Since that time we have gained much botanical experience and expertise on Doi Sutep–Pui. In March 1992 I joined the Biology Department after being released from the Faculty of Pharmacy where the herbarium I started was discontinued. A new CMU herbarium was established at the Biology Department which today contains over 18,500 specimens. The CMU Herbaria, including slightly over 10,000 specimens at the Pharmacy Herbarium, amounts to over 28,500 specimens and has by far the largest collection of any university in Thailand. This is the third largest herbarium in Thailand and one of the most active in the kingdom. A plant database was also initiated in 1992, initially for Doi Sutep–Pui and later for many other areas, mostly in northern Thailand. The first of our M.Sc. students doing work on Doi Sutep–Pui completed her work in 1994. In November 1994, the Forest Research Restoration Unit was established on Doi Sutep. This is a joint project between Chiang Mai University and Doi Sutep–Pui National Park, which we helped to create and develop with the assistance of several specialists in nursery techniques and forest restoration. The development and operation of the unit would have been impossible without detailed knowledge of the vegetation and flora of this mountain.

Since 1992, with the development of the CMU Herbaria and botanical database, we have often been asked to provide information on the flora of Doi Sutep–Pui National Park and other areas to people with legitimate requests. We have, however, never released by publication or internet the information from Doi Sutep–Pui National Park, mainly since we have been concerned about plagiarism and the fact that we never really felt that the research was complete. By January 1999, Dr. Warren Brockelman suggested that we submit a monograph of our work in Doi Sutep–Pui National Park for publication in the new monograph series called *Thai Studies in Biodiversity* published by the Biodiversity Research and Training Program in Bangkok.

During this time it was decided that in order to properly explain the vegetation in Doi Sutep–Pui National Park it was necessary to include a chapter on the vegetation of Thailand. This proved to be more of a challenge than originally anticipated since there have been many different, often confusing, systems presented. It was, therefore, necessary to devise a new system since all previous publications on this subject were considered to be inadequate. My simplified, but concise, system is presented in Part I.

Part II includes our analysis of the vegetation of Doi Sutep–Pui National Park. It is essentially the product of our own work which is presented in detail. Although we have reviewed previous major botanical work in the national park, we have conscientiously avoided adopting or accepting most of the terminology and plant lists available. We have been surprised by the amount of incomplete and inaccurate botanical work done in this national park. It has, therefore, been our ultimate goal to present our work objectively and with high professional standards.

The third part, Part III, is an annotated enumeration of the vascular flora in Doi Sutep–Pui National Park. After over 13 years of personal observations and refinement of the botanical database, we feel that it is as close to perfection as we can make it— unless we postpone publication for another decade merely to change some minor phenological details, alter a few names, or add a few more species.

Management and conservation in the national park are critical issues affecting the vegetation of the park and are, therefore, covered in some detail in Part IV of the monograph. Problems of fire, watershed management, encroachment for agriculture, and tourism development all continue to erode biodiversity and have not yet been satisfactorily addressed by the local government, the park authorities, or local people. To prevent further loss of species and habitats, degradation of water resources, contamination of soil, and commercialization of the park, immediate measures are necessary. Some suggestions are put forward in this part. From the species listed in this monograph as having disappeared or become endangered, it is obvious that current protective measures are ineffective. Unless conservation of the national park becomes a higher priority than exploitation, the plants, animals, and other environmental resources which the park is meant to protect will continue to decline.

J.F.Maxwell
May 2001

Abstract

Many systems of forest classification have been proposed for Thailand, but almost all are impractical because of their complexity, botanical inconsistency and/or impracticability, incredibility, or ecological unsuitability. A new system is proposed in which seasonality, vegetational structure, floristic composition, and elevation are the salient parameters. The original interpretation of rain forest as ever-wet forest is adopted here; thus because of seasonality throughout Thailand, rain forests are not considered to exist in the kingdom. The results of a 13 year study of the flora and vegetation in Doi Sutep–Pui National Park are highlighted in order to explain and give credibility to the forest types of northern Thailand which are the most complex and diverse in the country.

There are two basic forest types in Thailand, *viz.* deciduous and evergreen. Deciduous forests, especially in northern Thailand, are found from sea level to *c.* 850 m. Evergreen forests can be found from sea level to 2231 m—the highest point in Thailand. The dry season in northern, central, and north–eastern Thailand lasts from about November to May, while in the peninsula it lasts for 4–8 weeks during March–May. There is a mixed evergreen + deciduous, seasonal forest in some lowland forested areas from *c.* sea level to *c.* 850 m, while in northern Thailand it is from *c.* 850 to 1000 m. Above 1000 m is primary, evergreen, seasonal forest. The two species of pine found in Thailand can be found from about 600 to 1800 m in northern Thailand and from lower than 100 m in the Northeast. Forest destruction along with fires in the dry season have resulted in secondary and tertiary growth throughout the country.

An annotated enumeration of 2247 species, *etc.* of vascular plants found in the national park is given. The compilation includes habit, habitat, forest type, elevation, abundance, and flowering, fruiting, and leafing phenologies.

At least 512 species, *etc.* of vascular plants have been described during the past *c.* 90 years, that is since the first botanists started collecting, from the national park—the most from any single locale in Thailand. The enumeration includes 457 of these species while 55 were not rediscovered. Forest destruction and excessive exploitation are the main reasons why 55 of these new species, in addition to several other species recorded earlier, have become either very rare or extirpated from the national park.

One new species (since synonomized), two new combinations, and new records of one family, two genera, and 14 species are given here, along with emended descriptions/taxonomic notes on 13 species based on specimens collected during this reaearch in the national park.

Conservation of diminished biodiversity in the national park is discussed where various aspects of exploitation, *e.g.* deforestation, 'development,' fire, hunting, *etc.* are highlighted. Reforestation, an essential part of alleviating and rehabilitating the vast amount of environmental destruction which has occurred in the national park, is also included.

ACKNOWLEDGEMENTS

During more than thirteen years of study in Doi Sutep–Pui National Park we have been quite fortunate to have received assistance, in varying degrees, from many sources. We would like to thank all of the following for their encouragement and/or participation in our work.

Institutional support was given by the Faculty of Pharmacy, Chiang Mai University, until the end of October 1991 and by the Biology Department, Faculty of Science, Chiang Mai University, throughout the project. Some financial support was provided by Wildlife Conservation International during the beginning of our work. World Wildlife Fund U.S.A. supported establishment of the botanical database. Grirk Pakkad, our computer technician and student, has organized and maintained the CMU botanical database since its inception in 1992. Supadarath Suteepornwiroch, herbarium technician at the Faculty of Pharmacy, and Pranee Palee, herbarium technician and assistant in the Biology Department, have assisted in specimen collection and curation during our research. Mrs. Somporn Hirandramdej (Faculty of Pharmacy) and later Dr. Vilaiwan Anusarnsunthorn (Biology Department) have provided competent administrative support during our studies. Sai Jai Ngundahn has assisted us since the beginning of the project in July 1987. The administration of Doi Sutep–Pui National Park has cooperated with us throughout the project.

Professional botanical assistance, especially in specimen identification, has been received in the following families from:

Apocynaceae	*D. J. Middleton*
Araceae	*W. Hetterscheid*
Araliaceae	*H. J. Esser*
Athyriaceae	*P. Hovenkamp*
Burseraceae	*Rachan Pooma*
Cucurbitaceae	*B. & W. de Wilde*
Euphorbiaceae	*H. J. Esser*
Gesneriaceae	*B. L. Burtt*
Gramineae	*J. F. Veldkamp*
Gramineae, Bambusoideae	*C. Stapleton*
Labiatae	*Somran Suddee*
Magnoliaceae	*H. Nooteboom*
Melastomataceae	*S. Renner & N. Cellinese*
Musaceae	*H. Volkaert*
Orchidaceae	*G. Seidenfaden*
Palmae	*J. Dransfield*
Polygalaceae	*C. A. Pendry*
Zingiberaceae	*I. Theilade*

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Editor's note: The spelling of Thai proper names in this monograph follows a personalized phonetic English transliteration which generally differs from that of the Royal Institute which is used on most official Thai maps and other documents. Below are listed the official spellings (right side) corresponding to some of the authors' spellings (left).

Chamadevi (Princess)	Chamathewi
Doi Sutep	Doi Suthep
Daht Mawk	Tat Mok
Haripunchai	Hariphunchai
Mawk Fah	Mok Fa
Phuping Palace	Phuphing Palace
Hmong	Hu-Mong
Nong Hoy Gow	Nong Hoi Kao
Pah Ngeub	Pha Ngoeb
Mayo	Maeo
Chang Kian	Chang Khian
Doi Kuhn Tan	Doi Khun Tan
Lampoon Province	Lamphun Province
Wat Prataht	Wat Phrathat

PART I

A Reassessment of the Forest Types of Thailand

J. F. Maxwell

Introduction

The purpose of this part is to provide a clear and rational system for the classification of forest types in Thailand. A historical approach is made to trace the development of forest classification schemes as well as to provide insight on why such a bewildering assemblage of terminology has developed. A new, botanically and ecologically credible, system is also presented. Much emphasis is given to northern Thailand since this region includes the largest, most complex, and most diversified forests in the country.

Background

The forests of Thailand can be broadly divided into two categories, *viz.* deciduous and evergreen. The salient determining factor of these two forest types is soil moisture. Evergreen forests are found where soil moisture is plentiful, while deciduous forests occur where it is depleted during the dry season. The main reason why plants lose their leaves during the dry season is a response to water loss by transpiration when soil moisture is low.

Altitude is also important because of its effects on soil moisture. At higher elevations, soil moisture is rarely depleted because rainfall is greater due to orographic precipitation and temperatures are lower, leading to lower rates of evapotranspiration. Forests, therefore, tend to be evergreen at higher elevations.

Disturbance by man also has a marked effect on the vegetation, but mostly through its effects on soil moisture. Tree felling, fire, agricultural activities, and grazing open up the forest canopy, causing the soil to dry out, and lead to soil erosion, depletion of soil nutrients, and reduced plant growth. Lower primary production leads to less organic matter entering the soil and consequently reduced soil moisture-holding capacity. Only plants that are able to survive in more exposed, drier, and less fertile conditions can persist. Evergreen plants gradually die off and are replaced by deciduous plants and weeds. On degraded sites, deciduous plants and weeds often grow at higher elevations than they can in undisturbed places.

Fire has the most destructive impact on biodiversity, soil and watershed qualities, and stability of vegetational systems. Fire destroys seeds and seedlings, damages mature plants, eradicates soil organisms, many of which are vital for nutrient recycling; vaporizes biomass, and effectively degrades entire ecosystems (Maxwell, 1993).

Deciduous vegetation is more tolerant of fire, while evergreen systems are totally succeptible to its ravages. Fire combined with primitive agricultural systems, especially slash and burn, is a major reason why so much vegetation has become degraded. These factors cause soil erosion and diminished soil quality, and reduce water availability by damaging or destroying watersheds.

Other factors such as geology, especially bedrock, aspect, and slope can also affect the distribution, extent, or quality of forest types, but are less important than soil moisture.

Pioneer Work

Hosseus (1908), the first botanist to visit and collect Thailand's northern flora, recognized that much of this flora, especially in lowland regions and on Doi Sutep, strongly resembled that found in similar areas in Burma. Kurz (1877) describes these lowland forests as being quite seasonal, where the flora is leafless during the hot-dry months of November–May. Two kinds of deciduous forest are noted by Kurz, *viz.* "eng* or laterite forest" on the plains and "hill eng forest" on exposed ridges. *Dipterocarpus tuberculatus* Roxb. var. *tuberculatus* ("eng," Dipterocarpaceae) is noted to be the characteristic tree species in "eng the Burmese name for some lowland dipterocarps or laterite forest." "Hill eng forest" includes *Dipterocarpus tuberculatus* var. *tuberculatus* with *D. obtusifolius* Teijsm. *ex* Miq. var. *obtusifolius* and *D. costatus* Gaertn. f. These two kinds of forest have similar floras which often intermix. Kurz also mentions "low forests," a third deciduous category, which has fewer Dipterocarpaceae and more *Tectona grandis* L.f. (teak, Verbenaceae) components. Hosseus (1908) indicates that "eng or laterite forest" should be called Dipterocarpaceae forest and "hill eng" as Dipterocarpaceae hill forest.

Kerr (1911) also recognized this "eng jungle" on Doi Sutep where it is known locally as "pah paa." This forest extends from *c.* 350 to *c.* 700 m. Similar vegetation was encountered by Garrett & Kerr (1925) on their ascents of what was then Doi Angka and is now known as Doi Intanon. They referred to this lowland, fire-damaged, deciduous dipterocarp-dominated forest as "pa pe".

Kurz (1877) distinguished other kinds of deciduous forests, *viz.* "dry forests" and "mixed forests", both of which in pure form are floristically different from "eng" forests. He provides detailed lists of the most common trees in both "upper" and "lower" mixed forest. Upper mixed facies occur on rocky hills, while lower mixed vegetation is found in lowland and alluvial areas. The trees found in these two catagories are basically similar, but of lower stature and with different undergrowth in lower mixed areas. Some predominent trees are: *Xylia xylocarpa* (Roxb.) Taub. (Leguminosae, Mimosoideae), *Tectona grandis* L. f. (Verbenaceae, teak), *Bombax insigne* Wall. (Bombacaceae), *Eugenia cumini* (L.) Druce (Myrtaceae), *Garuga pinnata* Roxb. (Burseraceae), *Lagerstroemia tomentosa* Presl (Lythraceae), *Vitex glabrata* R. Br. (Verbenaceae), *Kydia calycina* Roxb. (Malvaceae), *Anogeissus acuminata* (Roxb. *ex* DC.) Guill. & Perr., and *Terminalia bellirica* (Gaertn.) Roxb. (both Combretaceae).

Dry forests include many deciduous trees that are mixed with "eng" elements. Some of these include: *Flacourtia indica* (Burm. f.) Merr. (Flacourtiaceae), *Cratoxylum neriifolium* Kurz (Guttiferae), *Melia azedarach* L. and *Chukrasia tabularis* A. Juss. (both Meliaceae), *Ziziphus nummularia* (Burm. f.) Wight & Arn. (Rhamnaceae), *Holarrhena pubescens* (Buch.–Ham.) Wall. *ex* G. Don (Apocynaceae), *Strychnos nux-vomica* L. (Loganiaceae), *Vitex limoniifolia* Wall. *ex* Kurz (Verbenaceae), and *Hymenodictyon orixense* (Roxb.) Mabb. (Rubiaceae). Kurz's "dry" forests, because they include "eng" species and lack teak, conform to degraded, fire-prone, "mixed" forests in Thailand. These "mixed" forest are best interpreted as teak-dominated vegetation (Mahidol University, 1992 and 1995). Because of extensive and excessive exploitation, both "dry" and "mixed" forests were destroyed or very degraded on Doi Sutep during the time of Hosseus and Kerr. It should be noted here that *Pinus merkusii* Jungh. & De Vriese (Pinaceae) is often found in lowland deciduous dipterocarp-dominated, *i.e.* "eng", forests from *c.* 650 to *c.* 950

*the Burmese name for some lowland dipterocarps m in some places in northern Thailand (Maxwell *et al.*, 1995). Santisuk (1977) indicates that it can be found at *c.* 70 m in central and eastern Thailand. This species has apparently been extirpated from many areas, including Doi Sutep, since both Hosseus and Kerr do not mention anything about it.

Kerr indicated that above "eng" forest, from *c.* 675 to 1000 m, there is a mixture of deciduous and evergreen tree species which he referred to as an "oak jungle." Hosseus calls it a "mixed oak-wood forest." This kind of forest is fire-damaged, but not as much as in "eng" areas. The valleys are more evergreen and include some of the tallest trees, 40–50 m, in the region.

Above *c.* 1000 m undisturbed forests in the region are primary and evergreen and extend to the summit of Doi Intanon (2565 m)—the highest peak in Thailand. *Pinus kesiya* Roy. *ex* Gord. (Pinaceae) is also found at *c.* 1000–1800 m, especially on exposed, well-drained, fire-prone areas. Kurz refers to evergreen forests above 1000 m as "hill forests" which are subdivided into "damp" and "drier" categories. The "drier" areas include "stunted hill forests" on exposed ridges at elevations above *c.* 2300 m. Pine forests are included under hill forests.

Development of Regional Forest Classifications

Craib (1931) presents a brief and very basic account of the vegetation of Thailand. By inference from the style and content of this article, plus the fact that Craib never visited Thailand (Kerr, 1933), this rarely cited paper must have been written by Kerr. In any case, it is noted that about 70% of the country was forested at that time. The basic forest types are: "pa deng" (deciduous dipterocarp–oak), which is noted to include over 50% of the forested area of the Kingdom; mixed deciduous, dry evergreen, and tropical rain forest—which is found in the SE and the lower part of the peninsula. This is the first time that tropical rain forest has been noted in Thailand. Savanna, mangrove, salt marsh, "open hill," pine, and secondary growth facies are also mentioned. The author also indicates that logging and agriculture have destroyed much of the original vegetation in the country.

Wilhelm Credner, a German geographer, who was apparently unaware of Craib's paper, provided more details on a basic system of vegetation classification for Thailand (Credner, 1935). Eight vegetational types are discussed, *viz.* mangrove, alluvial plains and rice fields, tropical rain forest, evergreen monsoon forest, deciduous monsoon (teak) forest, dry forest, thorn–bamboo scrub, and pine–oak forest. Credner's divisions and especially his vegetation map of Thailand (opposite p. 113) are basically correct, except for his use of "rain forest." "Dry forest" corresponds to what is often called "savanna" occupying most of the NE part of Thailand, while "deciduous monsoon," mostly in northern Thailand, includes all "eng" and teak associations.

H. G. Champion devised a classification system for forests in India and Burma in 1936 (Edwards, 1950). This system is divided into two basic divisions, *viz.* deciduous and evergreen, each with many subdivisions. This system, by necessity, is quite detailed and complex since it is based not only on ecological and floristic characteristics, but also on rainfall and elevation. Edwards's revised classification, which was intended for Burma, renamed some of Champion's categories and reassociated others. Most of these changes involved lowland deciduous forests. The transitional forest between lowland deciduous and evergreen forest was referred to as "semi-evergreen forest" by both authors.

Credner's system, because of its simplicity, is far more applicable to Thailand than Champion's system, which is too detailed and in most instances inflexible. In the case of deciduous forests, Credner has "deciduous monsoon" and "dry forest" corresponding to basically teak and "eng" forests, respectively. Champion and Edwards subdivide both of these forest types into numerous categories with regional (edaphic) examples based on the presence or absence of bamboo and varying abundances of teak and other commercially valuable deciduous hardwood trees, *e.g. Xylia xylocarpa* (Roxb.) Taub. (Leguminosae, Mimosoideae), *Homalium tomentosum* (Vent.) Bth. (Flacourtiaceae), *Anogeissus acuminata* (Roxb. *ex* DC.) Guill. & Perr. (Combretaceae), *Lagerstroemia tomentosa* Presl (Lythraceae), and *Mitragyna rotundifolia* (Roxb.) O. K. (Rubiaceae). The numerous subdivisions of deciduous forest are based on various floristic and ecological factors, which often mix and are otherwise variable, especially due to disturbance.

Two Royal Forest Department publications (1950, 1962) on forest types in Thailand, distinguish four basic kinds of evergreen forest, *viz.* tropical evergreen, hill evergreen, coniferous, and mangrove. Tropical evergreen forests extend from sea level to *c.* 1000 m, while hill evergreen forested areas are above 1000 m. Two kinds of deciduous forest are noted: mixed (teak) and deciduous dipterocarp. The term "mixed" originated with Kurz (1877) who provided a detailed explanation of exactly what this kind of forest consisted of. Champion (1936) and Edwards (1950) referred to this forest type as "mixed deciduous," a term which has been adopted by almost all other authors writing about the vegetation of Thailand. Credner (1935), more realistically, called this "mixed" forest "deciduous monsoon" forest. Mixed deciduous forests are further divided into three categories, *viz.* moist upper, dry upper, and lower. Moist upper mixed deciduous forest is said to include evergreen trees and merge into evergreen forest, *i.e.* the upper limits of teak. Dry upper areas are dominated by teak and include bamboo. Lower mixed deciduous areas lack teak, but have bamboo. The map (1963) accompanying the 1962 publication combines all mixed deciduous forests. No distinction has been made in either the 1950 or 1962 publications for a transitional forest existing between deciduous and evergreen forests. Moist upper mixed deciduous forest is, perhaps, an approximation of this transitional zone. The tree species, excluding teak, noted for these mixed deciduous forests are similar. These cumbersome and impractical categories have been uncritically lifted from the works of Champion and Edwards.

Samapuddi (1957) divides deciduous forests into mixed and deciduous dipterocarp—both of which are noted to be monsoonal (*i.e.* seasonal). His work otherwise follows the "official" (*i.e.* standard) version of the Royal Forest Department (RFD) from 1950. Loetsch (1957, 1957/58) distinguishes deciduous forests with dry dipterocarp and mixed deciduous monsoon forest with or without teak. Dry dipterocarp forest is also often associated with coniferous forest. Evergreen forests include tropical semi-evergreen, hill evergreen, and coniferous. Ogawa *et al.* (1961) include five major types of forest vegetation in northern Thailand, *viz.* savanna, with dipterocarp-savanna and mixed savanna formations; tall deciduous or monsoon (*i.e.* teak) forest, evergreen gallery forest, an ecotone of subtropical semi-evergreen forest, and temperate (above 1000 m) evergreen forest. All of these areas are quite seasonal with a distinct and prolonged dry season. The transitional zone between deciduous and evergreen forests from *c.* 800 to 1000 m is considered as an ecotone of sub-tropical semi-evergreen forest. Their impression of this zone is that of a mixture of lowland deciduous and upland evergreen species which vary in the amount and length of deciduousness of the lowland species (*i.e.* tropophylly). They do not consider this a distinct floristic region. In their opinion the upper limit of tropical components is between 1100 and 1300 m. Evergreen gallery forests are portrayed as an edaphic climax of tall evergreen trees along streams and in shaded ravines below 1000 m elevation. More arid locations are said to become more semi-deciduous.

The basic RFD system is presented again in a review of forest types in Thailand in a paper about the vegetation of Doi Intanon (Robbins & Smitinand, 1966.). Lowland forests include: deciduous dipterocarp, mixed deciduous (teak), mangrove, and tropical evergreen forests. Upland forests (*c.* 1000–2576 m) are noted to be lower montane and include hill evergreen and coniferous forests.

Neal (1967), obviously relying heavily on previous literature on the vegetation of Thailand, reintroduced Craib's and Credner's term tropical rain forest for lowland evergreen forest. Tropical rain forests were said to exist in Chantaburi and Trat Provinces as well as peninsular Thailand where the rainfall is above 2500 mm/year. He also specifically stated that these regions are monsoonal—a direct contradiction of the original definition of rain forests (see below). Neal's statistical data are more original and provide some interesting perspectives on the status of Thailand's vegetation at that time (Table 1). He estimated that approximately 60% of Thailand (321,289 km^2) was forested then. This estimate also included degraded primary and secondary growth, which were not specifically mentioned. Credner's (1935) vegetation map of Thailand, which specifically includes deciduous dipterocarp ("dry forest") and thorn–bamboo scrub formations, indicates that much more than 60% of the country was forested then. Our estimation of the present amount of primary forest cover in Thailand is about 15% and declining rapidly. This figure is based on a US NOAA ll satellite AVHRR (advanced, very high resolution radiometer) mosaic of images taken during the dry seasons of 1992 & 1993 plus our own observations, especially in northern Thailand.

Table 1. Kinds and amounts of different forest types in Thailand according to Neal (1967).

Forest type	km^2	% of total vegetation
beach, freshwater swamp, savanna	12,524	4.6
mangrove	1,620	0.5
deciduous forest	224,902	70
1. deciduous dipterocarp	147,000	46
2. mixed deciduous with teak	65,000	20.2
evergreen forest	96,387	30
1. tropical rain	3,620	2
2. hill evergreen and dry evergreen forests	92,767	28
coniferous forest	2,378	0.7

Williams (1967) provides a concise discussion on the four basic criteria for vegetational classification, *viz*. floristic, physiognomic, bioclimatic, and holistic. Floristic information requires the most botanical effort to categorize the species of plants found in an area, their abundances and distributions, and kind (*i.e.* stage) of growth, *i.e.* climax. primary, secondary, *etc*. Physiognomy, a common method utilized by ecologists with limited floristic skills, involves the structure or appearance of the vegetation. It typically involves determining tree heights, spacing, stratification, and canopy size. Very often other parameters are also included, *e.g.* leaf size, abundance of lianas, epiphytes, *etc*.; and soil quality. Bioclimatic parameters involve climatic variables, *viz*. the presence or absence of seasonality, deciduousness, temperature ranges, and amount of rainfall. Although not noted in this part, I would also include elevation here. The holistic approach takes into consideration all factors which have an influence on the vegetation. It is the most conclusive method since it involves all the other three criteria.

Williams includes a very comprehensive and creditable report on Thai vegetation. His approach is basically holistic with extensive information concerning floristics, structural, and climatic data for several areas in Thailand. Deciduous and evergreen forests are separated. Deciduous forests included deciduous dipterocarp and mixed deciduous forests—the latter being divided into moist mixed, which has much teak, and dry mixed, which has much bamboo without teak. In addition to savanna, Williams also includes thorn woodland which is described as being an open, scrub, mostly evergreen, spiny, microphyllous vegetation which often has bamboo. From his list of species for this kind of vegetation, it is obvious that this is a kind of degraded, fire-maintained, secondary growth which, in fact, is mostly deciduous. Bamboos, palms, and successional growth, specifically primary succession, are also discussed.

Williams divides evergreen forests into rain and seasonal categories, although his criteria for the former are weak. His example for rain forest is at Ranong, at *c*. 8° north latitude, which has notable dryness in February–March. Moist forest is considered by him to be synonymous with rain forest. He does note that some ecologists consider moist forest as having lower rainfall than rain forest and also having dry and rainy seasons of approximately equal length (*e.g.* Kao (Khao) Yai National Park in the central part of the country). Unfortunately a satisfactory definition of lower and upper hill evergreen forests in lacking. Dry evergreen and semi-evergreen forests, at least according to Williams' lists, include many deciduous species, often with bamboo. It is quite apparent that these are disturbed, non-climax, forested areas. His map (# 4, p. 248) includes all evergreen forests as "evergreen (rain) forest," which is scattered and patchy throughout most of the country.

Whitmore (1975) discusses in detail the kinds of forest vegetation in the tropical Far East. Monsoon forests are those that are seasonally dry, while tropical rain forests are ever-wet. Deciduous forests include dry deciduous dipterocarp and tropical moist deciduous (teak). Evergreen forests are all considered rain forests. This includes beach, mangrove, and swamp vegetation—obviously inappropriate for Thailand became of seasonality. Pine is understood to be mixed with dry deciduous dipterocarp forest at 1000 m.

Smitinand (1977) divided mixed deciduous forests into the three categories noted above in the RFD publication of 1950. He also lists "dry deciduous dipterocarp" and savanna forests. His evergreen forests include: tropical evergreen, coniferous, swamp, and beach forests—all of which are noted to be monsoonal. Tropical evergreen forests include: tropical rain forests, dry or semi–evergreen forests, and hill or lower montane forests. This system was initially presented in 1962, but remained unpublished until 1977. His concept of tropical rain forests, which are found in SE and peninsular Thailand from sea level to *c.* 600 m elevation, are areas where the annual precipitation is up to 2500 mm. Dry or semi-evergreen forest is found from sea level up to *c.* 500 m with an average rainfall of 1000–2000 m. Hill evergreen forest is found above 1000 m with an average rainfall of 1500–2000 m.

Smitinand *et al.* (1978) discuss the forest types of northern Thailand where evergreen and deciduous facies are distinguished. The vegetation is noted to vary because of elevation, soil, rainfall, and land use. A sensible and basically accurate discussion of the effects of fire, shifting cultivation, watershed quality, and soil conservation is also presented for upland areas. Deciduous forests include: dry deciduous dipterocarp, dry mixed deciduous, and moist mixed deciduous. Dry deciduous dipterocarp forest is found from 300 to 1000 m elevation in areas with less than 1000 mm of rain each year. Dry mixed deciduous forested areas are noted to be found scattered in both lowland and upland areas where rainfall is 600–1000 mm per year and include teak. Moist mixed deciduous forest occurs in places up to 600 m with rainfall of 1000–1500 mm annually and also has teak.

Evergreen forests include: lower montane, dry evergreen, and coniferous. Lower montane areas are found above 1000 m and have 1500–2000 mm of rainfall each year and are said to be places with "constant high humidity." Dry evergreen forested areas are found scattered in areas below 1000 m, which have 1000–2000 mm of rain annually. Coniferous forest is said to be edaphic, found on exposed ridges with extensive erosion, with 1000–1500 mm of rain each year. No elevation range is given for this open, presumed 3-storied habitat.

This series of botanically imprecise, confusing, and often contradictory systems is further complicated by vegetation reports of Doi Chiang Dao, Chiang Mai Province which, at 2175 m, is the highest limestone mountain in Thailand (Smitinand, 1966; Santisuk, 1985 and 1998). Smitinand (1966) based his ideas on floristics, elevation, and slope aspect. The lowlands ("350" –600 m) have dry evergreen forests, while moist upper mixed deciduous forest exists from 600 to 900 m, with *Tectona grandis* L. f. (Verbenaceae, teak) and several other deciduous tree species and bamboo at 700–850 m. A transitional zone between moist upper mixed deciduous forest and open hill evergreen (moist lower montane (rain) forest) is present at 900–1100 m. Lower hill evergreen forest is found from 1100 to 1300 m and upper hill evergreen forest at 1500–2200 m. The exposed limestone slopes and outcrops have numerous "temperate" species—many of which were described by Hosseus and Craib from collections by Hosseus and Kerr—and are known only from there (*i.e.* endemic). No mention is made about deciduous dipterocarp–oak and degraded primary forests, or secondary growth.

Santisuk (1985) follows Smitinand's (1966) concept of lowland vegetation with mixed deciduous and semi-evergreen forests. Upland forests are divided into lower montane (hill evergreen), oak-pine, and subalpine vegetation—the latter having many presumed temperate species.

Santisuk (1998) considers moisture and elevation to be of paramount importance in his second analysis of the vegetation of Doi Chiang Dao. Lowland vegetation, *i.e.* below 1000 m, includes seasonal rain (dry evergreen) and tropical mixed deciduous forests. Montane vegetation is present above 1000 m with lower montane rain forest (1000–1900 m), lower montane oak forest (at the same elevations), and upper montane scrub (1900–2190 m). Lower montane rain forest and lower montane oak forest are found in the same elevation range with the former in more moist and shaded places, while the latter is found in more exposed places.

From my own work on Doi Chiang Dao (Maxwell, 1992 and 1998) the lowland vegetation has extensive deciduous dipterocarp–oak (**dof**) and degraded deciduous hardwood + bamboo (*i.e.* former teak, **bb/df**) forests. A mixed evergreen + deciduous seasonal forest is present from as low as 450 m, but due to extensive forest destruction it is often only found from 850 to 1000 m, if at all. Evergreen forest is present above 1000 m with pine being common up to *c.* 1550 m and rare up to *c.* 1850 m. I do not recognize any basic difference in the structure and composition of evergreen forests there. The summit flora, *i.e.* above 1800 m, is basically evergreen hardwood with many deciduous and annual herbaceous species on the exposed ridges and outcrops.

Due to discrepancies in existing forest classifications, Küchler & Sawyer (1967) did not refer to any particular system for Doi Sutep. They divided the forest types into plant communities (phytocenoses), with descriptions of the various groups which included four types in lowland deciduous forest and five in upland areas. The term tropophyllous was discussed in detail. This is the phenomenon in which some tree species (*e.g. Dipterocarpus obtusifolius* var. *obtusifolius* and *D. tuberculatus* var. *tuberculatus* (Dipterocarpaceae) and *Anneslea fragrans* Wall. (Theaceae), normally deciduous in lowland areas, may be evergreen at higher elevations, or when all individuals drop their leaves in one year, but some individuals remain evergreen in other years. This term is not to be confused with the situation in semi-evergreen forests, which is how Ogawa *et al.* misinterpreted the situation. Küchler & Sawyer mention semi-deciduous forest, which is a mixture of deciduous and evergreen species, as found in the transitional zone by Hosseus and Kerr, but do not include this kind of forest in their survey.

Authors of various families in the Studies in the Flora of Thailand series (1961–1969) basically follow the RFD classification for forest types. Hjelmqvist (1968) includes some refinements for upland, seasonal, evergreen forests of northern Thailand. These areas with various Fagaceae are often referred to as "*Quercus* forest," "oak forest," "*Quercus*–dipterocarp forest," and "*Quercus–Vaccinium* forest" according to the collector's notes on the specimens he examined.

Santisuk (1988) divides deciduous forests into two categories, *viz.* tropical mixed deciduous, mostly below 800 m; and deciduous dipterocarp. He does not recognize any subcategories of tropical mixed deciduous forests, *i.e.* with or without teak and/or bamboo. His concept and terminology of evergreen forests, while imaginative, adds more confusion to several previously existing and inadequate systems of classification (Table 3). Craib (1931), Credner (1935), and Neal (1967) use the term "rain forest" for monsoonal (*i.e.* seasonal) lowland evergreen forests, which Santisuk refers to ironically as "seasonal rain forest"—a contradictory term as rain forest, in its original meaning, is the antithesis of seasonal forest. He distinguishes this kind of vegetation from tropical evergreen rain forest, which is said to exist in peninsular Thailand. "Monsoonal evergreen," formerly referred to as semi-evergreen or dry evergreen forest by others, extends up to *c.* 900 m. This forest type includes a few deciduous, often canopy or emergent, tree species.

Montane forests replace deciduous forests at *c.* 700 m and extend to *c.* 1800 m, and are subdivided into lower montane rain forest, lower montane oak forest, lower montane pine–oak forest, and upper montane vegetation above *c.*1800 m. The two species of pine found in northern Thailand, *viz. Pinus merkusii* and *P. kesiya*, are incorporated into Santisuk's system with pine-deciduous dipterocarp, pine–oak savanna, and lower montane pine forests (Santisuk, 1997).

Smitinand's (1989) final attempt at vegetation classification basically follows his previous ideas, but divides mixed deciduous forests into three groups. Moist upper mixed deciduous forest is said to occur from 300 to 600 m and dry upper mixed deciduous forest on ridges at 300 to 500 m. These two kinds of forests, which are of great commercial value, include teak. Lower mixed deciduous forest, which lacks teak, is found at 50–300 m and has been extensively destroyed.

Ashton (1990) recognizes three basic forest types for Thailand, *viz.* seasonal evergreen–dipterocarp (dry evergreen), dry deciduous (dipterocarp), and moist deciduous forest. This classification system is too simplified and inadequate for use in Thailand. He sensibly omits the term rain forest as well as deciduous monsoon and pine forests.

Werner (1993) discusses pine forests in Thailand. Pine–deciduous dipterocarp forest is found between 440 and 1100 m, while pine savanna is present on sandstone in NE Thailand. Lower montane pine–oak forest is present at 900–1100 m and often overlaps with pine–deciduous dipterocarp facies. Pine–seasonal rain forest is said to be found in NE Thailand.

Werner & Santisuk (1993) also distinguish between deciduous and evergreen forests. Deciduous forests (up to *c.* 900 m) include dry deciduous dipterocarp, mixed deciduous, and pine–deciduous dipterocarp forests. Montane rain forests are found from 900–1000 to 2565 m, the summit of Doi Intanon—the highest point in Thailand. Lower montane rain forest includes almost all upland areas, while upper montane rain forest is found only on the summit area of Doi Intanon. Lower montane oak forest and lower montane pine–oak forest are said to be degraded areas with an "impoverished" flora. These authors have come to the conclusion that lower montane pine–oak forest, due to fire and poor soils, has developed mainly because of the invasion of *Pinus kesiya* Roy. *ex* Gord. (Pinaceae) and is, therefore, not an original, *i.e.* primary, forest type.

I disagree with this view, since both species of pine found in Thailand are a natural, although extensively exploited, component of some forested areas in Thailand. The reason that pines seem to invade an area is because most of the oak and related components do not reappear as readily as pines when cut or severely damaged. Pine seeds are wind dispersed and germinate readily in disturbed areas. This contrasts greatly with oaks and other components which generally have large fruits/seeds which are animal dispersed. The ruthless extermination of most seed–dispersing animals has resulted in a decrease in reestablishment of oaks and other species and an apparent increase in pines. Centuries of abuse, including fire, erosion, cutting, and grazing have severely degraded these seasonal evergreen + pines areas. Although I have no precise evidence to support this claim, it is certain that the extent and abundance of both species of *Pinus* have been drastically reduced, especially in the past century, mainly by uncontrolled forest destruction by hill tribe folk. Pines are selectively logged by hill tribe people to build their houses, since these trees are abundant and the wood easier to cut than other trees. Pines are also severely damaged and eventually killed by villagers hacking living trees for kindling wood. In Doi Sutep–Pui National Park, *Pinus merkusii* has been reduced to a single isolated population, while *Pinus kesiya,* although extensively planted, is rare in natural conditions.

Rain Forests

The term "tropical rain forest" was established by the German plant geographer A. F. W. Schimper in 1898 (Richards, 1952 and 1996). This kind of vegetation is basically evergreen, dense, tall, and ever-wet, *i.e.* not monsoonal/seasonal. IUCN (1973) clearly distinguishes between tropical rain forests and tropical/subtropical seasonal forests. Richards (1952) provides information on various forest types in several countries. In Trinidad a rain forest is considered to have over 1800 mm of rainfall each year with no dry season. Areas with similar rainfall, but with a dry season, are called evergreen seasonal forest

L. R. Holdridge devised a life zone system in 1947 which was intended to be a refinement of world vegetation classification (Tosi, 1964; Holdridge *et al.*, 1971). The basic premise is that climate is the most important factor in the formation and development of terrestrial ecosystems. The macroclimate is considered to be the regulating factor in all terrestrial systems. The climate in any area can be used to determine the vegetation there, that is assuming that these plant formations or natural life zones are primary and undisturbed. Each of the 120 life zones envisioned to exist on the earth by Holdridge includes particular plant associations which are unique, *i.e.* restricted, to each life zone. The most important climatic factor is air temperature–specifically designated as mean annual biotemperature. On this basis, the earth is divided into seven latitudinal regions, *e.g.* tropical, temperate, and subpolar. The amount of rainfall, potential amount of evapotranspiration, and elevation are also needed to complete the model. Evapotranspiration includes water evaporation from the soil and other surfaces, and transpiration, *i.e.* the release of water from plant tissues to the atmosphere.

The specific life zones distinguished by these variables are recognizable locally from floristics, but plant species are not the primary determinants in this system. Seasonality is treated by Holdridge as a complicating or modifying factor in the classification of world plant formations. Tropical rain forests are noted to have an annual rainfall of over 8000 mm in the tropics and over 4000 mm in the subtropics. Dry forests have an annual rainfall of 1000–2000 mm, moist forests 2000–4000 mm, and wet forests are noted as having 4000–8000 mm. From this interpretation, there is no rain forest in Thailand, since areas with the highest precipitation are considered to be wet forests.

Puping Village at *c.* 1375 m in Doi Sutep–Pui National Park has an annual biotemperature of 19.9 °C and an average annual rainfall of 1855 mm (Figure 3). This corresponds to moist forest in the lower montane (subtropical) "altitudinal belt" according to Holdridge's natural life zone diagram presented by Tosi (1964).

Fosberg (1958) indicated that rain forests are evergreen and with no significant leafless period with canopy components. This is contrasted with deciduous forests, which are monsoonal. No temperature parameters are included. Van Steenis (1965) distinguishes two forms of rain forest, *viz.* areas below 1500 m elevation, which are ever-wet or have a "feeble" dry season, *i.e.* mixed lowland and hill rain forest; and montane ever-wet rain forest. Medway (1972) undertook vegetational work in an area near Kuala Lumpur, Malaysia (*c.* 3°N), which has an average lowland rainfall of 2000–3300 mm, with seasonal distribution, and a short dry period. He considered this to be a tropical rain forest.

The transition from tropical rain forest to deciduous monsoon forest in the Malay Peninsula occurs at about 5°N (Medway, 1972) and between 6° and 7°N (Whitmore, 1975). Monsoon areas above this latitude with over 2000 mm of rain per year are variously called tropical wet evergreen or tropical rain forest. There is, therefore, no definite agreement on a definition of rain forest. The basic concept of a rain forest includes a tall, evergreen forest with over 1800 mm of rainfall each year and no or only a very short (up to 4 weeks) dry period. With this concept in mind, the climatic and vegetational conditions throughout most of

Thailand and all of that above *c.* 8°N cannot realistically be considered rain forest. The southernmost provinces would, at best, be marginally included as rain forests. Seasonal (moist/wet) evergreen forest would be the most appropriate terminology for the forest there. Ashton (1990) refers to this kind of forest as seasonal wet evergreen and that below 5°N in the Malay Peninsula, Sumatra, Borneo, and Palawan as seasonal, mixed dipterocarp forest with edaphic and montane associates.

Whitmore (1975) gives Schimper's original definitions of rain forest and monsoon forest, and includes detailed discussions on temperature, rainfall, evapotranspiration, and the effects of seasonality in the tropics. Much of his system is inappropriate for Thailand. His concept of tropical rain forests is more suitable to more equatorial latitudes (*i.e.* below 6°) where rainfall is greater and seasonality none. His concept of tropical rain forests has 13 categories, including beach, mangrove, and swamp forest. A line from *c.* 6°N on the west coast of West Malaysia to *c.* 7°N on the east coast of Thailand is said to be a transition zone between tropical semi-evergreen rain forest to the north and tropical lowland evergreen rain forest to the south. This is an area which has a distinct dry season of at least 1 month, but does include both structural and floristic differences in the trees of the two forest types.

Whitmore (1991) defines a rain forest as an evergreen forest in which every month has at least 100 mm of rain or with a brief and irregular dry period ranging from a few days to several weeks. Monsoon forests exist where there is a regular dry period of several months with up to 60 mm of rain per month, *i.e.* tropical seasonal forest. The term tropical moist forests was established in 1976 by A. Sommer.

Walter (1985) presents a very realistic and workable classification for tropical forests based on rainfall and mean annual temperature (Table 2). This system implies that there is no rain forest in Thailand, since there is a dry season throughout the country. Evergreen seasonal forests, semi-evergreen seasonal forests, and deciduous seasonal forests are, however, present (Table 2).

Table 2. Classification of tropical forests according to Walter (1985) and Richards (1996).

Forest type	Rain forest	Evergreen seasonal forest	Semi-evergreen seasonal forest	Deciduous seasonal forest & savannas
total annual rainfall mm	more than 1800	more than 1800	1300–1800	800–1300
duration of the dry season	none	3 months, each month with 50–100 mm of rain	5 months, each month with 25–100 mm of rain	5 months, each month with under 100 mm of rain
mean annual temperature °C	23–27	24–28	24–28	24–28

Smitinand (1989) considers parts of SE and peninsular Thailand to have tropical rain forest vegetation. Although he notes that these places are seasonal, the fact that the rainfall is high, often more than 2500 mm per year, is his sole criterion for distinguishing this kind of forest. He maintains that "careful study" of this vegetation indicates that two categories are present, *viz.* lower, up to 600 m, and upper tropical rain forest, 600–900 m.

Zhu (1997) interprets Chinese rain forests on various floristic and ecological similiarities to those found in Guiana, Brazil, Nigeria, Borneo, Singapore, *etc.* He does not consider rainfall and seasonality in his classification scheme. Southern Yunnan, his study area, at 21°N lies at the northern extreme of the tropics. His use of seasonal rain forest and wet seasonal rain forest, with mixed rain forest and dipterocarp rain forest subtypes, for forest types similar to those found in northern Thailand are definitely not accepted here.

Kinta *et al.* (1999) provide a brief description of the vegetation and flora of Doi Intanon. The mountain lies in a tropical monsoon area and includes three basic kinds of forests. Dry *Dipterocarpus* forest is deciduous and ranges in elevation from 300 to 1000 m. *Pinus kesiya* forest is present from 1000 to 1600 m and above this to the summit (2590 m) is mountain evergreen broad–leaved forest, which is also noted to be the same as hill evergreen forest. Evergreen trees growing in valleys between the middle elevations of dry *Dipterocarpus* and mountain evergreen broad–leaved forests is referred to as mixed evergreen forest. Due to forest destruction, the elevation ranges of these forest types often varies. This paper, based on field work in February 1998, is far too brief and general to be of any ecological value. The use of the term mountain evergreen broad–leaved forest instead of hill evergreen, montane, or seasonal evergreen forests is a modest improvement in terminology.

A summary of various forest classification schemes in Thailand is presented in Table 3.

Advantages of the New Forest Classification Scheme

Although most authors have recognized seasonality as an important factor in forest classification for Thailand, none have linked this with both elevation and the developmental state, (*i.e.* primary, secondary, tertiary) of the vegetation. There is really nothing particularly innovative in my system, since all of the forest types I present have been noted previously, but not in the same combination as I recognize (Tables 3 & 4). My simplified version clarifies what forest types are found in Thailand, especially the northern part.

Deciduous dipterocarp–oak forest (**dof**) has been distinguished by all authors, mostly as dry dipterocarp forest. More open, seasonally burned and flooded, grassy areas are often called savannas. The fact that these **dof** areas are a secondary, fire-dependent climax vegetation which does not develop into a primary facies (*i.e.* original vegetation) has not been noted previously.

Mixed deciduous forest, with or without teak, has caused much confusion mainly because of the fact that disturbance plus the presence of bamboo have not been adequately considered. The influence of logging as having a degrading effect on primary forest and the development of secondary growth have generally not been realized or adequately discussed. Since there is only one remaining deciduous forest with natural teak present in Thailand (Mae Yom National Park, Phrae Province); all other "mixed" forests are either severely degraded, include much deciduous secondary growth, or are being transformed into **dof** (Maxwell, 1999). Deciduous primary forest always includes prominent amounts of bamboo plus seasonal fires. It is for this reason that I have called this kind of forest bamboo + deciduous forest (**bb/df**).

Table 3. Summary of Various Forest Classification Schemes in Thailand

Author	Deciduous			Deciduous + evergreen	Evergreen hardwood		Evergreen hardwood+pine
		sea level–c. 850 m		c. 800–1000 m	sea level–c. 1000 m	c. 1000–2565 m	c. 1000–1800 m
Kurz (1877)	eng, hill eng	low forest savanna	mixed forest (lower & upper), dry forest		tropical evergreen	hill evergreen	pine
Hosseus (1908)	dipterocarp forest, Dipterocarpaceae hill forest			mixed oak–wood		evergreen	evergreen
Kerr (1911)	eng, pah paa, pa pe			oak-jungle		evergreen	evergreen
Craib (1931)	pa deng	savanna	mixed deciduous	dry evergreen	tropical rain forest	open hill	pine
Credner (1935)	dry forest	thorn–bamboo	deciduous monsoon		tropical rain forest	hill evergreen	coniferous
Champion & Edwards (1936, 1950)	deciduous dipterocarp		mixed deciduous	semi-evergreen	–	hill evergreen (evergreen-oak)	pine
RFD (1950, 1962) & Samapudi (1957)	deciduous dipterocarp		mixed deciduous		tropical evergreen	hill evergreen	coniferous
Loetsch (1957, 1957/58)	dry dipterocarp		deciduous monsoon with or without teak	tropical semi-evergreen	hill evergreen	hill evergreen	coniferous
Ogawa (1961)	dipterocarp-savanna	mixed savanna	tall deciduous or monsoon	ecotone of subtropical semi-evergreen forest	evergreen gallery	temperate hill evergreen	
Smitinand (1966)			upper moist mixed deciduous	dry evergreen	upper hill evergreen/moist lower montane (rain) forest		pine
Robbins & Smitinand (1966)	deciduous dipterocarp		mixed deciduous		evergreen gallery	hill evergreen	coniferous
Küchler & Sawyer (1967)				semi-deciduous			
Neal (1967)	deciduous dipterocarp		mixed deciduous with teak	dry evergreen	tropical rain forest	hill evergreen	coniferous
Williams (1967)	deciduous (dry) dipterocarp	savanna	mixed deciduous (dry & moist)		rain forest, moist forest	hill evergreen (lower & upper)	coniferous
Whitmore (1975)	dry deciduous dipterocarp	savanna	tropical moist deciduous (teak)	tropical lowland evergreen rain forest	semi-evergreen rain forest		dry deciduous dipterocarp + pine
Smitinand (1977)	dry deciduous dipterocarp, savanna		mixed deciduous		tropical evergreen (rain forest), dry evergreen	hill evergreen	coniferous
Smitinand *et al.* (1978)	dry deciduous dipterocarp,		dry & moist mixed deciduous		dry evergreen	lower montane	coniferous
Santisuk (1988, 1997)	deciduous dipterocarp		tropical mixed deciduous		seasonal rain forest	montane	pine-deciduous dipterocarp, pine-oak-savanna, lower montane pine
Smitinand (1989)	dry deciduous dipterocarp	savanna	mixed deciduous, (moist upper, dry upper, lower)	dry or semi-evergreen	lower & upper tropical rain forest	hill evergreen	coniferous
Ashton (1990)	dry deciduous (dipterocarp)				seasonal wet evergreen	seasonal evergreen dipterocarp (dry evergreen)	
Werner (1993)		pine–deciduous dipterocarp; pine savanna					lower montane pine-oak forest, pine-seasonal rain forest
Werner & Santisuk (1993)	dry deciduous dipterocarp	pine–deciduous dipterocarp	mixed deciduous			lower & upper montane rain forest	lower montane pine-oak forest
Zhu (1997)					seasonal rain forest, wet seasonal rain forest, seasonal evergreen forest	seasonal evergreen forest	
Santisuk (1998)			tropical mixed deciduous	mixed evergreen	seasonal rain/dry evergreen	lower montane rain forest & lower montane oak forest	
Konta *et al.* (1999)	dry *Dipterocarpus*					primary evergreen broad-leaved (above 1600 m)	*Pinus kesiya* forest
Maxwell (1988, 1992, *etc.*)	deciduous dipterocarp-oak	degraded bamboo + deciduous forest	bamboo + deciduous	mixed evergreen + deciduous	primary evergreen without pine forest	primary evergreen without pine forest	primay evergreen+pine forest

Mixed evergreen + deciduous forest (**mxf**), not recognized by most authors and inadequately defined by others, is a distinct kind of vegetation, which is rapidly disappearing. It is commonly found in lowland areas, many of which have previously been considered as having lowland evergreen ("dry evergreen") vegetation (Maxwell, 1995). It is also found in remnant areas in northern Thailand between deciduous lowland forested areas and primary, evergreen, seasonal forest in a general range from *c.* (600) 800–1000 m. Pristine areas include a distinct flora, however disturbances at lower elevations (*c.* 800–900 m) have resulted in degradation with **dof** and **bb/df**. I have also studied this kind of forest in Khong District, Champasak Province, southern Laos where the elevation range is 60 to *c.* 240 m (Maxwell, 2000).

Evergreen forests in Thailand are all seasonal and basically structurally similar. It is difficult, if not impossible, to clearly distinguish lowland evergreen forests from upland ones either in structure or floristics. There is no realistic basis on which to distinguish upland evergreen forests with "lower" and "upper" subdivisions. All authors have complicated the situation by assuming that the different species found in lowland evergreen forests compared with upland forests constitute a different forest type.

The use of the word "montane," first introduced into Thai forest classification systems by Smitinand (1966), has not been interpreted correctly. Edwards (1950) includes montane forests in subtropical and temperate zones. Holdridge (Tosi, 1964) is more precise and indicates that the lower limit of montane forest is 3000 m in the tropics. Lower montane forests range from 2000–3000 m. According to his classification system, mean annual biotemperature must be taken into consideration when classifying a vegetational (life) zone. This was not done by Smitinand (1966) and others (Table 3) who have uncritically adopted this terminology. Until Holdridge's model is properly applied for upland areas in Thailand, I cannot accept lower and certainly not upper montane categories for Thai vegetation.

More detailed and holistic ecological work needs to be done in evergreen forests throughout Thailand. Although it is possible that evergreen forests in, for example, peninsular Thailand from sea level to 1000 m and the summit area of Doi Intanon (2300–2565 m) are different, I cannot make any creditable distinctions here. The vast conceptual differences as well as ecological and botanical credibilities of past research preclude me from doing this. Until convincing evidence is available on evergreen forest ecology, I am calling these evergreen areas primary, evergreen, seasonal forest with or without pine (Table 3). From my own experiences, much of what has been called "dry evergreen" or (seasonal) evergreen forest below 1000 m is actually mixed evergreen + deciduous, seasonal forest (**mxf**). Unfortunately, much of the original evergreen forest cover has been destroyed, therefore it will be difficult to fine suitable places to conduct ecological research to resolve the question about this kind of vegetation.

In my opinion much of the confusion and inaccuracies in the classification of Thai forest could have been avoided if Schimper's definition of rain forest had been followed. Misapplication of rain forest for lowland forests, mostly in peninsular Thailand, precludes me from including this forest type in Thailand.

There is no single standard system for forest/vegetation classification in Thailand—even in the Royal Forest Department. Since no suggested system is totally acceptable or reliable, I have developed a simplified vegetational scheme for the kingdom (Maxwell, 1988–1999; Maxwell *et al.* 1995–1999). This system was originally developed for use in northern Thailand, but was expanded to include all of the country (Table 4).

Table 4. Vegetation/Forest Types in Thailand

Forest Type			Primary Growth	Secondary/Degraded Growth (da/sg)	Tertiary Growth (da/sg)	Elevation (m)
Seasonal (Monsoonal)	Almost ever-wet ("rain forest")		evergreen (egf)	evergreen scrub	bamboo thickets, grassland, cultivated areas, plantations	sea level–*c.* 1800
	Distinctly Seasonal		evergreen (egf)	evergreen+bamboo (eg/bb) deciduous dipterocarp-oak (dof)	bamboo thickets, grassland, cultivated areas	sea level–*c.* 1000–*c.* 2565*
			deciduous with bamboo (bb/df)	bamboo thickets, grassland, deciduous dipterocarp-oak (dof)	cultivated areas	sea level–*c.* 850
			mixed evergreen+deciduous (mxf)	bamboo+mixed evergreen+ deciduous scrub, deciduous dipterocarp-oak (dof)	bamboo thickets, grassland, cultivated areas	sea level–*c.* 1000
			evergreen+pine (eg/pine), deciduous dipterocarp-oak with pine (do/pine)	deciduous dipterocarp-oak (dof)	grassland, cultivated areas	*c.* 60–*c.*1800
Aquatic		Saline	mangrove	no vegetation, mangrove scrub	no vegetation	sea level–25
		Fresh	lakes, ponds, swamps, marshes, rivers, *etc.*	scrub, grassland, cultivated areas	scrub, grassland, cultivated areas	sea level–2550
Beach			beach vegetation	scrub, grassland	grassland, cultivated areas	sea level

*In peninsular and central Thailand egf can be found starting at or near sea level, but in northern Thailand, where the dry season is longer and more severe, it starts at about 1000 m.

Conclusions

Conventional forest classifications used by botanists, foresters, ecologists, and others have basically been unoriginal (*i.e.* adapted), confused, and in many instances inadequately defined. Mixed deciduous forest and upland evergreen hardwood forests have been especially confused by authors who have tried to split forest types on the basis of the presence or absence of various species, *e.g.*. teak and pine, or assumed differences based on elevation. Much of this has been based on inadequate or faulty botanical work. The basic system adapted by foresters for Thailand, based on the work of Champion and Edwards for India–Burma, is inappropriate here because of its complexity and inconsistency. Credner's system, with modifications, should have been used since it is more realistic and less complicated than the India–Burma system.

Deciduous forests can only realistically be divided into deciduous dipterocarp, including savanna, and taller, more diverse deciduous forest, *i.e.* bamboo + deciduous hardwood–regardless of the presence or absence of teak and/or bamboo. The transitional, seasonal forest found between lowland deciduous and evergreen hardwood forest, *c.* 800–1000 m, has been neglected by most authors. Contrary to Ogawa *et al.* (1961), this forest is not characterized by tropophylly. As far as evergreen, seasonal forest is concerned, it is impractical to subdivide this facies, regardless of elevation, latitude, rainfall, or temperature, since as a vegetation type it is quite uniform in basic structure throughout the country. When considering all structural aspects of evergreen forests in Thailand, *i.e.* from ground flora to canopy, there is an overall uniformity. Although species compositions differ, all niches occupied in, for example a peninsular forest, have a corresponding counterpart in northern forests. It is even more difficult to distinguish between "lower" and "upper" zones in upland forests of northern Thailand. I certainly recognize a difference is some of the flora above 1700–1800 m, but this does not constitute a vegetational change.

There has been an unjustifiable use of the term "rain forest" in Thailand. All authors have recognized seasonality here in their papers, but have not recognized the distinction between evergreen seasonality and rain forests, which lack seasonality. Rain forests, defined as ever-wet or briefly dry forests with over 2000 mm of rainfall each year (Schimper, 1898), do not occur in Thailand. Seasonal areas with this amount or more of rainfall should be considered as seasonal, evergreen forested areas. These authors have deviated from Schimper's original concept by neglecting the basic distinction between ever-wet and seasonal (monsoonal) climates. Some authors have erroneously concluded that rain forests exist in Thailand based on a single parameter, *e.g.* the amount of rainfall or presumed structure and composition of the vegetation in an area. The fact that the duration of the dry season is intimately linked with soil moisture and evapotranspiration has not been generally realized; thus more rainfall is required to insure available water in warmer climates or months than in cool areas or months.

Future Research

The basic problem with most of the vegetation classifications for Thailand is that a holostic approach to all ecological parameters has not been adopted. A really accurate and reliable vegetation survey will require a team effort by experienced ecologists and competent plant taxonomists as well as climatologists, soil scientists, and hydrologists. The holistic approach must include climate and physiognomy, *i.e.* the exact amount of rainfall, duration of dry period, temperature; floristics, and forest structure. Transects should be done for all aspects of the flora, *i.e.* trees, ground flora, epiphytes; and include flowering, fruiting, and leafing phenologies. Forest structure includes the canopy height, stratification, the amount of shade, and analyses of habits, *e.g.* herb, tree, treelet, shrub, woody climber, epiphyte, *etc.* Bedrock, slope, soil, and water movement in forests should also be done to determine the amount of influence these factors have on the vegetation.

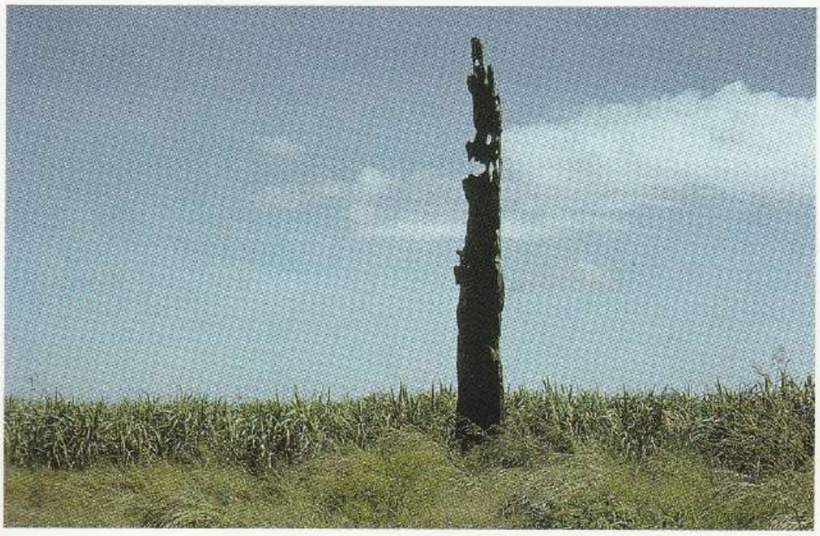
Eco-Pornography

The insidious, uncontrolled, and continuous destruction of Thailand's forest resources has resulted in dramatic ecological disasters which have caused serious reductions/disruptions in biodiversity and vegetational stability, as well as increases in flooding, erosion, and temperature throughout the country. Although sustainable use of Thailand's forests has occurred since people have lived here (*i.e.* thousands of years), the massive environmental disaster that we are confronted with today is due to rapacious commercial exploitation beginning in the 1870's by foreign loggers. The establishment of the Royal Forest Department in 1896, initially and ostensibly to regulate logging, has essentially resulted in the loss of perhaps 60% of Thai forest cover. The *c.* 15% of patchy, endangered remains of primary forested area in Thailand is vivid testimony to their effectiveness in protecting/conserving Thai forests. Population increases, especially from 1970 to 2000 when the number of Thais increased from 37 to 62 million, as well as an insatiable appetite for wealth, power, status, and influence by many Thais are contributing factors to the demise of Thai forests.

The following miscellaney of ecologically repugnant, but sadly common, photos have been selected to illustrate some of the basic reasons why Thai forests have and will continue to disappear. Immediate remedial and effective restorative programmes are required for all of these environmentally devastating scenes. If this task is not done then the 21st century will include not only the disappearance of the RFD, which will not be mourned by nature, but also what little remains of Thai forests — a heritage and resource which must be preserved.

The widespread use of bottled gas in Thailand since the early 1980's has mitigated forest destruction by charcoal makers. Forest devastation caused by these people will take centuries to recover. Even after 50–60 years (or more) these charcoal-making sites still have very degraded, secondary, mostly deciduous, fire-prone vegetation with much bamboo, eroded soil, and holes in the ground.
Photo: Warren Brockelman, SE of Takhong Reservoir, Nakorn Ratchisma Province, 3 August 1976.

Aquilaria crassna Pierre *ex* Lec. (Thymelaeaceae, agarwood) often has rotted internal xylem (heartwood) which produces a fragrant residue used to make incense. This has bocome a very profitable, but environmentally destructive, industry in the central and south-eastern parts of Thailand. This species has become extirpated to very rare (as in Doi Sutep–Pui National Park) in northern Thailand and endangered in the other two parts of the country where it is naturally distributed. Exploitation of this species in Khao Yai National Park (central area) has not only disrupted ecological work and pristine primary ecosystems there, but has also led to armed conflicts. A clash there three years ago resulted in the deaths of one national park ranger and one logger. RFD officials, as usual, have been unable (unwilling?) to control subsequent encroachment.
Photo: Warren Brockelman; Khao Yai National Park, Nakorn Nayok Province; July 1999.



A monument to incredibility. Destruction of forested land for agricultural "development" has been a major cause of environmental deterioration in Thailand. Economically profitable monocultures (e.g. rice, sugar cane, corn, cabbages, etc.) require cleared, usually burned, land and high inputs of fertilizers and pesticides for maximum yields. Destruction of forest cover, ravaging of the soil, plus toxic residues in the soil, water, food webs, etc. add further insults to already crippled ecosystems.
Photo: Warren Brockelman; Chonburi Province; December 1975.

Loggers in Thailand, whether they are sawmill operators or rural villagers cutting trees to make homes, have never considered sustainability or conservation when plundering the forest. The RFD has had a thoroughly dismal record for both of these factors. Logging, etc. scandals involving the RFD have been common.
Photo: Warren Brockelman; north of Takhong Reservoir, Nakorn Ratchisma Province; 4 April 1976.

Although there are laws against illegal logging in Thailand, they are often ignored and inadequately. Protection of the remaining forests has, therefore, been minimal; thus primary forested areas in the kingdom continue to disappear. Ecologically pornographic scenes, such as this teak house in Bong District, Payao Province, are common and continuous reminders that nature conservation in Thailand is still being blatantly violated.
Photo: Mike Rodenbaugh, 12 March 2000.

Lack of respect for the environment, ignorance, and greed—all without official control, has caused remaining forested land in Thailand to shrink to less than 15% of the total land area of the country.
Photo: Kevin Woods, Bang Mah Pah District, Mae Hong Sawn Province, *c.* 350 m, 15 April 2000.

PART II
The Vegetation of Doi Sutep–Pui National Park

J. F. Maxwell and Stephen Elliott

Introduction

Doi Sutep–Pui[1] National Park was established on 14 April 1981. It is situated directly west of Chiang Mai City in northern Thailand at *c.* 18° 50′ north latitude and 99° 0′ east longitude, and includes an area of 261 km² (Figure 1). The main part of the national park is Doi Sutep and Doi Pui, which is a N–S aligned mountain rising from *c.* 350 m to 1610 m (Doi Sutep) and 1685 m (Doi Pui). The two disjunct satellite portions of the national park are lowland, mostly severely degraded, areas north of the main mountain and include Däht Mawk and Mawk Fah waterfalls.

Doi Sutep Temple, located at 1050 m on the east side of Doi Sutep, was established over 600 years ago and is presently the major tourist attraction in the national park. Puping Palace, established by the present Royal Family in 1961, is situated at *c.* 1350 m on the eastside of Doi Sutep. Sahn Goo ("tomb ridge"), on the eastern summit of Doi Sutep, is the ruins of a monument/ shrine that predates Doi Sutep Temple[2]. There are four major hill tribe villages, all Hmong, in the national park. Nong Hoy Gow, situated on the southern tip of the northern section of the national park at *c.* 1100 m, was first settled over a century ago. Mr. Naeng Zae Zong, 50, a villager at Mae Sa Mai Village, which is directly south of Nong Hoy Gow Village, has informed us that the latter village was established several generations ago. The oldest people in his village can only recall that Nong Hoy Gow was already present when they were young and that their ancestors were the ones who lived there. Nong Hoy Gow Village was the first Hmong village to be established in the area. Mae Sa Mai, NW of Doi Pui, is situated at *c.* 1000 m and was established in 1947 (Photo 1). Mayo Doi Pui Village is located on the south side of Doi Sutep at *c.* 1000 m and was first settled in 1951. Chang Kian Village, established in 1955, is located on the east side of Doi Pui at *c.* 1350 m (Figure 1) (TDRI, 1996).

According to reports submitted in June 1999 by various ranger station chiefs in the national park, there are at least 4973, predominately hill tribe, people living in the National Park (Table 5). There must be at least another 500 people living in the Doi Sutep Village area, which includes Doi Sutep Temple and the national park headquarters. The total number of people living in upland, forested areas in the national park must approximate 5500. The 1999 statistics do not include any data concerning infringing lowland settlements.

All of the Hmong villages were originally established to exploit new areas for opium cultivation—the essential cash crop of these people. Much of the original forest cover was destroyed by cultivation of this crop as well as for upland rice—their main subsistence crop. While opium began to be officially curtailed in 1958 and essentially discontinued by *c.* 1990, various environmentally unacceptable cash crops have been offered as substitutes. The uncon-

[1] Thai: doi = mountain, sutep = beautiful angel, pui (pronounced "bui") = like fluffy clouds

[2] A recently installed plaque at Sahn Goo indicates that the ruins date from the 13th century A.D.

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Table 5. Population statistics for people living in the uplands of Doi Sutep–Pui National Park, June 1999.

Village	Ethnic Group	Population
Nong Hoi Gow	Hmong	706
Mae Sa Mai	Hmong	1700
Mayo Doi Pui	Hmong	595
Chang Kian	Hmong	697
Huay Mae Nai	Hmong	*c.* 50
Puping	Thai	443
Daht Mawk Station area	Karen	10
Mawk Fa Station area (8 villages)	Lisaw	790
Doi Sutep Village area	Thai	500 (estimate)
Total		**5473**

Source: Headquarters, Doi Sutep–Pui National Park

trolled agricultural practices of the Hmong have rapidly destroyed much of the original forest vegetation above *c.* 1000 m as well as severely damaging the associated water catchment areas. Two agricultural research sites were established in 1970 by the Faculty of Agriculture, Chiang Mai University, below Doi Pui and have become greatly enlarged since that time. Site "A", at *c.* 1350 m, was created for coffee research at the expense of pristine forest and an intact water catchment valley. Site "B", at *c.* 1250 m, intended for other cash crops, is located at a small, abandoned Hmong village, Ban Maeo Khun Huay Mae Na Sai, near the source of Mae Nai Stream. The present effectiveness of both of these stations, especially Site "B", in upland crop programmes is questionable, while their detrimental effects on the environment are great. Nong Hoi Gow and Mae Sa Mai villages are assisted in their agricultural activities by the Royal Project. In contrast to sites "A" and "B", the Royal Project uses land that has already been deforested. Much of the periphery of the national park has been settled by Thais and "developed" with some places actually encroaching on national park territory.

Editor's note: The spelling of Thai proper names in this monograph follows a personalized phonetic English transliteration which generally differs from that of the Royal Institute which is used on most official Thai maps and other documents. Below are listed the official spellings (right side) corresponding to some of the authors' spellings (left).

Chamadevi (Princess)	Chamathewi
Doi Sutep	Doi Suthep
Daht Mawk	Tat Mok
Haripunchai	Hariphunchai
Mawk Fah	Mok Fa
Puping Palace	Phuphing Palace
Hmong	Hu-Mong
Nong Hoy Gow	Nong Hoi Kao
Pah Ngeub	Pha Ngoeb
Mayo	Maeo
Chang Kian	Chang Khian
Doi Kuhn Tan	Doi Khun Tan
Lampoon Province	Lamphun Province
Wat Prataht	Wat Phrathat

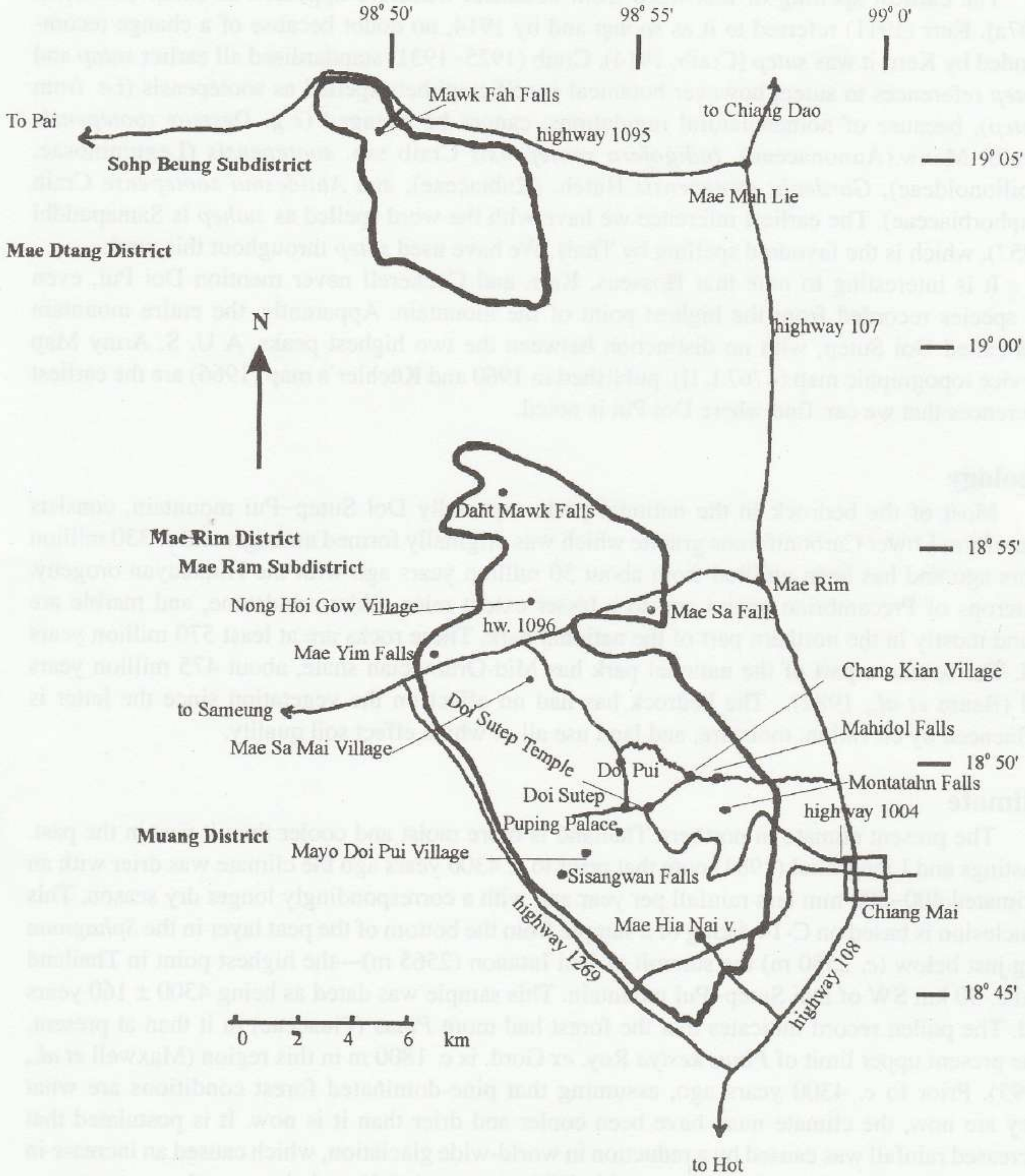

Figure 1. Doi Sutep–Pui National Park, Chiang Mai Province, Thailand

Etymology of "Sutep"

The earliest spelling of this word from botanical literature appeared as *sutap* (Hosseus, 1907a). Kerr (1911) referred to it as *sootep* and by 1914, no doubt because of a change recommended by Kerr, it was *sutep* (Craib, 1914). Craib (1925–1931) standardised all earlier *sutap* and *sootep* references to sutep, however botanical specific epithets spelled as sootepensis (*i.e.* from *sootep*), because of nomenclatural regulations, cannot be changed (*e.g. Desmos sootepensis* (Craib) Maxw.(Annonaceae), *Indigofera sootepensis* Craib ssp. *sootepensis* (Leguminosae, Papilionoideae), *Gardenia sootepensis* Hutch. (Rubiaceae), and *Antidesma sootepense* Craib (Euphorbiaceae). The earliest reference we have with the word spelled as *suthep* is Samapuddhi (1957), which is the favoured spelling by Thais. We have used *sutep* throughout this work.

It is interesting to note that Hosseus, Kerr, and Cockerell never mention Doi Pui, even for species recorded from the highest point of the mountain. Apparently, the entire mountain was called Doi Sutep, with no distinction between the two highest peaks. A U. S. Army Map Service topographic map (4767 I, II), published in 1960 and Küchler's map (1966) are the earliest references that we can find where Doi Pui is noted.

Geology

Most of the bedrock in the national park, especially Doi Sutep–Pui mountain, consists of uniform Lower Carboniferous granite which was originally formed underground *c.* 330 million years ago and has been uplifted from about 50 million years ago with the Himalayan orogeny. Outcrops of Precambrian gneiss and to a lesser extent mica schist, sandstone, and marble are found mostly in the northern part of the national park. These rocks are at least 570 million years old. The southern part of the national park has Mid-Ordovician shale, about 475 million years old (Baum *et al.*, 1982). The bedrock has had no effect on the vegetation since the latter is influenced by elevation, moisture, and land use all of which effect soil quality.

Climate

The present climate in northern Thailand is more moist and cooler than it was in the past. Hastings and Liengsakul (1984) note that prior to *c.* 4300 years ago the climate was drier with an estimated 400–500 mm less rainfall per year and with a correspondingly longer dry season. This conclusion is based on C-14 dating of a sample from the bottom of the peat layer in the *Sphagnum* bog just below (*c.* 2550 m) the summit of Doi Intanon (2565 m)—the highest point in Thailand and *c.* 50 km SW of Doi Sutep–Pui mountain. This sample was dated as being 4300 ± 160 years old. The pollen record indicates that the forest had more *Pinus* (Pinaceae) in it than at present. The present upper limit of *Pinus kesiya* Roy. *ex* Gord. is *c.* 1800 m in this region (Maxwell *et al.*, 1995). Prior to *c.* 4300 years ago, assuming that pine-dominated forest conditions are what they are now, the climate must have been cooler and drier than it is now. It is postulated that increased rainfall was caused by a reduction in world-wide glaciation, which caused an increase in water availability throughout the world. With more rainfall and decreased temperatures, pine gradually receded while seasonal evergreen forest, the present upland vegetation, became dominant.

The average amount of annual of rainfall in Chiang Mai city, *i.e.* at the base of Doi Sutep–Pui mountain (*c.* 350 m), is 1067.8 mm (Figure 2). August and September have the most rain with

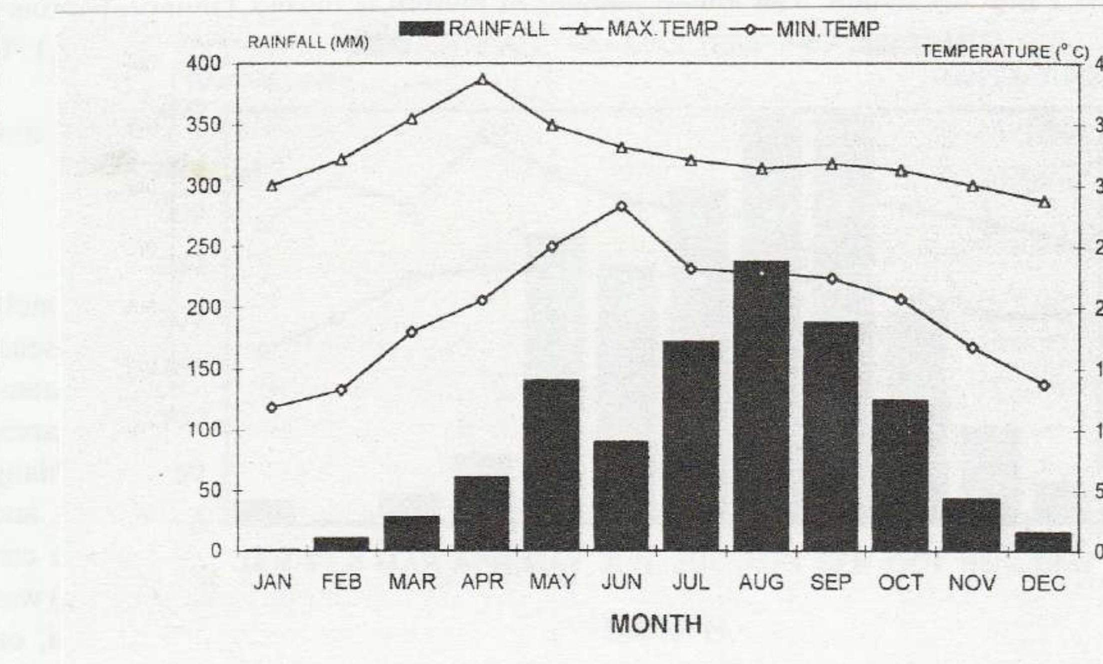

Figure 2. Rainfall and temperature averages for Chiang Mai, *c.* 350 m; 1952-1997.
Sources: Kaosoot *et al.*, 1996; Statistical Reports, 1992-1997; Suwatcherunkul & Srisawang, 1993.

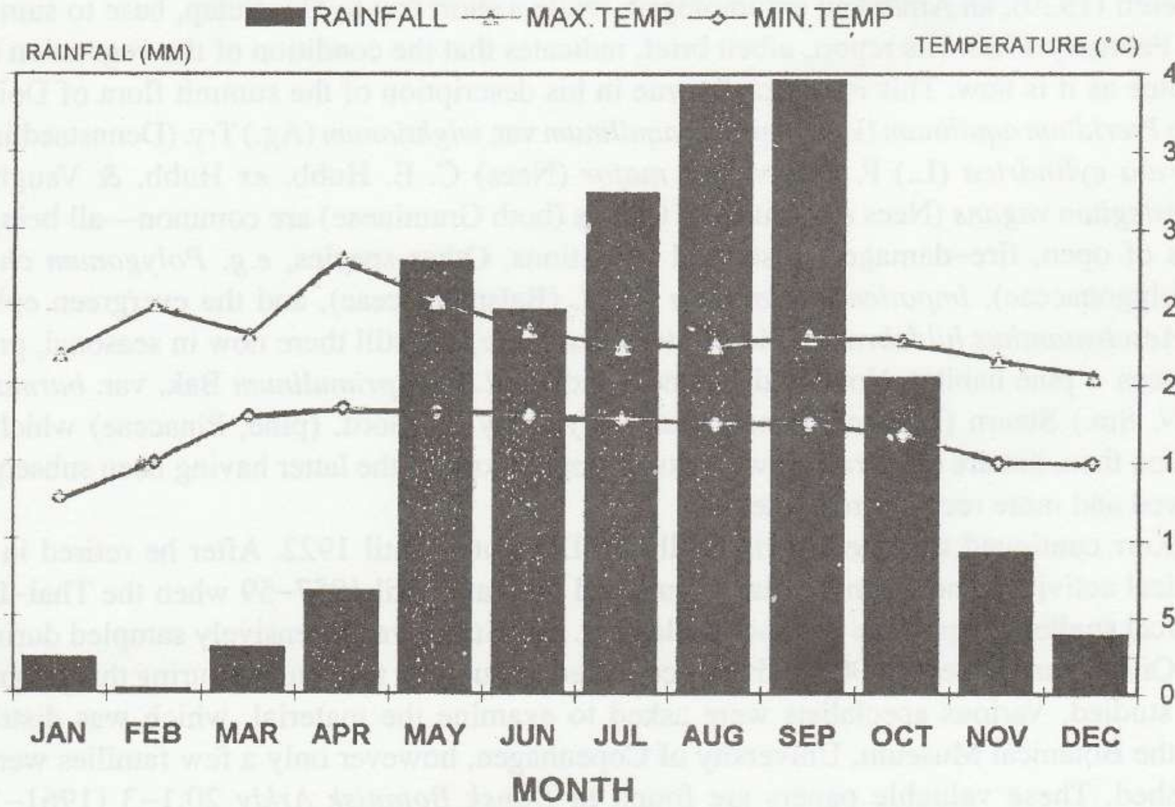

Figure 3. Rainfall and temperature averages for Puping Village, *c.* 1375 m; 1965–1998.
Source: Chatchai Tantasirin, Faculty of Forestry, Kasetsart University, Bangkok.

an average of 207.7 mm per month. The lowest amount of rainfall is during January–February with an average of 6.3 mm per month. Average lowland temperatures range from a low of 21.1 °C during December–January and a high of 29.0 °C during April–May.

The average amount of rainfall at the national park headquarters (*c.* 1050 m) is 1670.1 mm per year and 2095 mm at Puping village (*c.* 1375 m).

Previous Botanical Research on Doi Sutep–Pui

As noted in Part I about forest types in Thailand, Dr. Carl Hosseus (1878–1950), a privately financed German, was in 1904 the first botanist to collect on Doi Sutep–Pui mountain (Hosseus, 1908). Dr. Alfred Francis George Kerr (1877–1942), an Irish physician and initially amateur orchidologist, first arrived in Thailand in 1902. Jacobs (1962) provides the details of Kerr's career in Thailand and notes that Kerr was appointed medical officer of the British Consulate in Chiang Mai in August 1903. He became interested in local orchids where he collected, cultivated, and drew 215 species by 1908. His first sketch was made on 15 January 1904. As far as we can determine, *Bulbophyllum kerrii* Rol. (Orchidaceae, = *Bulbophyllum hirtum* (J. E. Sm.) Lindl.) was the first of Kerr's collections described as new from the "mountains round Chiengmai, on deciduous trees at about 2,000 feet (= *c.* 675 m) altitude". Seidenfaden (1979) interprets this indefinite locality as being Doi Sutep. *Oberonia umbraticola* Rol. (Orchidaceae, = *Oberonia pachyrachis* Rchb. f. *ex* Hk. f.) is the first of Kerr's orchids described as a new species with Doi Sutep (*sic.* Doi Govtep) noted as the collecting locality (Rolfe, 1909). Kerr, after a visit to Kew, received botanical inspiration and collecting equipment from enthusiastic botanists there in 1908 and returned to Chiang Mai in mid-December 1908 to begin serious botanical collecting. Cockerell (1929), an American entomologist, made a short trip to Doi Sutep, base to summit, in early February 1928. His report, albeit brief, indicates that the condition of the vegetation then is the same as it is now. This is especially true in his description of the summit flora of Doi Sutep where *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae), *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. *ex* Hubb. & Vaugh., and *Microstegium vagans* (Nees *ex* Steud.) A. Camus (both Gramineae) are common—all being indicators of open, fire–damaged, disturbed conditions. Other species, *e.g. Polygonum chinense* L. (Polygonaceae), *Impatiens violaeflora* Hk. f. (Balsmainaceae), and the evergreen epiphytic herb *Aeschynanthus hildebrandii* Hemsl. (Gesneriaceae) are still there now in seasonal, primary, evergreen + pine habitat. Notable differences include *Lilium primulinum* Bak. var. *burmanicum* (W. W. Sm.) Stearn (Liliaceae) and *Pinus kesiya* Roy. *ex* Gord. (pine, Pinaceae) which were common then, but are quite rare now—natural populations of the latter having been subsequently removed and more recently replanted.

Kerr continued to collect periodically on Doi Sutep until 1922. After he retired in 1932, botanical activity in northern Thailand remained dormant until 1957–59 when the Thai–Danish botanical studies programme resumed collecting. Doi Sutep was extensively sampled during this time. Only a part of the *c.* 8000 specimens collected throughout the country during this programme were studied. Various specialists were asked to examine the material, which was distributed from the Botanical Museum, University of Copenhagen, however only a few families were ever published. These valuable papers are found in *Dansk Botanisk Arkiv* 20:1–3 (1961–1963), 23:1–4 (1963–1968), and 27:1 (1969). Doi Sutep was visited in late 1965 during a Thai–Dutch botanical expedition, however no species are listed (Hennipman & Touw, 1966).

Küchler & Sawyer (1967), American plant geographers, were the first to intensively study the vegetation on Doi Sutep–Pui. This work, conducted from February–May 1966, resulted in the compilation of a detailed vegetation map (Küchler, 1966) and a preliminary flora (Sawyer & Chermsirivathana, 1969). A total of 679 species of vascular plants are enumerated in this flora which is less than 1/3 of the now known flora on the mountain. Botanical collecting continued on Doi Sutep–Pui with expeditions, especially from Denmark, Netherlands, and Japan, in collaboration with the Royal Forest Department Herbarium, however nothing has been enumerated. Our own research in the national park started in 1987 with the vegetation being published in 1988 (Maxwell, 1988) and a detailed ecological study in 1989 (Elliott *et al*., 1989).

Initial Literature on the Flora of Doi Sutep–Pui

Based on his collecting trip of 1904–1905 to northern Thailand, Hosseus's first paper on his collections, including those from Doi Sutep–Pui, was about Acanthaceae—which included several new species from the mountain (Hosseus, 1907). This and several subsequent papers produced until 1911 are the first lists of plants, including many new species, for northern Thailand (Hosseus, 1907a, 1907b, 1910, 1911,1911a). W. G. Craib, then at Kew*, combined all the known plants from the country, including those collected by Hosseus as well as Kerr and collaborators, into two publications (Craib, 1911, 1912). Craib, recipient of Kerr's and other collections until 1932 when the latter retired and continued his botanical work at Kew, continued his work on the Thai flora until his death at Kew on 1 September 1933 (Jacobs, 1962). The *Florae Siamensis Enumeratio*, which is essentially a summary of Craib's botanical work on Thai plants, was continued by Kerr, and after his demise on 21 January 1942, by Euphemia Barnett (Craib, 1925–1934; Kerr, 1936–1954; Barnett, 1962). The series was discontinued with Barnett's completion of Gesneriaceae, thus ending British dominance in studies on the Thai flora. It is very unfortunate that the *Florae Siamensis Enumeratio* has remained incomplete. The information that it contains, especially the details concerning distribution, elevation, types, and collections are not included in the *Flora of Thailand* (1970–present). The information presented in the *Dansk Botanisk Arkiv* series (1961–1969) is only useful for certain families from a few areas. Most of Kerr's early collections of Orchidaceae were studied by R. A. Rolfe (1855–1921) at Kew. The earliest of these were from the "mountains round Chiengmai" and include *Bulbophyllum kerrii* Rol. (=*Bulbophyllum hirtum* (J. E. Sm.) Lindl.; Rolfe, 1906), *Cirrhopetalum papillosum* Rol. (= *Bulbophyllum thaiorum* J. J. Sm.; Rolfe, 1908), *Bulbophyllum dixoni* Rol. (= *Bulbophyllum morphologorum* Krzl.) and *Ione siamensis* Rol. (= *Sunipia australis* (Seid.) P. F. Hunt (Rolfe, 1908a). The majority of Kerr's other orchid collections were also examined by Rolfe and published posthumously by Downie (1925). Most of the new species of vascular plants found on Doi Sutep–Pui, indeed throughout Thailand, were collected by Kerr, and described by Craib. Table 6 is a list of new species, *etc.* described from Doi Sutep–Pui that have been found during our project. Approximately 1/4 of these taxa have been synonymized with previously known species described from other countries.

*Craib worked at Kew, London 1909–1915; Edinburgh, Scotland 1915–1920; and finally at Aberdeen, Scotland 1920–1933 where he was Regius Professor of Botany.

Table 6. Vascular plants described from specimens collected in Doi Sutep–Pui National Park, *i.e.* the type locality, which have been rediscovered during this project (topotypes).

Species, *etc.*	Type
Ranunculaceae	
Clematis eichleri (M. Tam.) M. Tam.	topo
Clematis sikkimensis (Hk. f. & Th.) Drum. *ex* Burk.	topo of *Clematis siamensis* Drum. & Craib
Naravelia siamensis Craib	topo
Dilleniaceae	
Dillenia parviflora Griff. var. *kerrii* (Craib) Hoogl.	topo of paratype
Magnoliaceae	
Michelia floribunda Fin. & Gagnep.	topo of *Michelia kerrii* Craib
Annonaceae	
Desmos dumosus (Roxb.) Saff. var. *glabrior* Craib	topo
Desmos sootepense (Craib) Maxw.	topo
Fissistigma oblongum (Craib) Merr.	topo
Fissistigma sp.	topo of *Melodorum affine* Craib
Miliusa cuneata Craib	topo
Polyathia debilis (Pierre) Fin. & Gagnep	topo of *Desmos dubius* (Craib) Craib
Menispermaceae	
Cyclea barbata Miers	topo of *Cyclea ciliata* Craib
Stephania brevipes Craib	topo
Stephania oblata Craib	topo, also topo of *Stephania kerrii* Craib
Berberidaceae	
Mahonia nepalensis DC.	topo of *Mahonia siamensis* Tak. *ex* Craib
Capparaceae	
Capparis kerrii Craib	topo
Guttiferae	
Garcinia mckeaniana Craib	topo
Flacourtiaceae	
Casearia flexuosa Craib	topo
Casearia grewiifolia Vent. var. *grewiifolia*	topo of *Cassearia kerrii* Craib
Flacourtia indica (Burm. f.) Merr.	topo of *Flacourtia lenis* Craib
Xylosma brachystachys Craib	topo
Theaceae	
Camellia oleifera Abel var. *confusa* (Craib) Sealy	topo
Eurya nitida Korth. var. *siamensis* (Craib) H. Keng	topo
Gordonia dalglieshiana Craib	topo
Schima wallichii (DC.) Korth.	topo of *Schima brevipes* Craib
Dipterocarpaceae	
Dipterocarpus tuberculatus Roxb. var. *tomentosus* Kerr	topo
Malvaceae	
Hibiscus glanduliferus Craib	topo
Sterculiaceae	
Byttneria aspera Colebr.	topo of *Byttneria siamensis* Craib
Pterospermum grandiflorum Craib	topo
Tiliaceae	
Colona flagrocarpa (Cl.) Craib	topo of *Colona flagrocarpa* (Cl.) Craib var. *siamensis* Craib

Species, *etc.*	Type
Elaeocarpaceae *Elaeocarpus stipularis* Bl.	topo of *Elaeocarpus siamensis* Craib
Rutaceae *Euodia glomerata* Craib	topo
Burseraceae *Canarium subulatum* Guill.	topo of *Canarium kerrii* Craib
Icacinaceae *Pittosporopsis kerrii* Craib	topo
Celastraceae *Euonymus similis* Craib	topo
Euonymus sootepensis Craib	topo
Vitaceae *Tetrastigma cruciatum* Craib & Gagnep.	topo
Tetrastigma quadrangulum Gagnep. & Craib	topo
Leeaceae *Leea guineensis* G. Don	topo of *Leea dentata* Craib
Leea macrophylla Roxb. *ex* Horn.	topo of *Leea pallida* Craib
Sapindaceae *Allophyllus cobbe* (L.) Raeusch.	topo of *Allophyllus sootepensis* Craib
Meliosma simplicifolia (Roxb.) Walp. ssp. *fordii* (Hemsl. *ex* Forb. & Hemsl.) Beus.	topo of *Meliosma simplicifolia* (Roxb.) Walp.var. *sootepensis* Craib
Connaraceae *Rourea minor* (Gaertn.) Leenh. ssp. *minor*	topo of *Santaloides siamensis* Schellenb.
Leguminosae, Mimosoideae *Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Niels.	topo
Leguminosae, Caesalpinioideae *Afzelia xylocarpa* (Kurz) Craib	topo of *Afzelia siamica* Craib
Bauhinia ornata Kurz var. *kerrii* (Gagnep.) K. & S. S. Lar.	topo
Cassia bakeriana Craib	topo
Leguminosae, Papilionoideae *Crotalaria albida* Hey. *ex* Roth	topo of *Crotalaria hossei* Craib
Dalbergia lanceolaria L. f. var. *lakhonensis* (Gagnep.) Niyo. & Ho	topo of paratype of *Dalbergia lakonensis* Gagnep. var. *appendiculata* Craib
Dalbergia velutina Bth. var. *succirubra* (Gagnep. & Craib) Niyo.	topo
Dalbergia velutina Bth. var. *velutina*	topo of *Dalbergia abbreviata* Craib
Desmodium longipes Craib	topo
Dunbaria bella Prain	topo of *Dunbaria longeracemosa* Craib
Flemingia sootepensis Craib	topo
Indigofera laxiflora Craib	topo
Millettia latifolia Dunn	topo
Mucuna bracteata A. DC.	topo of *Mucuna brevipes* Craib
Pueraria mirifica A. S. & Suvat.	topo
Pueraria stricta Kurz	topo of *Pueraria siamica* Craib
Spatholobus suberectus Dunn	topo of *Spatholobus floribundus* Craib
Tephrosia kerrii Drum. & Craib	topo
Teyleria barbata (Craib) Lack. *ex* Maes.	topo

Species, *etc.*	Type
Rosaceae	
Parinari anamensis Hance	topo of *Parinarium albidum* Craib
Prunus cerasoides D. Don	topo of *Prunus hosseusii* Diels
Sorbus verrucosa (Decne.) Rehd. var. *verrucosa*	topo of *Pyrus granulosa* Bertol. var. *siamensis* Craib
Escalloniaceae	
Itea puberula Craib	topo
Combretaceae	
Terminalia glaucifolia Craib	topo
Terminalia mucronata Craib & Hutch.	topo
Myrtaceae	
Eugenia tetragona Wight	topo of *Eugenia subviridis* Craib
Melastomataceae	
Memecylon plebejum Kurz	topo of syntypes of *Memecylon plebejum* Kurz var. *siamense* Craib and *Memecylon plebejum* Kurz var. *symplocinum* Craib
Osbeckia chinensis L. var. *chinensis*	topo of *Oxyspora parva* Gedd.
Osbeckia stellata Ham. *ex* Ker–Gawl. var. *crinita* (Bth. *ex* Naud.) C. Han.	topo of *Osbeckia paludosa* Craib, *Osbeckia pulchra* Gedd., and *Osbeckia pulchra* Gedd. var. *rubra* Craib
Osbeckia stellata Ham. *ex* Ker–Gawl. var. *marginulata* (Cl.) C. Han.	topo of *Osbekia racemosa* Craib
Sonerila erecta Jack	topo of *Sonerila nisbetiana* Craib
Sonerila griffithii Cl.	topo of *Sonerila kerrii* Craib & Stapf
Lythraceae	
Lagerstroemia cochinchinensis Pierre var. *ovalifolia* Furt. & Mont.	topo of paratype
Lagerstroemia macrocarpa Kurz var. *macrocarpa*	topo of *Lagerstroemia hossei* Koeh. and *Lagerstroemia intermedia* Koeh. var. *oblonga* Craib
Lagerstroemia venusta Wall. *ex* Cl.	topo of *Lagerstroemia collettii* Craib
Rotala diversifolia Koeh.	topo
Passifloraceae	
Adenia pinnasecta (Craib) Craib var. *pinnasecta*	topo
Passiflora siamica Craib	topo of paratype
Cucurbitaceae	
Gynostemma laxum (Wall.) Cogn.	topo of *Gynostemma siamensis* Craib
Neoalsomitra integrifoliola (Cogn.) Hutch.	topo of *Gynostemma angustipetala* Craib and *Alsomitra angustipetala* (Craib) Craib
Begoniaceae	
Begonia acetosella Craib	topo
Begonia siamensis Gagenp.	topo
Begonia yunnanensis Lev.	topo of *Begonia sootepensis* Craib
Umbelliferae	
Hydrocotyle siamica Craib	topo
Seseli siamicum Craib	topo
Nyssaceae	
Nyssa javanica (Bl.) Wang.	topo of *Nyssa bifida* Craib
Caprifoliaceae	
Viburnum inopinatum Craib	topo

Species, *etc.*	**Type**
Rubiaceae	
Argostemma ebracteolatum Gedd.	topo of *Argostemma pubescens* Gedd.
Gardenia sootepensis Hutch.	topo
Hedyotis nalampooni Fuku.	topo
Hedyotis tenelliflora Bl. var. *kerrii* (Craib) Fuku.	topo
Hyptianthera bracteata Craib	topo
Ixora butterwickii Hole var. *lepida* Craib	topo of paratype
Ixora cibdela Craib var. *cibdela*	topo
Ixora kerrii Craib	topo
Morinda angustifolia Roxb. var. *scabridula* Craib	topo of paratype
Mussaenda kerrii Craib	topo
Mussaenda parva Wall. *ex* G. Don	topo of *Mussaenda sootepensis* Hoss. and *Mussaenda neosoootepensis* Craib
Mussaenda sanderiana Ridl.	topo of *Mussaenda sutepensis* Hoss. and *Mussaenda hossei* Craib *ex* Hoss.
Mycetia glandulosa Craib	topo
Mycetia gracilis Craib	topo
Mycetia rivicola Craib	topo
Ophiorrhiza ridleyana Craib	topo
Paederia pilifera Hk.f.	topo of *Paederia pilifera* Hk. f. var. *siamensis* Craib
Paederia wallichii Hk.f.	topo of *Paederia kerrii* Craib
Pavetta fruticosa Craib	topo
Psychotria siamica (Craib) Hutch.	topo
Rothmannia sootepensis (Craib) Brem.	topo
Rubia siamensis Craib	topo
Wendlandia tinctoria (Roxb.) DC. ssp. *floribunda* (Craib) Cowan	topo
Compositae	
Blumea hossei Craib *ex* Hoss.	topo
Camchaya eberhardtii (Gagnep.) Kit.	topo of *Iodocepphalus glandulosus* Kerr
Gynura longifolia Kerr	topo
Lactuca parishii Craib *ex* Hoss.	topo
Vernonia silhetensis (DC.) Craib var. *silhetensis*	topo of *Vernonia silhetensis* (DC.) Craib var. *subserrata* (Hoss.) Craib
Vernonia sutepensis Kerr	topo
Ericaceae	
Agapetes hosseana Diels	topo
Rhododendron molumainense Hk.	topo of *Rhododendron siamensis* Diels
Primulaceae	
Lysimachia lancifolia Craib	topo
Myrsinaceae	
Ardisia attenuata Wall. *ex* A. DC.	topo of paratype of *Ardisia garrettii* Flet.
Ardisia kerrii Craib	topo

Species, *etc.*	Type
Embelia impressa Flet.	topo
Embelia oblongifolia Hemsl.	topo *Embelia impressa* Flet. var. *serrata* Flet.
Embelia sessiliflora Kurz	topo of *Embelia stricta* Craib
Embelia sootepensis Craib var. *sootepensis*	topo
Symplocaceae	
Symplocos macrophylla Wall. *ex* DC. ssp. *sulcata* (Kurz) Noot. var. *sulcata*	topo of *Symplocos kerrii* Craib var. *kerrii* and *Symplocos rajaniana* Craib
Styracaceae	
Styrax benzoides Craib	topo
Oleaceae	
Jasminum funale Decne. ssp. *sootepense* (Craib) P. S. Green	topo
Chionanthus sutepensis (Kerr) P. S. Green	topo
Olea oblanceolata Craib	topo
Olea rosea Craib	topo
Apocynaceae	
Aganosma siamensis Craib	topo
Alyxia siamensis Craib	topo
Melodinus cochinchinensis (Lour.) Merr.	topo of *Melodinus henryi* Craib
Trachelospermum gracilipes Hk. f.	topo of *Trachelospermum siamensis* Craib
Asclepiadaceae	
Ceropegia sootepensis Craib	topo
Dischidia singularis Craib	topo
Gymnema griffithii Craib	topo
Heterostemma siamicum Craib	topo
Hoya engleriana Hoss.	topo
Hoya kerrii Craib	topo
Hoya siamica Craib	topo
Tylophora sootepensis Craib	topo
Gentianaceae	
Exacum sutapense Hoss. *ex* Craib	topo
Boraginaceae	
Tournefortia intonsa Kerr	topo
Convolvulaceae	
Argyreia henryi (Craib) Craib	topo
Argyreia kerrii Craib	topo
Ipomoea siamensis Craib	topo
Lentibulariaceae	
Utricularia caerulea L.	topo of *Utricularia kerrii* Craib and *Utricularia sootepensis* Craib
Gesneriaceae	
Aeschynanthus hildebrandii Hemsl.	topo of *Aeschynanthus persimilis* Craib
Aeschynanthus hosseusii Pell.	topo of *Aeschynanthus macrocalyx* Hoss.
Didymocarpus aureoglandulosus Cl.	topo, also topo of *Didymocarpus rodgeri* W. W. Sm. & Ban. var. *siamensis* W.W. Sm.
Didymocarpus kerrii Craib	topo, also topo of *Didymocarpus squamosus* Craib

Species, *etc.*	Type
Embelia impressa Flet.	topo
Embelia oblongifolia Hemsl.	topo *Embelia impressa* Flet. var. *serrata* Flet.
Embelia sessiliflora Kurz	topo of *Embelia stricta* Craib
Embelia sootepensis Craib var. *sootepensis*	topo
Symplocaceae	
Symplocos macrophylla Wall. *ex* DC. ssp. *sulcata* (Kurz) Noot. var. *sulcata*	topo of *Symplocos kerrii* Craib var. *kerrii* and *Symplocos rajaniana* Craib
Styracaceae	
Styrax benzoides Craib	topo
Oleaceae	
Jasminum funale Decne. ssp. *sootepense* (Craib) P. S. Green	topo
Chionanthus sutepensis (Kerr) P. S. Green	topo
Olea oblanceolata Craib	topo
Olea rosea Craib	topo
Apocynaceae	
Aganosma siamensis Craib	topo
Alyxia siamensis Craib	topo
Melodinus cochinchinensis (Lour.) Merr.	topo of *Melodinus henryi* Craib
Trachelospermum gracilipes Hk. f.	topo of *Trachelospermum siamensis* Craib
Asclepiadaceae	
Ceropegia sootepensis Craib	topo
Dischidia singularis Craib	topo
Gymnema griffithii Craib	topo
Heterostemma siamicum Craib	topo
Hoya engleriana Hoss.	topo
Hoya kerrii Craib	topo
Hoya siamica Craib	topo
Tylophora sootepensis Craib	topo
Gentianaceae	
Exacum sutapense Hoss. *ex* Craib	topo
Boraginaceae	
Tournefortia intonsa Kerr	topo
Convolvulaceae	
Argyreia henryi (Craib) Craib	topo
Argyreia kerrii Craib	topo
Ipomoea siamensis Craib	topo
Lentibulariaceae	
Utricularia caerulea L.	topo of *Utricularia kerrii* Craib and *Utricularia sootepensis* Craib
Gesneriaceae	
Aeschynanthus hildebrandii Hemsl.	topo of *Aeschynanthus persimilis* Craib
Aeschynanthus hosseusii Pell.	topo of *Aeschynanthus macrocalyx* Hoss.
Didymocarpus aureoglandulosus Cl.	topo, also topo of *Didymocarpus rodgeri* W. W. Sm. & Ban. var. *siamensis* W.W. Sm.
Didymocarpus kerrii Craib	topo, also topo of *Didymocarpus squamosus* Craib

Species, *etc.*	Type
Santalaceae	
Scleropyrum wallichianum (A. DC.) Arn. var. *siamensis* H. Lec.	topo
Euphorbiaceae	
Acalypha kerrii Craib	topo
Antidesma bunius (L.) Spreng.	topo of *Antidesma collettii* Craib
Antidesma sootepense Craib	topo
Baliospermum siamense Craib	topo
Breynia glauca Craib	topo
Bridelia affinis Craib	topo
Glochidion acuminatum M.-A. var. *siamense* A. S.	topo
Glochidion kerrii Craib	topo
Macaranga kurzii (O. K.) Pax & Hoffm.	topo of *syntype of Macaranga andersonii* Craib
Ostodes paniculata Bl.	topo of *Ostodes kerrii* Craib
Phyllanthus roseus (Craib & Hutch.) Beille	topo, also topo of *Phyllanthodendron album* Craib & Hutch., *Phyllanthodendron roseum* Craib & Hutch. var. *glabrum* Craib *ex* Hoss. and var. *siamensis* (Pax & Hoffm.) Craib
Phyllanthus sootepensis Craib	topo
Sauropus bicolor Craib var. *bicolor*	topo, also topo of *Sauropus rigidus* Craib
Sauropus bicolor Craib var. *minor* A. S.	topo
Sauropus orbicularis Craib var. *orbicularis*	topo
Sauropus similis Craib	topo
Urticaceae	
Boehmeria chiangmaiensis Yaha.	topo of paratype
Boehmeria pseudotomentosa Yaha.	topo
Boehmeria thailandica Yaha.	topo of paratype
Fagaceae	
Lithocarpus aggregatus Barn.	topo
Lithocarpus craibianus Barn.	topo
Lithocarpus finetii (Hick. & A. Camus) A. Camus	topo of paratype of *Lithocarpus intermedius* Barn.
Lithocarpus garrettianus (Craib) A. Camus	topo
Lithocarpus sootepensis (Craib) A. Camus	topo
Quercus kerrii Craib var. *kerrii*	topo
Quercus kerrii Craib var. *pubescens* Barn.	topo
Quercus kingiana Craib	topo
Triuridaceae	
Sciaphila thaidanica K. Lar.	topo
Commelinaceae	
Aneilema discretum Craib	topo
Zingiberaceae	
Amomum siamense Craib	topo
Curcuma ecomata Craib	topo
Globba kerrii Craib	topo
Globba nisbetiana Craib	topo

Species, *etc.*	Type
Globba nuda K. Lar.	topo
Globba purpurascens Craib	topo
Globba reflexa Craib	topo
Zingiber bradleyanum Craib	topo
Zingiber kerrii Craib	topo
Zingiber smilesianum Craib	topo
Liliaceae	
Aspidistra sutepensis K. Lar.	topo
Chlorophytum intermedium Craib var. *intermedium*	topo
Disporopsis longifolia Craib	topo
Ophiopogon longifolius Decne.	topo of *Ophiopogon brevipes* Craib
Peliosanthes teta Andr. ssp. *humilis* (Andr.) Jess.	topo of *Ophiopogon gracilipes* Craib
Tupistra albiflora K. Lar.	topo
Smilacaceae	
Smilax zeylanica L. ssp. *hemsleyana* (Craib) T. Koy.	topo
Araceae	
Amorphophallus corrugatus N. E. Br.	topo of *Thomsonia sutepensis* Hu
Amorphophallus krausei Engl.	topo of *Amorphophallus sutepensis* Gagnep.
Amorphophallus macrorhizus Craib	topo, also topo of *Amorphophallus longituberosus* (Engl.) Engl. & Gehrm. var. *robustus* Hu
Amorphophallus yunnanensis Engl.	topo of *Amorphophallus kerrii* N.E. Br.
Arisaema erubescens (Wall.) Schott	topo of *Arisaema hypoglaucum* Craib and *Arisaema kerrii* Craib
Arisaema praseri Hk. f.	topo of *Arisaema sootepensis* Craib
Colocasia fallax Schott	topo of *Colocasia kerrii* Gagnep.
Typhonium hirsutum (Hu) Mur. & Mayo	topo
Typhonium horsfieldii (Miq.) Steen.	topo of *Typhonium larsenii* Hu
Stemonaceae	
Stemona kerrii Craib	topo
Dioscoreaceae	
Dioscorea arachidna Prain & Burk. var. *arachidna*	topo
Dioscorea glabra Roxb. var. *glabra*	topo of *Dioscorea glaba* Roxb. var. *vera* Pr. & Burk. and *Dioscorea siamensis* R. Kunth
Dioscorea hispida Denn. var. *neo-scaphoides* Prain & Burk.	topo
Dioscorea kamoonensis Kunth var. *straminea* Prain & Burk.	topo
Dioscorea kerrii Prain & Burk.	topo
Dioscorea pentaphylla L. var. *communis* Prain & Burk.	topo
Palmae	
Calamus kerrianus Becc.	topo
Plectocomia kerrana Becc.	topo
Pandanaceae	
Pandanus penetrans St. John	topo
Orchidaceae	
Anoectochilus repens (Dow.) Seid. & Smit.	topo
Anoectochilus siamensis Schltr.	topo
Aphyllorchis caudata Rol. *ex* Dow.	topo

Species, *etc.*	Type
Aphyllorchis montana Rchb. f.	topo of *Aphyllorchis unguiculata* Rol. *ex* Dow.
Brachcorythis helferi (Rchb. f.) Summ.	topo
Brachycorythis henryi (Schltr.) Summ.	topo
Bulbophyllum bittnerianum Schltr.	topo of *Bulbophyllum bractescens* Rol. *ex* Kerr
Bulbophyllum morphologorum Krzl.	topo of *Bulbophyllum dixoni* Rol.
Bulbophyllum propinquum Krzl.	topo of *Bulbophyllum chlorostachys* Schltr.
Bulbophyllum retusiusculum Rchb. f.	topo of *Calanthe hosseusiana* Krzl.
Calanthe cardioglossa Schltr.	topo
Cleisostoma arietinum (Rchb. f.) Gar.	topo of *Sarcanthus recurvus* Rol. *ex* Dow.
Cleisostoma fuerstenbergianum Krzl.	topo of *Sarcanthus flagelliformis* Rol. *ex* Dow.
Crepidium acuminatum (D. Don) Szlach.	topo of *Microstylis siamensis* Rol. *ex* Dow.
Crepidium biauritum (Lindl.) Szlach.	topo of *Microstylis sutepensis* Rol. *ex* Dow.
Crepidium orbicularum (W. W. Sm. & Jeff.) Seid.	topo of *Microstylis tenebrosa* Rol *ex.* Dow.
Cymbidium dayanum Rchb. f.	topo of *Cymbidium sutepense* Rol. *ex* Dow.
Cymbidium lancifolium Hk.	topo of *Cymbidium kerrii* Rol. *ex* Dow.
Cymbidium siamense Rol. *ex* Dow.	topo
Cyrtosia nana (Rol. *ex* Dow.) Garay	topo
Dendrobium compactum Rol. *ex* W. Hack.	topo
Dendrobium sutepense Rol. *ex* Dow.	topo
Dendrobium wilmsianum Schltr.	topo
Didymoplexiella siamensis (Rol. *ex* Dow.) Seid.	topo
Disperis siamensis Rol. *ex* Dow.	topo
Drymoda siamensis Schltr.	topo
Eria siamensis Schltr.	topo
Eria sutepensis Rol. *ex* Dow.	topo
Eulophia nuda Lindl.	topo of *Eulophia burkei* Rol. *ex* Dow.
Eulophia siamensis Rol. *ex* Dow.	topo
Galeola integra Rol. *ex* Dow.	topo
Gastrodia exilis Hk. f.	topo of *Gastrodia siamensis* Rol. *ex* Dow.
Geodorum siamense Rol. *ex* Dow.	topo
Goodyera fumata Thw.	topo
Habenaria amplexicaule Rol. *ex* Dow.	topo
Habenaria humistrata Rol. *ex* Dow.	topo
Habenaria limprichtii Schltr.	topo
Habenaria lucida Wall. *ex* Lindl.	topo of *Habenaria recurva* Rol. *ex* Dow.
Habenaria medioflexa Turr.	topo of *Habenaria trichochila* Rol. *ex* Dow.
Habenaria stenopetala Lindl. var. *stenopetala*	topo of *Habenaria sutepensis* Rol. *ex* Dow.
Liparis paradoxa (Lindl.) Rchb. f.	topo of *Liparis odorata* Lindl. var. *longiscapa* Rol. *ex* Dow.
Liparis regnieri Fin.	topo of *Liparis craibiana* Kerr
Liparis siamensis Rol. *ex* Dow.	topo
Liparis sutepensis Rol. *ex* Dow.	topo
Liparis wrayi Hk. f.	topo of *Liparis fimbriata* Kerr

Species, *etc.*	Type	
Luisia thailandica Seid.	topo of paratype	
Oberonia acaulis Griff.	topo of *Oberonia hosseusii* Schltr. *ex* Hoss.	
Oberonia pachyrachis Rchb. f. *ex* Hk. f.	topo of *Oberonia umbraticola* Rol.	
Peristylus tentaculatus (Lindl.) J. J. Sm.	topo of *Habenaria garrettii* Rol. *ex* Dow.	
Polystachya concreta (Jacq.) Garay & Sweet	topo of *Dendrobium parvum* Seid.	
Staurochilus loratus (Rol. *ex* Dow.) Seid.	topo	
Tainia angustifolia (Lindl.) Bth. & Hk. f.	topo of *Tainia sutepensis* (Rol. *ex* Dow.) Seid. & Smit.	
Tainia hookeriana King & Pantl.	topo of *Ascotainia siamensis* Rol. *ex* Dow.	
Vanilla siamensis Rol. *ex* Dow.	topo	
Zeuxine affinis (Lindl.) Bth. *ex* Hk. f.	topo of *Zeuxine sutepensis* Rol. *ex* Dow.	
Cyperaceae *Carex doisutepensis* T. Koy.	topo	
Carex indica L. var. *microcarpa* T. Koy.	topo	
Carex speciosa Kunth ssp. *latifolia* T. Koy.	topo	
Carex tricephala Boeck.	topo of *Carex plesiocephala* Turr.	
Fimbristylis eragrostis (Nees & Mey.) Hance	topo of *Fimbristylis tortispica* Turr.	
Fimbristylis straminea Turr.	topo	
Scleria kerrii Turr.	topo	
Gramineae *Digitaria siamensis* Henr.	topo	
Eulalia siamensis Bor	topo	
Hyparrhenia rufa (Nees) Stapf var. *siamensis* Clayton	topo	
Gramineae, Bambusoideae *Dendrocalamus nudus* Pilg.	topo	
Cycadaceae *Epicycas tonkinensis* (L. Lind. & Rod.) de Laub.	topo of *Cycas micholitzii* Dyer var. *simplicipinna* Smit.	
Aspleniaceae *Asplenium rockii* C. Chr.	topo	
Athyriaceae *Diplazium siamense* C. Chr.	topo	
totals: topotypes of current sp., var. 322	topotypes of synonymous sp., var. 135	total number of topotypes 457

Table 7 lists species whose type locality is Doi Sutep–Pui which have not been found during our field work. Some of these may eventually become synonyms of other species, while habitat loss and exploitation, especially for Orchidaceae, may have caused others to become very rare or extirpated from the national park. As far as we can determine, a total of 512 species, subspecies, and varieties of vascular plants have been described from Doi Sutep–Pui National Park. Among, these, 457 species, *etc.* have been collected during our research there. These two lists, while not exhaustive, indicate that more species of vascular plants have been described from Doi Sutep–Pui than anywhere else in Thailand. The second most prolific area is Doi Chiang Dao from where less than 100 species, *etc.* have been described.

Table 7. Vascular plants described from specimens collected in Doi Sutep–Pui National Park, *i.e.* the type locality, which have not been rediscovered during this project. The elevation for each entry is according to the protolog of the species.

Family	Species	Elevation (m)
Theaceae	*Camellia connata* (Craib) Craib	1500–1650
Rutaceae	*Paramignya surasiana* Craib	1650
Celastraceae	*Euonymus colonoides* Craib	1670
Leguminosae, Papilionoideae	*Dalbergia suthepensis* Niyo.	1200
	Indigofera sootepensis Craib ssp. *sootepensis*	480–900
Rosaceae	*Rubus rufus* Focke, topotype of *Rubus kerrii* Rol. *ex* Craib	720
Melastomataceae	*Osbeckia chinensis* L. var. *pusilla* (Zoll.) Triana, topotype of *Osbeckia parva* Gedd.	1330
Cucurbitaceae	*Siraitia siamensis* (Craib) C. Jeff. *ex* S. Q. Zhong & D. Fang, topotype of *Thladiantha siamensis* Craib	c. 660
Begoniaceae	*Begonia discreta* Craib	1350
Compositae	*Blumea hossei* Craib *ex* Hoss.	900
Rubiaceae	*Argostemma stellatum* Gedd.	400
	Diplospora siamica Craib	1650
	Fagerindia sp., topotype of *Randia plumbea* Craib	1050–1400
	Lasianthus kerrii Craib	1250
	Psychotria sempervirens Gedd.	900–1250
Ericaceae	*Rhododendron surasianum* Balf. f. & Craib	1560
Ebenaceae	*Diospyros kerrii* Craib	660–900
	Diospyros truncata Zoll. & Mor., topotype of *Diospyros viridis* Craib	1670
Apocynaceae	*Aganosma breviloba* Kerr	750
	Anodendron paniculatum A. DC., topotype of *Anodendron sutepense* Kerr	1650
Asclepiadaceae	*Brachystelma kerrii* Craib	360
	Tylophora kerrii Craib	1350
Gentianaceae	*Gentiana timida* Kerr	1500
Solanaceae	*Porana sutepensis* Kerr	900
Scrophulariaceae	*Limnophila villifera* Miq. ssp. *gracilipes* (Craib *ex* Hoss.) Yama.	330 (marsh)
Gesneriaceae	*Didymocarpus purpureo–pictus* Craib	700
Santalaceae	*Henslowia sessilis* Craib	1050(–1500)
Lauraceae	*Litsea pseudo–umbellata* Kosterm.	1200–1250
Euphorbiaceae	*Antidesma kerrii* Craib	1200
	Sauropus siamensis T. Chakrab. & Gang.	c. 730
Zingiberaceae	*Globba yeatsiana* Craib	960
Smilacaceae	*Heterosmilax pertenuis* (T. Koy.) T. Koy.	?

Family	Species	Elevation (m)
Orchidaceae	*Aerides flabellata* Rol. *ex* Dow.	360
	Anoectochilus molumeinensis (Par. & Rchb. f.) Seid., topotype of *Anoectochilus multiflorus* Rol. *ex* Dow.	1650
	Bulbophyllum craibianum Kerr	1200–1500
	Bulbophyllum hirtum (J. E. Sm.) Lindl., topotype of *Bulbophyllum* kerrii Rol.	675
	Bulbophyllum sutepense (Rol.) Seid. & Smit.	600–750
	Bulbophyllum thaiorum J. J. Sm., topotype of *Cirrhopetalum papillosum* Rol.	600
	Ceratostylis siamensis Rol. *ex* Dow.	1560
	Cleisostoma duplicilodium (J. J. Sm.) Garay, topotype of *Sarcanthus carinatus* Rol. *ex* Dow.	450–750
	Dienia ophrydis (Koen.) Orm. & Seid., topotype of *Microstylis carnulosa* Rol. *ex* Dow.	900 (–1450)
	Diploproa truncata Rol. *ex* Dow.	1650
	Galeola cathcartii Hk. f., topotypes of *Galeola kerrii* Rol. *ex* Dow. and *Galeola siamensis* Rol. *ex* Dow.	900 960
	Galeola siamensis Rol. *ex* Dow.	
	Gastrochilus pseudosistichus (King & Pantl.) Schltr.,	1650
	Gastrochilus sutepensis (Rol. *ex* Dow.) Seid. & Smit.	1400
	Gastrochilus yunnanensis Schltr., topotype of *Sacciolabium monticolum* Rol. *ex* Dow.	1500
	Habenaria marginata Colebr., topotype of *Habenaria auranticea* Rol. *ex* Dow.	350
	Liparis tenuis Rol. *ex* Dow.	960 (–1100)
	Pecteilis henryi Schltr., topotype of *Platanthera lacei* Rol. *ex* Dow.	660
	Schoenorchis spatulata (Rol. *ex* Dow.) Seid. & Smit.	1350–1650
	Sunipia andersonii (King & Pantl.) P. F. Hunt, topotype of *Ione purpurata* Braid	1550–1670
	Sunipia australis (Seid.) P.F. Hunt, topotype of *Ione siamensis* Rol.	?
	Thrixspermum stuepense (Rol. *ex* Dow.) Tang & Wang	1500–1650

Total : 55 species

Teak Forest And Bamboo + Deciduous Seasonal Forest (bb/df)

Before the advent of large scale commercial logging in northern Thailand, about a hundred years ago, vast forests, dominated by teak (*Tectona grandis* L. f. (Verbenaceae), covered most of the lowlands and foothills up to an elevation of about 900 m. Today teak forest survives only in Mae Yom National Park (Mahidol University, 1992; Maxwell, 1999). Everywhere else, teak is absent or reduced to a minor component of degraded bamboo + deciduous forest, or deciduous secondary growth. Many of these destroyed teak forests have developed into deciduous dipterocarp-oak facies **(dof)**, most of which have been subsequently degraded. Kurz (1877) referred to what I call **bb/df** as "mixed" forest and since that time almost every author, especially those in the Royal Forest Department, has called this kind of forest "mixed deciduous". This type of forest has often been segregated from teak forest, but this is impracticable and has caused considerable confusion. Kurz provides detailed lists of what constitutes upper and lower mixed forests which, in my opinion, can hardly be considered distinct. There is no question that the 'mixed deciduous' forests in Thailand are very similar to those described by Kurz (Mahidol University, 1992 & 1995). "Mixed deciduous" forest, which is included here under **bb/df**, is in no way related to mixed evergreen + deciduous, seasonal, hardwood forest **(mxf)**, which is discussed below.

Tree species richness is relatively high in bamboo + deciduous forest (173 compared with only 99 in deciduous dipterocarp–oak forest). Removal of the previously dominant teak has released other tree species from competition and allowed more of them to achieve maturity. In bamboo + deciduous forest, the main canopy trees are up to 20–30 m tall. Deciduous trees comprise more than 80 % of individual trees. No single tree species approaches dominance. Buttresses, cauliflory, ramiflory, and palms are rare, but woody climbers can be abundant. Dense thickets of bamboo, which, as the name suggests are characteristic of this forest type, are a sign of disturbance because they are far more abundant than in the original teak forest at Mae Yom. Although they grow up when canopy cover is reduced by tree felling or fire, they can persist even after over-topped by trees and they can inhibit tree seedling regeneration by their shade. Epiphytes are moderately common. The shrub layer is dense and the ground layer consists mostly of mixed dicot herbs and grasses, especially where affected by fire.

Of the 173 tree species which occur in bamboo + deciduous forest, 125 (72 %) are deciduous and 31 are common or abundant. Valuable commercial tree species are still present, though in much reduced numbers *e.g.* teak (*Tectona grandis* L. f. (Verbenaceae), *Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Niels. (Leguminosae, Mimosoideae), *Dalbergia cultrata* Grah. *ex* Bth. and *Pterocarpus macrocarpus* Kurz (both Leguminosae, Papilionoideae), *Lagerstroemia cochinchinensis* (Lythraceae), *Chukrasia tabularis* A. Juss. (Meliaceae), and *Afzelia xylocarpa* (Kurz) Craib (Leguminosae, Caesalpinioideae). Logging favoured other less valuable species. Particularly characteristic are *Colona flagrocarpa* (Cl). Craib (Tiliaceae), *Schleichera oleosa* (Lour.) Oken (Sapindaceae), *Terminalia chebula* Retz. var. *chebula* and *T. mucronata* Craib & Hutch. (Combretaceae), and *Sterculia pexa* Pierre (Sterculiaceae). Others include *Spondias pinnata* (L. f.) Kurz (Anacardiaceae), *Alstonia scholaris* (L.) R. Br. var. *scholaris* (Apocynaceae), *Protium serratum* (Wall. *ex* Colebr.) Engl. (Burseraceae) and, especially near streams, *Metadina trichotoma* (Zoll. & Mor.) Bakh. f. (Rubiaceae). Common understorey trees include: *Vitex canescens* Kurz and *V. limoniifolia* Wall. *ex* Kurz (both Verbenaceae), *Cassia fistula* L. (Leguminosae, Caesalpinioideae), *Antidesma acidum* Retz. and *Phyllanthus emblica*

L. (both Euphorbiaceae), *Stereospermum neuranthum* Kurz and *Oroxylum indicum* (L.) Kurz (both Bignoniaceae). Particularly characteristic deciduous understorey treelets include *Desmodium laxiflorum* DC. ssp. *laxiflorum* and *D. pulchellum* (L.) Bth. (both Leguminosae, Papilionoideae).

Woody climbers (lianas), often quite large, are a notable feature of this forest type. There are 55 species of which 65% are deciduous. They include: *Millettia cinerea* Bth. and *M. extensa* (Bth.) Bth. *ex* Bak. (Leguminosae, Papilionoideae), *Combretum latifolium* Bl. (Combretaceae), and *Congea tomentosa* Roxb. var. *tomentosa* (Verbenaceae).

There are 30 shrub species, of which 63 % are deciduous. Shrubs are represented by many species in bamboo + deciduous forest. Some typical examples are: *Helicteres elongata* Wall. *ex* Boj. and *Helicteres hirsuta* Lour. (Sterculiaceae), *Desmodium gangeticum* (L.) DC. and *Desmodium velutinum* (Willd.) DC. ssp. *velutinum* var. *velutinum* (Leguminosae, Papilionoideae), *Sericocalyx quadrafarius* (Wall. *ex* Nees) Brem. (Acanthaceae), *Phyllanthus sootepensis* Craib, and *Sauropus hirsutus* Beille (both Euphorbiaceae). Bamboos (Gramineae, Bambusoideae) are abundant, especially in more disturbed areas *e.g. Bambusa membranacea* (Munro) Stap. & Xia, *Bambusa tulda* Roxb., and *Dendrocalamus nudus* Pilg.

Bamboo + deciduous forest supports 38 species of epiphytes, most of which are perennial and 58 % of which are evergreen. They mostly belong to 3 groups: Moraceae (figs, many of which begin their lives as epiphytes), Orchidaceae (orchids), and Pteridophytes (ferns). Species particularly characteristic of bamboo + deciduous forest include: *Ficus heterophylla* L. f. var. *heterophylla*, an evergreen woody climber; *Ficus microcarpa* L. f. var. *microcarpa forma microcapra* (Moraceae), an evergreen tree; *Cymbidium aloifolium* (L.) Sw. (Orchidaceae), a succulent evergreen herb; *Platycerium wallichii* Hk. and *Drynaria bonii* C. Chr. (both deciduous Polypodiaceae). The evergreen hemiparasitic epiphyte, *Scurrula atropurpurea* (Bl.) Dans. (Loranthaceae) is also restricted to bamboo + deciduous forest. Epiliths include 12 species, usually restricted to rocks in streams, including ferns such as *Selaginella kurzii* Bak.(Selaginellaceae) and *Pteris decrescens* Christ (Pteridaceae) and several species of the family Gesneriaceae, such as *Chirita hamosa* Wall. *ex* R. Br. and *Streptocarpus orientalis* Craib.

The ground is mostly bare during the dry season (November–April). The first herbs to appear are gingers (*e.g. Globba nuda* K. Lar. and *Kaempferia rotunda* L. (Zingiberaceae)), orchids (*e.g. Geodorum siamense* Rol. *ex* Dow., *Nervilia aragoana* Gaud. and *N. plicata* (Andr.) Schltr. (Orchidaceae), and aroids (*e.g. Amorphophallus macrorhizus* Craib (Araceae)), all of which flower in April before their leaves appear. After the first rains have fallen in May, more species appear and flower *e.g. Curcuma parviflora* Wall. (Zingiberaceae), *Stemona burkillii* Prain (Stemonaceae, a vine), *Geodorum recurvum* (Roxb.) Alst., *Habenaria thailandica* Seid., and *Peristylus constrictus* (Lindl.) Lindl. (all Orchidaceae). By about July, many other herbs have matured, including many fern allies, *e.g. Selaginella ostenfeldii* Hier. (Selaginellaceae) and ferns such as *Aniscocampium cumingianum* Presl and *Kuniwatsukia cuspidata* (Bedd.) Pichi-Ser. (both Athyriaceae). By August, the ground is covered with a diverse herbaceous vegetation which dies back and later burns with the onset of the following dry season. *Dryopteris cochleata* (D. Don) C. Chr. (Dryopteridaceae), with its bimorphic fronds, is a characteristic fern among the ground flora. The grass most characteristic of the ground flora in bamboo + deciduous forest is *Oryza meyeriana* (Zoll. & Mor.) Baill. var. *granulata* (Watt) Duist. (Gramineae). Other common grasses, which also occur in other habitats, are *Microstegium vagans* (Nees *ex* Steud.) A. Camus and *Panicum notatum* Retz. (both Gramineae). They are a serious problem for forest regeneration, since they are very combustible. Man-made fires, to clear the ground vegetation for gathering mushrooms and hunting, are common in such forest. A total of 316 herb species have been recorded in bamboo + deciduous forest, of which 294 are ground herbs. Of those, 65% are perennial.

Deciduous Dipterocarp–Oak Seasonal Forest (dof)

In seasonally dry or degraded areas, from the lowlands up to about 800–900 m elevation, deciduous dipterocarp–oak forest replaces bamboo + deciduous forest. It is a secondary, fire climax forest which merges with bamboo + deciduous forest, but is never replaced with mixed evergreen + deciduous forest (Photo 2).

Evidence for this claim comes from Maxwell's participation in an ecological survey of Mae Yom National Park, Prae Province, which is the last remaining, albeit rapidly disappearing, teak forest in Thailand (Mahidol University, 1992; Maxwell, 1999). Twenty transect lines spaced 2 km apart were established from the Yom River west following *Tectona grandis* L.f. (Verbenaceae, teak) to its upper limit. The lower 18 transects included **bb/df** facies, while the upper two lines, in clear-cut areas, were **dof**. An area between transects 18–19 was mixed **bb/df** and **dof**. The **dof** had no **bb/df** components. This shows that **dof** is secondary vegetation, since there was no trace of it in the lower part of the forest. It was not until this evidence was realized that definite conclusions concerning the origin, in this case from destroyed **bb/df**, could be made. Since **dof** is so abundant in NE Thailand, as well as in the lowlands of northern Thailand, it must be assumed that the original vegetation was primary, *i.e.* lowland evergreen, **bb/df**, and **mxf** (Table 4). In Khong District, Champasak Province, southern Laos, the original vegetation was mixed evergreen + deciduous seasonal forest (**mxf**) with an elevation range of 60– *c.* 239 m. Destruction of this vegetation has resulted in regrowth of **dof** (Maxwell, 2000). It is interesting to note that **dof**, when maintained by annual fire plus constant degredation by man, does not regenerate into its original facies. The soil in **dof** is generally more exposed, very eroded, and of inferior fertility than that found in **egf**, **bb/df**, and **mxf**.

Typically, **dof** occurs in lowlands and along dry ridges with little or no top soil, alternating with bamboo + deciduous forest in the moister gullies. Fires are very common in this forest type (Photo 4). Where they occur frequently, oaks (Fagaceae) may be rare or absent, but if such areas are protected from fire for 30 years or more, they can slowly re-establish themselves, provided mature, seed-producing trees survive nearby (*e.g. Quercus kerrii* Craib var. *kerrii*, *Castanopsis diversifolia* King *ex* Hk. f., and *Lithocarpus elegans* (Bl.) Hatus. *ex* Soep. (Fagaceae) (Kafle, 1997 and Meng, 1997)). In burnt areas at the upper elevation limits of this forest type, pine (*Pinus kesiya* Roy. *ex* Gord. (Pinaceae)) sometimes grows with the dipterocarps. Such forest is termed deciduous dipterocarp–oak + pine forest (Photo 5). *Pinus merkusii* Jungh. & De Vriese, formerly abundant from as low as *c.* 600 m, can only be found in one place on the southern side of Doi Sutep at 1200 m. This species, as well as *P. kesiya*, have been nearly extirpated because of logging, damage to mature trees by resin and kindling collectors, and habitat destruction (Photo 6).

As noted above, **dof** grows in places where the orginal primary forest, *i.e.* lowland evergreen, **bb/df**, and **mxf**; has been destroyed. Another possible source of **dof** is in lowland areas that orginally included *Pinus merkusii*, *i.e.* **dof** + pine forest. There are a few remnant areas where **dof** + pine forest is still found in lowland areas, *e.g.* the Wiang Haeng area in Chiang Dao District, Chiang Mai Province and at Doi Kuhn Tan National Park, Lamphun–Lampang Provinces (Maxwell *et al.*, 1995). In late February 2000, Maxwell had an opportunity to visit an area in

Toong Hoa Chang District, Lampoon Province, where *Pinus merkusii* was found, albeit sparsely, at 550 m in **dof**. The removal of *Pinus merkusii*, which has probably happened extensively in the past, could also be another reason for the development of **dof**. As far as Doi Sutep–Pui National Park is concerned, there is no evidence for the origin of **dof**, but it is assumed that both the destruction of **bb/df** and removal (to the point of extirpation below 1000 m) of *Pinus merkusii* are involved. The original extent of **bb/df** in northern Thailand is well known, since most of this kind of forest has been destroyed in the past 100 years (De'Ath, 1992). Similar information for *Pinus merkusii* is lacking, but it is certain that it has been exploited for centuries and its original distribution and abundance have been reduced considerably. Both original teak-dominated **bb/df** and lowland **dof** with *Pinus merkusii* are absent in the national park.

In **dof**, most of the tree species which have been recorded there (82%) are completely deciduous, shedding their leaves in the dry season and flushing green again, usually before the onset of the rainy season. The trees are much shorter (rarely exceeding 20 m) than in bamboo + deciduous forest and the canopy is open or irregular. This allows a distinctive ground layer to develop, dominated by grasses and sedges which, along with dead leaves falling from the trees in the dry season, provide ample fuel for ground fires. Woody climbers are rare in this forest type and the shrub layer consists mainly of the saplings of the common tree species. Large bamboos are generally absent. Although the ground flora of deciduous dipterocarp–oak forest tends to be quite similar to that of bamboo + deciduous forest, the trees are very different.

With only 99 tree species, of which 24 are common or abundant, deciduous dipterocarp–oak forest has a relatively low tree species richness compared with the other forest types. In many of the most degraded areas, especially along ridge crests the tree *Dipterocarpus tuberculatus* Roxb. var. *tuberculatus* (Dipterocarpaceae) approaches dominance, but on gentle slopes or in slightly moister areas, this species tends to be replaced by *D. obtusifolius* Teijsm. *ex* Miq. var. *obtusifolius*. Other dominating tree species of the Dipterocarpaceae include *Shorea obtusa* Wall. *ex* Bl. and *S. siamensis* Miq. var. *siamensis* (Dipterocarpaceae). The most characteristic members of the Fagaceae are *Quercus kerrii* Craib var. *kerrii*, *Q. aliena* Bl., *Q. brandisiana* Kurz, and *Castanopsis argyrophylla* King *ex* Hk. f. (the last is one of the very few evergreen tree species in deciduous dipterocarp–oak forest). The small, fire resistant palm, *Phoenix loureiri* Kunth var. *loureiri* (Palmae), is an easily recognized indicator species of this forest type. Another particularly characteristic tree is *Ochna integerrima* (Lour.) Merr. (Ochnaceae). Also common are *Buchanania lanzan* Spreng. and *B. glabra* Wall. *ex* Hk. f., (both Anacardiaceae), *Craibiodendron stellatum* (Pierre) W. W. Sm. (Ericaceae), *Eugenia cumini* (L.) Druce (Myrtaceae), *Dalbergia cultrata* Grah. *ex* Bth. (Leguminosae, Papilionoideae), *Gluta usitata* (Wall.) Hou (Anacardiaceae), *Symplocos racemosa* Roxb. (Symplocaceae, Photo 7), and *Strychnos nux-vomica* L. (Loganiaceae). Two tree species exhibit rapid leaf turnover, flushing new leaves at the same time as the old leaves are shed, *viz. Tristaniopsis burmanica* (Griff.) Wils. & Wat. var. *rufescens* (Hance) Parn. & Lug. (Myrtaceae), which is abundant and highly characteristic of this forest type, and *Anneslea fragrans* Wall. (Theaceae), which is also found in other forest types. At higher elevations (650–800 m) these two species, along with *Aporusa villosa* (Lindl.) Baill. (Euphorbiaceae), become very common (Elliott, Maxwell, & Beaver, 1989).

Deciduous dipterocarp–oak forest supports only 14 species of woody climbers, but the deciduous species *Spatholobus parviflorus* (Roxb.) O.K. (Leguminosae, Papilionoideae), *Aganosma marginata* (Roxb.) G. Don (Apocynaceae), and *Celastrus paniculatus* Willd. (Celastraceae) can be easily found.

Shrubs (29 species) and treelets (48 species) are abundant. Some common examples are: *Helicteres isora* L. (Sterculiaceae), *Grewia abutilifolia* Vent. *ex* Juss. and *Grewia lacei* Drum. & Craib (Tiliaceae), *Desmodium motorium* (Houtt.) Merr., *Desmodium triangulare* (Retz.) Merr., and *Indigofera cassioides* Rottl. *ex* DC. (all Leguminosae, Papilionoideae); *Gardenia obtusifolia* Roxb. *ex* Kurz and *Pavetta fruticosa* L. (both Rubiaceae), *Strobilanthes apricus* (Hance) T. And. var. *pedunculatus* (Craib) Ben. (Acanthaceae), *Premna herbacea* Roxb. and *Premna nana* Coll. & Hemsl. (Verbenaceae), *Breynia fruticosa* (L.) Hk. f., *Breynia glauca* Craib, *Sauropus bicolor* Craib var. *bicolor*, and *Sauropus quadrangularis* (Willd.) M.-A. var. *quadrangularis* (all Euphorbiaceae). *Pueraria wallichii* DC. (Leguminosae, Papilionoideae) grows as a deciduous shrub, which is often scandent, while *Mussaenda parva* Wall. *ex* G. Don (Rubiaceae, Photo 24) can be found as a deciduous vine, woody climber, or scandent shrub.

Vines are also common with *Dunbaria bella* Prain (Leguminosae, Papilionoideae), *Solena amplexicaulis* (Roxb.) Ghandi (Cucurbitaceae), *Streptocaulon juventas* (Lour.) Merr. (Asclepiadaceae), and *Argyreia henryi* Craib (Convolvulaceae) commonly found in open, often burned, areas.

Forty-seven of the recorded vascular plant species in **dof** live as epiphytes. Some of the most charateristic are evergreen, succulent, vines and creepers in the Asclepiadaceae, *viz. Dischidia major* (Vahl) Merr., which has two kinds of leaves, *i.e.* normal and bladder-like ones which have a symbiotic relationship with ants; *Dischidia nummularia* R. Br. (Photo 3), and *Hoya kerrii* Craib, which is less common than *Hoya verticillata* (Vahl) G. Don var. *verticillata.* Numerous, succulent, evergreen and deciduous *Orchidaceae* (orchids) are also found, but as with the Asclepidaceae taxa noted above, have been severely reduced in abundance by excessive collection for their commercial horticultural value. Some of these include: *Cleisomeria lanata* (Lindl.) Lindl., *Cleisostoma arietinum* (Rchb. f.) Garay, *Cymbidium ensifolium* (L.) Sw., *Dendrobium lindleyi* Steud., *Dendrobium porphyrophyllum* Guill., *Dendrobium secundum* (Bl.) Lindl., *Eria acervata* Lindl., *Eria pannea* Lindl., *Rhynchogyna saccata* Seid. & Garay, and *Vanda brunnea* Rchb. f. Two deciduous Polypodiaceae (ferns), both with characteristcally distinct growth forms, are also frequently seen in **dof**, *viz. Drynaria rigidula* (Sw.) Bedd. and *Platycerium wallichii* Hk.

Of the 274 ground herbs which have been recorded in **dof**, 111 (40 %) are annuals. Some of the more common examples are: *Polygala longifolia* Poir. (Polygalaceae), *Biophytum umbraculum* Welw. (Oxalidaceae), *Crotalaria alata* D. Don, *C. albida* Hey. *ex* Roth, *C. neriifolia* Wall. *ex* Bth., *Indigofera hirsuta* L., *Uraria lacei* Craib (all Leguminosae, Papilionoideae), *Blumea lacera* (Burm. f.) DC., *Gynura integrifolia* Gagnep., and *Pluchea polygonata* (DC.) Gagnep. (all Compositae). Robust, deciduous Gramineae (grasses) dominate and are all very combustible during the hot–dry season, especially March–May. Some of the more common representatives are: *Apluda mutica* L., *Aristida cumingiana* Trin. & Rupr., *Arundinella setosa* Trin. var. *setosa*, *Capillipedium assimile* (Steud.) A. Camus, *Eulalia siamensis* Bor, *Heteropogon contortus* (L.) P. Beauv. *ex* Roem. & Schult., *Polytoca digita* (L. f.) Druce, and *Schizachyrium sanguineum* (Retz.) Alst. Cyperaceae (sedges) are also common in this fire-prone habitat with *Bulbostylis barbata* (Rottb.) Cl., *Carex continua* Cl., *Cyperus cuspidatus* Kunth, *Fimbristylis straminea* Turr., *Rhynchospora rubra* (Lour.) Mak., *Scleria kerrii* Turr., and *Scleria levis* Retz. as typical examples. Members of the *Zingiberaceae* (gingers) are quite common with *Curcuma ecomata* Craib, *Curcuma parviflora* Wall., *Curcuma zedoaria* (Berg.) Rosc., *Globba nuda* K. Lar., *Globba villosula* Gagnep., ,and *Kaempferia rotunda* L.—all of which are deciduous. Other common ground herbs include *Barleria cristata* L. (Acanthaceae), *Geniosporum coloratum* (D. Don) O.K. (Labiatae), *Striga masuria* (B.-H. *ex* Bth.) Bth. (Scrophulariaceae), and *Aeginetia indica* Roxb. (Orobanchaceae)—the latter two being parasitic on the roots of other plants. *Selaginella ostenfeldii* Hiern. (Selaginellaceae) is a common, deciduous, ground fern ally while *Adiantum philippense* L., *A. zollingeri* Mett. *ex* Kuhn, and *Cheilanthes tenuifolia* (Burm. f.) Sw. (all Parkeriaceae) are common ferns of this forest type.

Mixed Evergreen + Deciduous, Seasonal Forest (mxf)

From about 800 m elevation (600 m near permanent streams) to about 1000 m, there is a mixture of deciduous and evergreen trees. Mixed evergreen + deciduous forest is a transitional zone between evergreen and deciduous forest types, but supports many species which do not occur in the other forest types. Such forest has exceptionally high tree species richness, up to 90 trees per hectare with a dbh of 10 cm or more (Elliott, Maxwell , & Beaver, 1989). In general, canopy height varies from 20 to 30 m, but emergent trees exceeding 30 m are fairly common. Canopy cover is usually complete, though less dense than in evergreen forest. Epiphytes are relatively common. Bamboos are present, but less prevalent than in bamboo + deciduous forest. There is usually a dense ground layer of herbs and tree seedlings. Grasses occasionally dominate the ground layer where fire has occurred.

A total of 217 tree species have been recorded in mixed evergreen + deciduous forest, of which only about 43% are deciduous. There are strong similarities between the tree floras of mixed evergreen + deciduous forest and bamboo + deciduous forest. Of the 38 tree species, common or abundant in the former, 21 (55%) are shared with the latter. The most easily recognized evergreen canopy tree species, characteristic of this forest type, are the tall, emergent, evergreen, dipterocarps, *viz. Dipterocarpus costatus* Gaertn. f. (Photo 8) and *D. turbinatus* Gaertn. f. (Dipterocarpaceae). Their massive grey trunks, small leaves, and open, broad crowns readily distinguish them from the large-leaved dipterocarps of deciduous dipterocarp–oak forest. *Mangifera caloneura* Kurz (Anacardiaceae) and *Eugenia albiflora* Duth. *ex* Kurz (Myrtaceae) are also common, while *Balakata baccata* (Roxb.) Ess. (Euphorbiaceae) is shared with evergreen forest. *Duabanga grandiflora* (Roxb. *ex* DC.) Walp. (Sonneratiaceae) and *Irvingia malayana* Oliv. *ex* Benn. (Irvingiaceae) are tall evergreen species which are also found in this habitat. Some common deciduous canopy trees are *Lagerstroemia cochinchinensis* Pierre var. *ovalifolia* Furt. & Mont. and *L. tomentosa* Presl (Lythraceae), *Spondias pinnata* (L. f.) Kurz (Anacardiaceae), *Terminalia mucronata* Craib & Hutch. (Combretaceae), and *Engelhardia serrata* Bl. var. *serrata* (Juglandaceae). Common evergreen understorey trees include *Garcinia speciosa* Wall. (Guttiferae), *Lithocarpus elegans* (Bl.) Hatus. *ex* Soep. (Fagaceae), *Scleropyrum wallichianum* Arn. var. *siamensis H. Lec.* (Santalaceae), *Turpinia pomifera* (Roxb.) Wall. *ex* DC. (Staphyleaceae), *Knema laurina* (Bl.) Warb. (Myristicaceae), *Cinnamomum iners* Reinw. *ex* Bl. (Lauraceae), and *Baccaurea ramiflora* Lour. (Euphorbiaceae), while *Bauhinia variegata* L. (Leguminosae, Caesalpinioideae) is deciduous.

Seventy-one treelet and 19 shrub species have been recorded in **mxf**. Treelets and shrubs frequently seen include *Millettia caerulea* Grah. *ex* Bak. (Leguminosae, Papilionoideae), which is deciduous and *Ixora cibdela* Craib var. *puberula* Craib and *Psychotria opioxyloides* Wall. (both Rubiaceae), both of which are evergreen.

Woody climbers are common. Sixty two species have been recorded in **mxf**, including *Combretum trifoliatum* Vent., *C. latifolium* Bl. (Combretaceae), and *Ventilago denticulata* Willd. (Rhamnaceae), all of which are deciduous; while *Combretum sundaicum* Miq. (Combretaceae), *Rhamnus nipalensis* (Wall.) Laws. (Rhamnaceae), and *Tetrastigma laoticum* Gagnep. (Vitaceae) are common evergreen representatives, especially along streams.

Fifty-seven of the vascular plant species recorded in **mxf** grow as epiphytes. The most specious groups are the figs (Moraceae, many of which are epiphytes only when young), orchids, and Pteridophytes, but the Gesneriaceae and Loranthaceae are also represented. Epiphytes, particularly characteristic of **mxf** include, *Bulbophyllum congestum* Rol. and *B. propinquum* Krzl. (Orchidaceae) and the hemiparasites *Helixanthera pulchra* (DC.) Dans. and *Dendrophthoe pentandra* (L.) Miq. (both Loranthaceae).

The ground flora is diverse and includes both annual, perennial, deciduous and evergreen species. Of the 278 ground herbs recorded in **mxf**, 25 % are annuals. Common deciduous herbs include *Strobilanthes anfractuosus* Cl. *ex* Hoss. and *Ruellia siamensis* Im. (both Acanthaceae), *Begonia integrifolia* Dalz. (Begoniaceae), and *Zingiber kerrii* Craib and *Globba villosula* Gagnep. (both Zingiberaceae). Evergreen herb species are more common (comprising 60% of ground perennials) and include: *Tacca chantrieri* Andr. (Taccaceae), *Amomum uliginosum* Koen. (Zingiberaceae), while *Thelypteris arida* (D. Don) Mort. (Thelypteridaceae) and *Cibotium barometz* (L.) J. Sm. (Dicksoniaceae) are typical ferns. Seedlings, saplings, and immature herbs are also common constituents of the ground flora, especially in areas that are shaded and less disturbed.

Primary, Evergreen, Seasonal Forest Without Pine (egf)

The upper part of the mixed evergreen + deciduous forest usually merges with the lower part of the evergreen forest at *c.* 900–950 m elevation. The vascular flora of evergreen forest is quite distinct. The main canopy of evergreen forest is higher and denser than that of the other forest types, often exceeding 30 m in height. Emergent trees sometimes occur and beneath the main canopy there is usually a lower story, comprised of smaller trees, treelets, and shrubs. Woody climbers are common. The high abundance of epiphytes is an obvious feature of evergreen forest, especially on exposed slopes and near summits, where in addition to the vascular plants mentioned below, bryophytes and lichens encrust tree trunks and branches. Tall bamboos are scarce. The ground flora is often dense and consists of tree seedlings and herbs, including several which have a saprophytic or parasitic way of life. Grasses only invade into burnt or otherwise disturbed areas. Fires are less common in evergreen than in deciduous forests, but evergreen forest is less resilient of fire damage than deciduous forest. In particular shrubs and the ground flora take many years to recover after burning.

Evergreen forest supports more tree species than any of the other forest types, 250 have been recorded, of which only 67 (27%) are deciduous. Although no species or genus dominates, several families tend to be better represented there than in the deciduous forest types *e.g.* Lauraceae, Fagaceae, Theaceae, Moraceae, Magnoliaceae, *etc.* Most canopy trees tend to be evergreen. Characteristic ones include *Alseodaphne andersonii* (King *ex* Hk. f.) Kosterm., *Beilschmiedia* aff. *intermedia* Allen, and *Cryptocarya amygdalina* Nees (all Lauraceae), *Artocarpus lanceolata* Trec., and several gigantic "strangling" figs, *e.g. Ficus altissima* Bl. and *F. benjamina* L. var. *benjamina* (all Moraceae). Of the Fagaceae, *Quercus vestita* Rehd. & Wils., *Q. glabricupula* Barn., *Q. incana* Roxb., and *Q. lineata* Bl. are all highly characteristic, while *Castanopsis* spp. tend to be shared with other forest types, *e.g. Castanopsis acuminatissima* (Bl.) A. DC. and *Castanopsis armata* (Roxb.) Spach. Other characteristic evergreen trees include *Pyrenaria garrettiana* Craib (Theaceae), *Garcinia mckeaniana* Craib (Guttiferae), *Casearia grewiifolia* Vent. var. *gelonioides* (Bl.) Sleum. (Flacourtiaceae), *Chionanthus sutepensis* (Kerr) P. S. Green (Oleaceae), *Elaeocarpus prunifolius* Wall. *ex* C. Muell. (Elaeocarpaceae), *Dysoxylum* aff. *hamiltonii* Hiern (Meliaceae), *Ostodes paniculata* Bl. (Euphorbiaceae), and *Diospyros marlabarica* Cl. (Ebenaceae). Very few deciduous tree species are truly characteristic of evergreen forest. Most also occur in the deciduous forest types. A few of the larger deciduous canopy species include *Michelia champaca* L. var. *champaca* and *Michelia baillonii* Pierre (both Magnoliaceae), *Homalium ceylanicum* (Gardn.) Bth. (Flacourtiaceae), *Melia toosendan* Sieb. & Zucc. (Meliaceae), and *Morus macroura* Miq. (Moraceae). Some of the deciduous trees which are restricted to evergreen forest are rather rare *e.g. Hovenia dulcis* Thunb. (Rhamnaceae), *Acrocarpus fraxinifolius* Wight & Arn. (Leguminosae, Caesalpinioideae), and *Litsea zeylanica* (Nees) Nees (Lauraceae). Other deciduous trees more typical of deciduous forest types sometimes spread up into evergreen forest where disturbance, especially fire, has occurred. Common tree species shared with other forest types include *Balakata baccata* (Roxb.) Ess. (Euphorbiaceae), *Schima wallichii* (DC.) Korth. (Theaceae), *Gluta obovata* Craib (Anacardiaceae), *Duabanga grandiflora* (Roxb. *ex* DC.) Walp. (Sonneratiaceae), and *Mischocarpus pentapetalus* Radlk. (Sapindaceae).

The understorey is denser than that of forests at lower elevations and is especially diverse in stream valleys. Understorey trees include: *Phoebe lanceolata* (Wall. *ex* Nees) Nees (Lauraceae), *Acronychia pedunculata* (L.) Miq. (Rutaceae), *Sarcosperma arboreum* Bth. (Sapotaceae), and *Diospyros glandulosa* Lace (Ebenaceae). *Styrax benzoides* Craib (Styracaceae) and *Maesa ramentacea* Wall. *ex* Roxb. (Myrsinaceae) are also common, but grow in disturbed places. Some understory trees species, rarely exceeding 15 m tall, include *Elaeocarpus prunifolius* Wall. *ex C. Muell.* (Elaeocarpaceae), *Semecarpus cochinchinensis* Engl. (Anacardiaceae), *Turpinia pomifera* (Roxb.) Wall. *ex* DC. (Staphyleaceae), *Eugenia fruticosa* (DC.) Roxb. (Myrtaceae), *Actinodaphine henryi* Gamb. (Lauraceae), and *Helicia nilagirica* Bedd. (Proteaceae)—all of which are evergreen. *Spondias axillaris* Roxb. (Anacardiaceae) and *Engelhardia spicata* Lechen. *ex* Bl. var. *spicata* (Juglandaceae) are deciduous representatives.

Treelets and shrubs (91 and 22 recorded species, respectively) are numerous. Characteristic treelets include *Vernonia volkameriifolia* DC. var. *volkameriifolia* (Compositae), *Glochidion kerrii* Craib (Euphorbiaceae), *Debregesia longifolia* (Burm. f.) Wedd. (Urticaceae), *Archidendron glomeriflorum* (Kurz) Niels. (Leguminosae, Mimosoideae), the palm *Areca laosensis* Becc. (Palmae), and *Litsea salicifolia* (Roxb. *ex* Nees) Hk. f. and *L. cubeba* (Lour.) Pers. var. *cubeba* (both Lauraceae). Characteristic evergreen shrubs include *Psychotria ophioxyloides* Wall. (Rubiaceae) and *Phlogacanthus curviflorus* (Wall.) Nees var. *curviflorus* (Acanthaceae) in wet places. *Pandanus penetrans* St. John (Pandanaceae) and *Musa itinerans* Cheesm. (Musaceae) are particularly characteristic of shaded, undisturbed stream valleys. Also common are *Clerodendrum serratum* (L.) Moon var. *wallichii* Cl. (Verbenaceae), *Ardisia virens* Kurz (Myrsinaceae), and *Euodia triphylla* DC. (Rutaceae).

A high species richness of woody climbers (78 species) is a notable feature of evergreen forest. Some characteristic evergreen examples include: *Toddalia asiatica* (L.) Lmk. (Rutaceae), *Ficus parietalis* Bl. (Moraceae), *Bauhinia glauca* (Wall. *ex* Bth.) Bth. ssp. *tenuiflora* (Watt *ex* Cl.) K. & S.S. Lar. (Leguminosae, Caesalpinioideae), *Combretum punctatum* Bl. ssp. *squamosum* (Roxb.

ex G. Don) Exell (Combretaceae), and *Uncaria macrophylla* Wall. (Rubiaceae). Also common are several species of *Tetrastigma* (*e.g. T. laoticum* Gagnep. and *T. obovatum* (Laws.) Gagnep. (Vitaceae)) and *Mucuna macrocarpa* Wall. (Leguminosae, Papilionoideae, Photo 23), which also occur in mixed evergreen + deciduous forest. Rattans (Palmae) include three species which, because of extensive human explotation and loss of habitat, are much less common than they used to be. *Calamus kerrianus* Becc. and *Plectocomia kerrana* Becc., both evergreen woody climbers and originally described from specimens collected on Doi Sutep, are continually destroyed for their valuable stems ("cane"), which are used for many purposes. Although *Calamus kerrianus* is frequently seen immature, it is rarely found mature and even less so in flower or fruit. Its range is from *c.* 700–1525 m in mainly **mxf** and **egf**. *Plectocomia kerrana* is a much more robust species and is only known from the upper part of Chang Kian Valley, 1350–1400 m, where it is severely threatened by people living in the area. *Calamus arborescens* Griff., a treelet or shrub, is only known from the middle of Chang Kian Valley at 1050 m.

Epiphytes abound in evergreen forest. The 82 species recorded there include trees, shrubs, vines, and herbs. The trees include the so–called "strangling" figs which begin life as epiphytes, *e.g. Ficus superba* (Miq.) Miq. var. *superba* (Moraceae), and the very rare *Sorbus verrucosa* (Decne.) Rehd. var. *verrucosa* (Rosaceae). Characteristic epiphytic shrubs include *Rhododendron vietchianum* Hk. (Ericaceae), several evergreen hemiparasitic species of the family Loranthaceae, *e.g. Macrosolen cochinchinensis* (Lour.) Tiegh., *Viscum ovalifolium* Wall. *ex* DC., and *V. orientale* Willd.; and the very rare *Fagraea ceilanica* Thunb. (Loganiaceae). Characteristic epiphytic vines include the rather uncommon species *Rhaphidophora glauca* (Wall.) Schott (Araceae) and *Hoya siamica* Craib (Asclepiadaceae). Epiphytic herbs are nearly all perennials. Species particularly characteristic of evergreen forest include: *Hedychium ellipticum* Ham. *ex* J. Sm. (Zingiberaceae), orchids, *e.g. Bulbophyllum bittnerianum* Schltr., *Coelogyne schultesii* Jain & Das., and *Trichotosia dasyphylla* (Par. & Rchb. f.) Krzl. (Orchidaceae); ferns, *e.g. Lepisorus nudus* (Hk.) Ching (Polypodiaceae) and *Davallodes membranulosum* (Hk.) Copel. (Davalliaceae), and members of the Gesneriaceae *e.g. Didymocarpus wattianus* Craib and *Aeschynanthus hosseusii* Pell.

The herbaceous ground flora (321 recorded species) is very diverse and includes numerous species of dicots, monocots, and ferns. Some of the most characteristic ferns of this forest type are *Brainea insignis* (Hk.) J. Sm. (Blechnaceae) and *Dicranopteris linearis* (Burm. f.) Underw. var. *linearis* (Gleicheniaceae), in open, fire-damaged places; while *Arachnoides henryi* (Christ) Ching and *Tectaria herpetocaulos* Holtt. (both Dryopteridaceae), *Thelypteris subelata* (Bak.) K. Iw. (Thelypteridaceae), and *Diplazium dilatatum* Bl. (Athyriaceae) are in shaded, mostly pristine areas. Some common dicots are: *Impatiens violaeflora* Hk. f. (Balsaminaceae), *Hydrocotyle siamica* Craib (Umbelliferae), *Ophiorrhiza hispidula* Wall. *ex* G. Don var. *hispidula* and *Geophila repens* (L.) I.M. John. (both Rubiaceae), *Wedelia montana* (Bl.) Boerl. var. *wallichii* (Less.) H. Koy. (Compositae), and *Pilea trinervia* Wight (Utricaceae). Frequently encountered herbaceous monocots are: *Aneilema sinicum* Lindl., *Commelina diffusa* Burm. f., and *Murdannia gigantea* (Vahl) Bruck (all Commelinaceae); *Globba kerrii* Craib, *G. villosula* Gagnep., and *Zingiber smilesianum* Craib (all Zingiberaceae), *Acorus gramineus* Sol. *ex* W. Ait., an epilithic rheophyte, and *Amorphophallus corrugatus* N.E. Br. (both Araceae), the very rare *Vanilla siamensis* Rol. *ex* Dow. (Orchidaceae, a vine), and *Carex baccans* Nees (Cyperaceae). Parasitic or saprophytic members of the ground flora include several *Balanophora* species, *viz. B. abbreviata* Bl. and

B. fungosa J. R. & G. Forst. ssp. *indica* (Arn.) B. Han. var. *indica* (Balanophoraceae), *Aeginetia indica* Roxb. (Orobanchaceae, Photo 9), *Sapria himalayana* Griff. (Rafflesiaceae), and rare orchids, *e.g. Epipogium roseum* (D. Don) Lindl. and *Stereosandra javanica* Bl. (Orchidaceae).

Primary Evergreen, Seasonal Forest With Pine (eg/pine)

On fire-prone, exposed ridges at elevations of about 950–1,800 m *Pinus kesiya* Roy. *ex* Gord. (Pinaceae, pine) grows together with other evergreen forest tree species and in some places it dominates the forest. The canopy of evergreen forest with pine tends to be more open than that of evergreen forest. Some species more commonly found with *Pinus kesiya* than elsewhere, mostly due to the lower pH of the soil, include *Viburnum inopinatum* Craib (Caprifoliaceae), *Helicia nilagirica* Bedd. (Proteaceae), *Myrica esculenta* B.-H. *ex* D. Don (Myricaceae); *Castanopsis argyrophylla* King *ex* Hk. f., *Quercus brandisiana* Kurz, which is deciduous, and *Q. leticellata* Barn. (all Fagaceae). Where fires are particularly frequent, plants of deciduous dipterocarp–oak forest spread up into the pine forests at much higher elevations than is typical, *e.g. Craibiodendron stellatum* (Pierre) W.W. Sm. and *Vaccinium sprengelii* (D. Don) Sleum. (Photo 10) (both Ericaceae), *Anneslea fragrans* Wall. (Theaceae), and *Aporusa villosa* (Lindl.) Baill. In such areas, trees of the Fagaceae family are also common, *e.g. Castanopsis armata* (Roxb.) Spach, *C. tribuloides* (Sm.) A. DC., *Lithocarpus elegans* (Bl.) Hatus. *ex* Soep., *L. fenestratus* (Roxb.) Rehd., and *Quercus vestita* Rehd. & Wils. Altogether 99 tree species have been recorded in **eg/pine**, of which only 27 (27%) are deciduous.

The ground flora includes 263 recorded herb species, both annuals (32%) and perennials (68%). Annual herbs include: *Blumeopsis flava* (DC.) Gagnep. and *Anaphalis margaritacea* (L.) Bth. & Hk. f. (both Compositae), *Lobeia nicotianaefolia* Roth *ex* Roem. & Schult. (Campanulaceae) and *Exacum pteranthum* Wall. *ex* Colebr. (Genitanaceae). Some deciduous, perennial counterparts are *Inula cappa* (Ham. *ex* D. Don) DC. *forma cappa* (Compositae), *Pratia begoniifolia* (Wall. *ex* Roxb.) Lindl. (Campanulaceae), a creeper, *Anthogonium gracile* Wall. *ex* Lindl. (Orchidaceae)., *Oleandra undulata* (Willd.) Ching (Oleandraceae), and *Kuniwatsukia cuspidata* (Bedd.) Pic.–Ser. (Athyriaceae).

Epiphytes (86 recorded species) are especially conspicuous and include both evergreen species (68%) and annual or deciduous ones (32%). Epiphytic, hemi-parasitic Loranthaceae, all evergreen shrubs, are common with *Dendrophthoe pentandra* (L.) Miq., *Helixanthera parasitica* Lour., *Macrosolen avenis* (Bl.) Dans., *Scurrula ferruginea* (Roxb. *ex* Jack) Dans., and *Viscum ovalifolium* Wall. *ex* DC.. Autotrophic evergreen, epiphytic and epilithic shrubs are frequently encountered with *Agapetes hosseana* Diels (Ericaceae), *Aeschynanthus hildebrandii* Hemsl. and *Aeschynanthus hosseusii* Pell. (Gesneriaceae). Some common evergreen epiphytic and epilithic herbs are: *Vittaria flexuosa* Fee (Vittariaceae), *Elaphoglossum yoshinagae* (Yat.) Mak. (Lomariopsidaceae), *Lepisorus bicolor* (Tag.) Ching, and *Pyrrosia stigmosa* (Sw.) Ching (both Polypodiaceae). Deciduous representatives include *Didymocarpus aureoglandulosus* Cl., *Didymocarpus kerrii* Craib (Gesneriaceae, Photo 11), *Araiostegia pulchra* (D. Don) Copel. (Davalliaceae); *Crypsinus cruciformis* (Ching) Tag., *Crypsinus oxylobus* (Wall. *ex* O.K.) Sledge, *Drynaria propinqua* (Wall. *ex* Mett.) J. Sm. *ex* Bedd. and *Microsorum membranaceum* (D. Don) Ching (all Polypodiaceae).

Epiphytic Orchidaceae, all of which have been extensively exploited for the horticulture market, are now much less common than they were 25 years ago. Some evergreen examples are: *Cleisostoma fuerstenbergianum* Krzl., *Coelogyne trinervis* Lindl., *Dendrobium christyanthum* Rchb. f., *Dendrobium cariniferum* Rchb. f., *Pholidota articulata* Lindl., and *Trichotosia dasyphylla* (Par. & Rchb. f.) Krzl. Some deciduous representatives are: *Bulbophyllum secundum* Hk. f., *Bulbophyllum suavissimum* Rol., *Dendrobium falconeri* Hk., *Dendrobium heterocarpum* Lindl., *Diploprora championi* (Lindl.) Hk. f., and *Oberonia pachyphylla* King & Pantl. *Zeuxine affinis* (Lindl.) Bth. *ex* Hk. f., a delicate, deciduous, saprophytic ground herb is still commonly found in **eg/pine** areas. *Phaius tankervilleae* (Banks *ex* L'Her.) Bl., a particularly showy, evergreen ground orchid has perhaps become extirpated from the park, while the deciduous *Tainia viridifusca* (Hk.) Bth. & Hk. f., with highly conspicuous inflorescences, has become extremely rare.

Thirty-five vine species have been recorded in **eg/pine**, including: *Codonopsis javanica* (Bl.) Hk. f. (Campanulaceae), an evergreen species, while *Clitoria mariana* L. and *Shuteria involucrata* (Wall.) Wight & Arn. var. *involucrata* (both Leguminosae, Papilionoideae) are deciduous.

Summit Flora

Hosseus and Kerr collected many specimens in the summit areas (1500–1685 m) of Doi Sutep and Doi Pui, many of which were described as new species. This summit flora, because of the peculiar habitats it requires, includes many species that are not found or are found in less abundance at lower elevations. The original forest was **eg/pine** with a dense **egf** flora in the upper water catchment valleys. Unfortunately, the upper summit area, *c.* 1600–1685 m, was cleared in 1957 and replanted with *Cupressus torulosa* D. Don (Cupressaceae), which is native to the Himalayas, and *Pinus kesiya* Roy. *ex* Gord. (Pinaceae), a native tree. Although these trees are now mature, much of the original flora has been extirpated. Some surviving relicts of the past can still be found there, but are mixed with weeds, secondary growth, and invading components of **do/pine**.

Table 7 lists 55 species described from Doi Sutep–Pui National Park (type locality) which were not found during our research. Nineteen of these species were originally found at or above 1500 m, while twelve of them were found above 1650 m. It is quite reasonable to assume, especially with those species with a woody habit (*e.g. Camellia connata* (Craib) Craib (Theaceae), *Paramignya surasiana* Craib (Rutaceae), and *Euonymus colonoides* Craib (Celastraceae)), that most, if not all, of them are no longer present in the national park. Other species, *e.g. Hoya engleriana* Hoss. (Asclepiadaceae) and *Dendrobium sutapense* Rol. *ex* Dow. (Orchidaceae), both epiphytic and type locality species, have not been seen since the early days of our work and might also have become extirpated. It is only by visiting other nearby mountains with intact vegetation at elevations above 1650 m that we have been able to get an idea of what the upper summit areas were originally like. These mountains are Doi Intanon (2565 m), Doi Chang (1975 m), and Doi Lahng Gah (2031 m). With the disastrous clearing of the summit area of Doi Pui, along with centuries-old destruction of the summit of Doi Sutep, both places have become more open, drier, and fire-prone. It is most unlikely that the original flora will ever be able (? centuries) to re-establish itself, since a seed source for many of the extirpated plants no long exists nearby (Photo 12).

Some of the original epiphytic flora has returned to the summit of Doi Pui with *Agapetes hosseana* Diels (Ericaceae), *Aeschynanthus lineatus* Craib (Gesneriaceae), *Cheriostylis griffithii* Lindl. and *Trichotosia dasyphylla* (Par. & Rchb.f.) Krzl. (both Orchidaceae); *Crypsinus cruciformis* (Ching) Tag., *Crypsinus oxylobus* (Wall. *ex* O.K.) Sledge, *Lepisorus heterolepis* (Rosenst.) Ching, *Microsorum membranaceum* (D. Don) Ching, and *Polypodium amoenum* (J. Sm. *ex* Hk. & Grev.) Mett. (all Polypodiaceae). In addition to obvious habitat changes, the soil pH on the summit area of Doi Pui has become reduced to below the original **eg/pine** conditions, thus much of the original ground flora has not reappeared. Some evergreen herbs which have returned, albeit in diminished populations, include: *Hydrocotyle siamica* Craib (Umbelliferae), *Strobilanthes anfractuosus* Cl. *ex* Hoss., *Strobilanthes consors* Cl. *ex* Hoss. (Acanthaceae), and *Aspidistra sutepesis* K Lar. (Liliaceae). Deciduous herbs are more common with: *Elsholtzia winitiana* Craib (Labiatae), *Globba clarkei* Baker (Zingiberaceae), *Hypoxis aurea* Lour. (Amaryllidaceae), *Arisaema erubescens* (Wall.) Schott (Araceae), *Asparagus filicinus* Ham. *ex* D. Don and *Paris polyphylla* J. E. Sm. (both Liliaceae); *Crepidium acuminatum* (D. Don) Szlach., *Crepidium orbicularum* (W. W. Sm. & Jeff.) Seid., and *Habenaria stenopetala* Lindl. var. *stenopetala* (all Orchidacae).

Nine plant species, all of which are rare or down to a few individuals, are entirely restricted to summit areas between 1620 and 1685 m above sea level. They are *Poa annua* L. (Gramineae), *Hedychium villosum* Wall. (Zingiberaceae), *Thalictrum foliolosum* DC. (Ranunculaceae), *Aeschynanthus lineatus* Craib (Gesneriaceae), *Strobilanthes consors* Cl. *ex* Hoss. (Acanthaceae), *Alpinia blepharocalyx* K. Sch. (Zingiberaceae) and *Cleisostoma rolfeanum* (King & Pantl.) Garay, *Cymbidium tracyanum* O' Brien, and *Dendrobium sutepense* Rol. *ex* Dow. (all Orchidaceae).

Disturbed Areas and Secondary Growth (da/sg)

Due to extensive and uncontrolled exploitation of the vegetation disturbed areas and secondary growth are common at all elevations. Logging, fire, bulldozing, and various other deleterious effects of development, *e.g.* construction of villages, roads, check dams (Photo 13), and expansion of the agriculutral and tourism industries, have added to the degradation of the natural vegetation. Siltation, flash floods, erosion, exposure, fire, soil removal, trash dumping (Photo 18), grazing, *etc.* are becoming increasingly serious problems.

In recent decades, that is after all the original lowland deciduous forests were logged and almost all upland pines were cut, agricultural activities by Hmong settlers destroyed vast areas of the forest above 1000 m elevation (Photo 14). This resulted in rapid invasion by noxious, herbaceous weeds, many of which are naturalized exotics. This represents the initial stage of plant succession, which, if left undisturbed, would allow woody secondary growth to develop. After a decade, or so, of secondary growth many primary species would begin to appear. However, regeneration to the original degree of biodiversity takes considerably longer—perhaps a century and cannot occur at all, unless a source of seeds of primary forest trees is available nearby (Photo 15).

A total of 288 species of ground herbs survive in disturbed areas or secondary growth, of which exactly half are annuals and half perennials. Annual herbaceous weeds, *i.e.* tertiary growth, all of which require exposure to sunlight for germination and growth, are numerous. Some of the more common representatives found at all elevations include: *Urena lobata* L. ssp. *lobata* var. *lobata* (Malvaceae) *Triumfetta rhomboidea* Jacq. (Tiliaceae), *Mimosa pudica* L. var. *hispida* Bren. (Leguminosae, Mimosoideae), *Passiflora foetida* L. (Passifloraceae); *Borreria laevis* (Lmk.) Griseb., *Hedyotis corymbosa* (L.) Lmk., and *Mitracarpus villosus* (Sw.) DC. (all Rubiaceae); *Ageratum conyzoides* L., *Bidens pilosa* L. var. *minor* (Bl.) Sherff, *Conyza sumatrensis* (Retz.) Walk., *Crassocephalum crepioides* (Bth.) S. Moore, *Eupatorium odoratum*

L., *Spilanthes paniculata* Wall. *ex* DC., *Synedrella nodiflora* (L.) Gaertn., and *Vernonia cinerea* (L.) Less. var. *cinerea* (all Compositae); *Physalis angulata* L. (Solanaceae), *Scoparia dulcis* L. (Scrophulariaceae), *Justicia procumbens* L. (Acanthaceae); *Euphorbia heterophylla* L., *E. hirta* L., *Phyllanthus amarus* Schum. & Thonn., and *P. urinaria* L. (all Euphorbiaceae)—all of which are dicots.

Monocot weeds are also diverse and abundant. Some common examples are: *Commelina diffusa Burm*.f. (Commelinaceae); *Cyperus cyperoides* (L.) O.K., *C. kyllingia* Endl., *Fimbristylis dichotoma* (L.) Vahl spp. *dichotoma* (all Cyperaceae); *Arundinella setosa* Trin. var. *setosa, Cyrtococcum accrescens* (Trin.) Stapf and *C. oxyphyllum* (Steud.) Stapf, *Digitaria setigera* Roth *ex* Roem. & Schult. var. *setigera, Eragrostis nigra* (Nees *ex* Steud.) A. Camus, *Paspalum conjugatum* Berg., *Sacciolepis indica* (L.) Chase, *Setaria palmifolia* (Koen.) Stapf var. *palmifolia*, *Setaria parviflora* (Poir.) Kerg., and *Sporobolus diander* (Retz.) P. Beauv. (all Gramineae). Robust perennial Gramineae (grasses) are especially common in upland areas and include: *Apluda mutica* L., *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. *ex* Hubb. & Vaugh., *Pennisetum pedicellatum* Trin., *Phragmites vallatoria* (Pluk. *ex* L.) Veldk., *Themeda triandra* Forssk., and *Thysanolaena latifolia* (Roxb. *ex* Horn.) Honda.

Eupatorium adenophorum Spreng. (Compositae) and *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae) are robust, evergreen, and very persistent weeds in open, fire-damaged, upland areas. *Mimosa pigra* L. (Leguminosae, Mimosoideae), *Solanum verbascifolium* L. (Solanaceae), and *Lantana camara* L. (Verbenaceae), all naturalized woody weeds, often dominate open, disturbed areas.

Secondary growth treelets and trees are both conspicuous and common and number 36 and 81 recorded species respectively. If left undisturbed, they will be replaced by primary forest trees. Some typical examples are: *Albizia chinensis* (Osb.) Merr. and *Leucaena leucocephala* (Lmk.) De Wit, which is both introduced and cultivated and often becomes locally naturalized (both Leguminosae, Mimosoideae); *Rhus chinensis* Mill. (Anacardiaceae), *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae); *Glochidion sphaerogynum* (M.-A.) Kurz, *Macaranga denticulata* (Bl.) M.-A., *Mallotus paniculatus* (Lmk.) M.-A., and *M. philippensis* (Lmk.) M.-A. (all Euphorbiaceae); *Ficus fistulosa* Reinw. *ex* Bl. and *F. hispida* L. f. var. *hispida* (Moraceae), and *Trema orientalis* (L.) Bl. (Ulmaceae).

Cultivated Plants

Before official curtailment in 1958, *Papaver somniferum* L. (Papaveraceae, opium poppy) and *Cannabis sativa* L. (Cannabidaceae, cannabis) were the main cash crops for upland farmers throughout northern Thailand. These two profitable and environmentally "friendly" crops have been suppressed by the dictates of western developed nations because they contain legally unacceptable narcotics. Since that time, many cash crop substitutes have been introduced, studied, and implemented. Unfortunately, most of these plants are environmentally "unfriendly", not only because they are introduced, but also because they require massive amounts of fertilizers and pesticides—which opium and cannabis do not need. Because of uncontrolled use of fertilizers and pesticides in northern Thailand the environment has suffered because of chemical contamination, while many food products are a public health hazard.

Various cultivars of *Brassica oleracea* L. var. *capitata* L. and *B. rapa* L. (cauliflowers, cabbages, and kale; Cruciferae); *Fragaria vesca* L. (strawberry, Rosaceae), *Apium graveolens*

L. cultivars (celery, Umbelliferae), *Petroselinum crispum* (Mill.) A. W. Hill (parsley, Umbelliferae), cultivars of *Cucurbita moschata* (Duch. *ex* Lmk.) Duch. *ex* Poir. and *C. pepo* L. (gourds, pumpkins, squashes; Cucurbitaceae), cultivars of *Allium cepa* L. (onions, shallots) and *A. sativum* L. (garlic, both Liliaceae) are all commonly grown, most of which are highly contaminated, both externally and internally, with extremely toxic pesticide residues.

More traditional crops, *i.e.* those that have been used as both subsistence and cash crops before prohibition of opium and cannabis, include cultivars of *Oryza sativa* L. (rice) and *Zea mays* L. (corn, both Gramineae), *Gossypium barbadense* L. var. *acuminatum* (Roxb.) Mast. (cotton, Malvaceae), *Glycine max* (L.) Merr. (soy bean; Leguminosae, Papilionoideae), *Lycopersicon lycopersicum* (L.) Karst. (tomato, Solanaceae), *Nicotiana tabacum* L. (tobacco, Solanaceae), and *Citrullus lanatus* (Thunb.) Mats. & Nakai (watermelon, Cucurbitaceae).

Various temperate fruit trees have also been planted, none of which have become economically successful, and include *Prunus persica* (L.) Bat. (peach), *Pyrus lindleyi* Rehd. (pear), and *Malus doumeri* (Bois.) Chev. (apple, all Rosaceae); *Diospyros kaki* Thunb. (persimmon, Ebenaceae), *Persea americana* L. (avocado, Lauraceae), and *Coffea canephora* Pierre *ex* Froh. var. *robusta* (Lind. & De Wildem.) Chev. (robusta coffee, Rubiaceae). *Camellia sinensis* (L.) O. K. var. *assamica* (Mast.) Kita. (*miang*, tea; Theaceae), which is native to northern Thailand and is also the only successful agroforestry crop system in Thailand, has not been developed in Doi Sutep–Pui National Park. *Dimocarpus longan* Lour. ssp. *longan* var. *longan* (longan, Sapindaceae), a native tree, and *Litchi chinensis* Sonn. ssp. *chinensis* (litchi, Sapindaceae), from China, are the most extensive and economically rewarding fruit trees grown in the region.

Settlements and Home Gardens

Due to the massive influx of people living in Doi Sutep–Pui National Park at temples, settlements, stations, and Puping Palace, many cultivated plants in residential areas and home gardens have been introduced. These plants are desired because of their ornamental, medicinal, and food values. Common shade trees include *Samanea saman* (Jacq.) Merr. (rain tree; Leguminosae, Mimosoideae) and *Ficus religiosa* L. (*bo* tree, Moraceae), while *Mangifera indica* L. (mango, Anacardiaceae), *Tamarindus indica* L. (tamarind; Leguminosae, Caesalpinioideae), and *Artocarpus heterophyllus* Lmk. (jackfruit, Moraceae) also provide edible fruits/seeds. *Carica papaya* L. (papaya, Caricaceae), *Citrus grandis* (L.) Osb. (pomelo) and *C. limon* (L.) Burm. f. (lemon, Rutaceae), and *Psidium guajava* L. (guava, Myrtaceae) are small trees which produce edible fruit. *Ceiba pentandra* (L.) Gaertn. (kapok, Bombacaceae) is cultivated for its useful seed fibre, *Hibiscus rosa-sinensis* L. (Malvaceae) is a shrub which has showy flowers, and *Bougainvillea spectabilis* Willd. (Nyctaginaceae) is scandent with colourful inflorescences. *Oroxylum indicum* (L.) Kurz (Bignoniaceae) has flowers and young fruits which are edible, while *Jatropha curcas* L. and *Riccinus communis* L. (castor, both Euphorbiaceae) have medicinal uses.

Many herbs are also grown for a variety of useful purposes. *Capsicum annuum* L. (chili, Solanaceae) has spicy fruits, *Eryngium foetidum* L. (Umbelliferae) grows edible leaves, while the leaves of *Piper betel* L. (betel pepper, Piperaceae) are chewed. *Canna hybrida* Hort. *ex* Back. (Cannaceae) has large, colourful flowers throughout the year. *Musa paradisica* L. (banana, Musaceae) and *Ananas comosus* (L.) Merr. (pineapple, Bromeliaceae) have delicious fruits. *Mentha arvensis* L. (mint) and *Ocimum basilicum* L. (basil, both Labiatae), *Cymbopogon citratus* (DC.) Stapf (lemon grass, Gramineae), and *Zingiber officinale* Rosc. (ginger, Zingiberaceae) are all cultivated for their spice properties.

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Ornamental Plants

Since the construction of the first road to Doi Sutep Temple in 1935 and the establishment of the national park in April 1981, many kinds of ornamental and home garden plants have been planted in the national park. Most of these plants are introduced or exotic and, fortunately, have not spread. In addition to *Tectona grandis* and *Pinus kesiya*, which have mostly been planted for commercial purposes under the guise of reforestation or watershed protection, several other trees are frequently seen, especially along roadsides and at stations and tourist areas. Some of these exotics are: *Bauhinia purpurea* L., *Delonix regia* (Boj. *ex* Hk.) Raf., and *Senna spectabilis* (DC.) Irw. & Barne. (all Leguminosae, Caesalpinioideae), *Lagerstroemia speciosa* (L.) Pers. var. *speciosa* (Lythraceae), and *Jacaranda obtusifolia* H. B. K. ssp. *rhombifolia* (Meij.) Gent. (Bignoniaceae). *Tithonia diversifolia* (Hemsl.) A. Gray (Compositae) and *Euphorbia pulcherrima* Willd. *ex* Klot. (Euphorbiaceae), both of which have large, colourful inflorescences, have now escaped cultivation and are extirpating native species.

Comparisons Among The Forest Types

Figure 4 compares species richness among the various forest types. With 930 species, **egf** is clearly the most valuable forest type in terms of species richness. **bb/df** and **mxf** are also highly diverse habitats, with similar numbers of species of 740 and 755 respectively. Habitats characteristic of disturbed or degraded areas generally support the lowest number of plant species with **dof, eg/pine** and **da/sg** supporting only 533, 540 and 534 species, respectively.

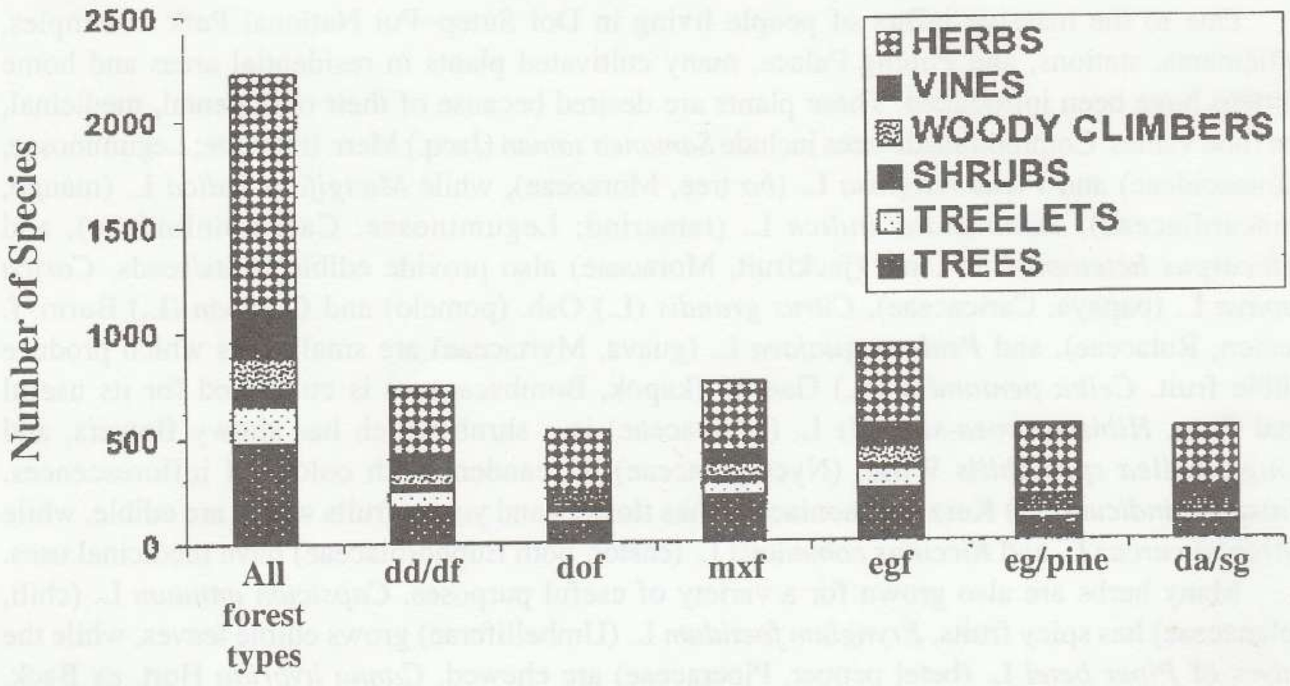

Figure 4. Species richness of the various forest types

Table 8. Relative percentages of plant species of different habits in the floras of each forest type

	All forest types	bb/df	dof	mxf	egf	eg/pine	da/sg
Trees	21.6	23.4	18.6	28.7	26.9	18.3	15.2
Treelets	7.8	9.7	9.0	9.4	9.8	6.1	6.7
Shrubs	3.5	4.1	5.4	2.5	2.4	3.9	1.9
Woody Climbers	6.7	7.4	2.6	8.2	8.4	3.5	4.3
Vines	10.3	12.7	6.9	8.2	11.4	6.5	17.6
Herbs	50.1	42.7	57.4	42.9	41.2	61.7	54.3

Table 8 shows that the distribution of species among the various plant habits is remarkably consistent among the various forest types. Only one of the percentage values for each habitat differs more than 10% from the combined values for all forest types. Some differences might be large enough to indicate significant differences in ecosystem structure. For example, the flora of **bb/df** has a relatively low percentage of herb species, while that of **dof** and **eg/pine** has much higher than average percentage of herbs. This is probably due to the more open nature of the latter two forest types, allowing greater niche space for the establishment of a wider range of herb species. In **mxf** and **egf**, tree species make up a greater percentage of the flora than everage and herbs contribute less. This is probably a reflection of the denser canopies of these two forest types. Disturbed areas and secondary growth are poor in tree species (undoubtedly due to chopping and burning), while vines make up a higher percentage of the flora than for any other vegetation type.

Sorensen's index is :

$$\frac{2C}{A+B}$$

where C = number of species common to both communities, A = total number of species in one community and B = total number of species in the other community. It is a convenient measure of similarity between two plant communities. The index varies from I for identical communities to 0 for communities with no species in common.

Table 9 shows no values of Sorensen's index greater than 0.5, indicating that all the forest types identified in this monograph are sufficiently different to justify being classified as separate forest types. The greatest similarity is between **mxf** and **egf**, which merge with each other at 900–1100 m elevation. These two forest types share 412 species. Other adjacent forest types are also relatively similar. **dof–bb/df** and **bb/df-mxf** share 255 and 320 species, respectively. Not surpisingly, forest types that are topographically furthest apart exhibit lowest similarity *e.g.* **dof–egf** shared only 77 species.

Table 9. Sorensen's index of overlap between the main forest types

Forest type	dof	mxf	egf	eg/pine	da/sg
bb/df	0.40	0.43	0.19	0.17	0.27
dof		0.19	0.10	0.17	0.15
mxf			0.49	0.26	0.22
egf				0.34	0.26
eg/pine					0.34

Table 10 provides some indication of the distinctiveness of the various forest types. The first column lists the numbers of species that have been recorded in only a single forest type. It indicates the numbers of species that would become extirpated if each forest type were degraded or destroyed. Evergreen forest clearly supports the most habitat-restricted vascular plant species. In contrast, **mxf** supports the least habitat-restricted species. This is also confirmed by the total Sorensen's index, which indicates that **mxf** has the greatest total similarity with the other forest types. The data also indicate that **dof** is one of the most distinctive forest types, with more than 28% of its species occurring nowhere else on the mountain.

Table 10. Measures of the distinctiveness of the various forest types

Forest type	Number of species restricted to each forest type	Percentage of total species in each forest type	Total Sorensen's index
bb/df	141	19.0%	1.46
dof	150	28.1%	1.01
mxf	58	7.7%	1.59
egf	230	24.7%	1.38
eg/pine	120	22.2%	1.28
da/sg	102	19.1%	1.24

Table 11 shows, once again the high conservation value of **egf**, due to the large number of rare species or those threatened with extirpation that grow there. Conversely, it also shows that degraded areas support mostly ubiquitous or common species and are therefore of low conservation value.

Table 11. Numbers of rare species or those in danger of extirpation in each forest type

Forest type	Number of rare or endangered species	Percentage of total species in each forest type
bb/df	153	20.7
dof	121	22.7
mxf	147	19.5
egf	314	33.8
eg/pine	141	26.1
da/sg	83	15.5

Analyses such as this can help national park managers direct limited resources (*e.g.* labour, funds, *etc.*) to conserve the greatest biodiversity. In the case of Doi Sutep–Pui, it is clear that **egf** has the greatest conservation value, both in terms of species richness, rare species, and habitat restricted species and should receive the highest priority for conservation action. Conservation of **egf** alone, however, would ignore the considerable and distinctive botanical richness of **dof**, which is not shared with the other forest types. Although **bb/df** and **mxf** both have relatively high species richness, they share a relatively large proportion of their botanical diversity with **egf** or **dof**. In addition the analysis shows the relatively low conservation value of **da/sg**. Converting such areas back into forest would, therefore, significantly increase the value of Doi Sutep–Pui National Park for the conservation of biodiversity.