Forest Habitats and Flora in Laos PDR, Cambodia and Vietnam

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Conservation Priorities In Indochina - WWF Desk Study

FOREST HABITATS AND FLORA IN LAO PDR, CAMBODIA, AND VIETNAM

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INTRODUCTION

1. Geomorphology of Southeast Asia

1.1 Geologic History

Mainland Southeast Asia forms a primary geomorphological unit underlain by a nucleus of Pre-Cambrian crystalline rock that consolidated to form a stable core area in Late Triassic times. This unit, variously designated as the Southeast Asian or Sundaland prong of the Eurasian Plate, extends from the Andaman Islands to the west across Burma, Thailand, Cambodia and Lao to northern Vietnam. To the south this unit includes Sumatra, a small portion of western Java, and western Borneo and western Sulawesi. The Sunda Shelf, a shallow ocean area of the Gulf of Thailand and South China Sea, is also a core area of Sundaland. This area was exposed at extended periods of geologic , including much of the Mesozoic and Tertiary as well as during the Pleistocene glacial periods when sea levels were lower.

The oldest rocks of Indochina are the metamorphic crystalline complexes formed in Pre-Cambrian and early Paleozoic periods of geologic activity. These rocks appear to have remained structural intact at least since the Devonian. Large exposed areas of these basement rocks exist today as the Kontum Plateau of southern Vietnam and in adjacent areas of Lao and Cambodia. This massif extends on its eastern side today to the coast, while Mesozoic sediments cover it to the west. Fold belts from tectonic activity in the Carboniferous mark its northern (Annamitic zone) and southern (Dalat zone) boundaries today. Basement crystalline rock is also exposed today near Pailin in western Cambodia.

Shallow seas covered much of central and northern Indochina during the late Paleozoic, leading to the formation of extensive deposits of limestone. Spectacular karst topography developed today across eastern Lao and northern and central Vietnam is formed of limestone from the Permian. Marine transgressions continued into the Triassic, with seas covering eastern Cambodia and parts of southern Vietnam. Continental formations characterized as red beds (terrain rouge) were also deposited over widespread areas at this time in Cambodia and southern Vietnam (Fontaine and Workman 1978).

At least three periods of tectonic folding impacted Indochina around the central block of ancient metamorphic rock during the late Paleozoic (Carboniferous) and Mesozoic (Permian-early Triassic and Triassic-Liassic). The earlier period of folding established an enlarged stable block covering central and southern Vietnam, much of central and southern Lao, northeastern Cambodia and possibly much of northeastern Thailand. This core region, which has been termed Annamia, appears to have remained relatively stable since this time, with only limited amounts of subsequent folding (Fontaine and Workman 1978). The Dalat Plateau of southern Vietnam represents an uplifted area of folded sedimentary rock and Carboniferous granitic intrusives south of the stable Kontum Massif.

Marine basins around the northern, western and southwestern margins of the Annamia block were the focus of strong folding in a series of tectonic activities from the late Permian to the Liassic. This folding, termed the Indosinian, is most evident today in one broad arc across central Thailand, northwestern Lao and much of Cambodia, and

another narrow belt across northeastern Lao and north-central Vietnam. Cretaceous uplift and vulcanism in the latter area produced a series of northwest-trending tectonic zones across northern Vietnam to the border with Lao.

Extensive areas of granitic rocks exposed in northern Vietnam are intrusives formed primarily in the late Permian and Triassic during periods of folding, termed the Indosinian, which affected this area. Some younger intrusive granites of late Cretaceous to early Tertiary are also present, with the youngest of these dating to only 29-30 million years in the Fan Si Pan massif. Small areas of serpentines were also formed in northern Vietnam and Lao at this time.

By the late Triassic, the Indochina segment of continental crust was consolidated and uplifted and folded by orogenic activity. This landmass including the Sunda Shelf, which remained an emergent area from the late Triassic to the time of late Tertiary tectonic events that led to the modern geographical configuration of Southeast Asia, has been given the paleogeographic name of Indosinia.

Core highland areas of Indosinia experienced steady erosion from the late Triassic through the Jurassic and Cretaceous into the early Tertiary, with a inland sea covering much of northeastern Thailand and portions of Lao and Cambodia. Similar marine basins formed in northern and southern Vietnam. Local volcanic activity was also present over this period. The deposition of terrestrial sediments into these inland seas produced extensive sandstones that are exposed today in the Khorat Plateau of northeastern Thailand and the Cardamom Mountains of Cambodia. Other important basins of such sediments include the Lomphat Basin of eastern Cambodia and the Tu Le and Au Chau Basins of northern Vietnam.

Overall, the Southeast Asian subcontinent and adjacent areas of southeastern China reacted as a single crustal unit throughout the Cenozoic as surrounding areas exhibited considerable tectonic activity (Fontaine and Workman 1978). These events included the northern migration of the Indian subcontinent on the Indian Ocean Plate and sea-floor spreading in the western Pacific with subduction along the East Asian margin. On the west, Indosinia was bordered by the Cretaceous-Tertiary orogenies of western and central Burma, and to the south by the Mesozoic-Cenozoic orogenies of Sumatra, Java, Borneo and the Philippines. Indosinia itself represents a distinctive geomorphological unit from an older structural block of south-central China that extends into northern Vietnam. The dividing line between these blocks, which roughly follows the present course of the Red River, experienced differential movements from late Cretaceous to Eocene times. These movements resulted in granitic and alkaline magmatism.

These tectonic events in surrounding regions of the enclosed Indosinia produced a broad warping of the block with associated uplift of mountainous terrain reaching modern elevations of 2,000-3,000 m to the west and north, and a subsidence of the Sunda shelf area to below sea level in the southeast. Compressional forces from northward movements of the Indian subcontinent and tensional forces from sea floor spreading in the western Pacific Ocean continued to affect Indosinia throughout the Tertiary, leading to the folding of older substrates into broad domes and structural basins and the uplift of many small granite plutons. Many of these domes were later subjected to extensive weathering. The lake basin of Tonle Sap in Cambodia was formed in the Pleistocene by subsidence along a northeast-southwest trending fault line.

Basalt flows of late Tertiary and Quaternary age cover thousands of square kilometers of land area in southern Vietnam, eastern Cambodia and the Bolovens Plateau of southern Lao. The largest of these areas are the Dac Lac (Darlac), Pleiku, Haute Cochinchine, and Djiring-Blao plateaus of southern Vietnam (see Schmid 1974). Smaller outliers of basalt cover occur in western Cambodia, northwestern Lao, and north-central Vietnam. Volcanic eruptions have occurred as recently as 1923 in the South China Sea off the southeastern coast of Vietnam (Fontaine and Workman 1978).

Quaternary alluvial deposits cover broad areas today in Cambodia, northern Vietnam, and southern Vietnam. Older alluvium dating from the lower Pleistocene reaches a thickness of more than 500 m in the eastern Mekong delta and tens of meters around Xuan Loc to the north. Fontaine and Workman (1978) describe a prominent Pleistocene marine terrace extending discontinuously along nearly 100 km of coastline near Phan Rang in southeastern Vietnam. The Red River basin around Hanoi is entirely covered by Quaternary alluvial deposits.

Holocene deposits of continental origin cover an extensive area of the Tonle Sap basin in central Cambodia. Holocene alluvium of increasing amounts extends down the Mekong River from Cambodia, reaching up to about 100 m depth at the delta. Deposits of pure quartz sand of Holocene age extend inland from modern beach sands along the coast of central Vietnam and alluvial terraces of this age are common along much of the coast over limestone substrates.

1.2 Geomophological Provinces

Bridges (1990) divided the Sundaland area into ten geomorphological provinces:

1.2.1 Shan Plateau

The Shan Plateau of western Burma represents an area of peneplained ancient granites and gneiss, uplifted to a plateau at 1,000-1,300 m elevation. Slates, quartzites and limestones have been formed on this surface from Pre-Cambrian to Jurassic times, followed by mid-Tertiary clays and Pleistocene lacustrine deposits. Block faulting has led to a landscape structure of simple hills and valleys. The Salween River, the major drainage through this province, has cut a deep valley 300 m below the plateau surface. This mineral-rich area is known for rubies, jade, silver, lead, zinc and lapis lazuli.

1.2.2 Irrawaddy Lowlands

The basin of the Irrawaddy lowlands, drained by the Irrawaddy River and its major tributary the Chinwin, lies between the Arakan Yoma to the west and Shan Plateau to the east. Also included in this province is the smaller basin of the Sitang River. This Irrawaddy Basin is a geosynclinal downwarp that has been infilled by thousands of meters of sandstones and shales during the mid-Tertiary. Volcanic intrusions in the Oligocene led to the formation of a number of extinct volcanic cones that remain today. Late Tertiary and Pleistocene fluvial deposits and laterites are also present. Oil is present in small anticlines that run north-to-south parallel with the Irrawaddy River.

1.2.3 Peninsular Ranges

The Peninsular Ranges form the border area between Burma and Thailand and extend southward along the Malay Peninsula into Malaysia. The north-south trend of these ranges follows that of the eastern Himalayas. The Dawna Range in the northern area of this province reaches elevations of 2,000 m, although most of the crest is lower. To the south the Peninsular Ranges are known as the Bilanktaung Range. Offshore islands of the Mergui archipelago along the Andaman Sea coast of Burma are drowned peaks of the same structural unit. Interestingly, many rivers draining this area also maintain a north-south trend before to entering the sea. After narrowing sharply at the Isthmus of Kra, the peninsular ranges broaden out in Malaysia and again reach over 2,000 m elevation in the Cameron Highlands and Trengganu Hills. These ranges are composed of folded sandstones, shales and limestones, intruded with granite crystalline rock. Karst features are well developed in areas of limestone. Where broader coastal plains are present, particularly along the west coast, finer sediments collect and mangrove forests are common. In contrast where the coastal plain is narrow and the mountains fall abruptly to the sea, as along much of the coast of the Gulf of Thailand, sandy beaches are more typical.

1.2.4 Annamite Province

The Annamite Province in its broad geomorphic sense extends from northern Vietnam along the border area with Lao and south into southern Vietnam. This is a an area with a complex geological history, and a modern delineation of this province would differ depending on whether one used geomorphic, geologic, or biogeographic criteria. Sediments in the northern Annamites were folded in the Miocene and subsequently uplifted to 1,000-1,500 m elevation in the Pliocene after an erosion surface was cut. Conglomeratic gravels subsequently covered this surface over large areas to the west of Fan Si Pan. This peak, a granitic intrusive massif, forms the highest point in mainland Southeast Asia at 3,143 m. An extensive lower erosional surface developed in southern Vietnam during the late Pliocene was uplifted to 600-1,000 m elevation. The greater Annamite Province includes the ancient granites of the Kontum Massif and younger intrusive granites and volcanic plateaus of the Dalat, Pleiku, Haute Cochinchine, and Djiring-Blao Plateaus.

1.2.5 Khorat Plateau

The Khorat Plateau of eastern Thailand, or Khorat Basin as it is more accurately termed, is a broad erosional surface formed of Triassic sandstones covering 154,800 km^2. This plateau tilts gently to the east, ranging from 1200-1600 m along its western margins against the central highlands of Thailand to about 100-200 m along the Mekong Valley to the east. It is separated from the Cambodian lowlands by the east-west trending Phanom Dongrack Range that forms the Thai-Cambodian border.

1.2.6 Chao Phraya Lowlands

The Chao Phraya Lowlands are the alluvial plains that extended 500 km inland from the Gulf of Thailand between the Peninsular Ranges to the west and the Central Highlands and Khorat Plateau to the east.

1.2.7 Cambodian Lowlands

The lower delta region of the Mekong River, including the lake basin of Tonle Sap, has been termed the Cambodian lowlands. The modern delta of the Mekong occupies an area of 38,700 km^2. Sediment brought by the river has been estimated to be adding 60 m annually to the front edge of the delta. The basin of Tonle Sap also comprises a large area of Quaternary sediments. Much of this land area has been laterized, and it is these laterites that were used in the construction of early Khymer temples. Tonle Sap itself expands from an area of about 2,580 km^2 in the dry season to 10,400 km^2 or more in the wet season. The southwestern margin of the Cambodian lowlands are marked by the Cardamom and Elephant Mountains with peaks reaching 1,500-1,600 m in several areas and 1,813 m in the isolated mountain block of Phnom Aural.

1.2.8 Red River Basin

The Red River rises in the mountains of the southern Himalayas and flows through a relatively narrow valley to the Gulf of Tonkin. Here it has produced a large delta of 14,000 km^2. The Yangtze River apparently captured large areas of what once formed the upper reaches of the Red River in Yunnan Province in relatively recent geological times. Coastal areas along the Gulf of Tonkin around the Red River delta have Pleistocene terraces.

1.2.9 Sunda Shelf

The shallow ocean area extending from the Gulf of Thailand southeast toward Sumatra, Java and Borneo is an integral part of the Sundaland landmass, as are major parts of the islands of Borneo and Sulawesi. The Sunda shelf is formed of crystalline basement rock that has been gently folded into broad basins and swells. Nowhere does this shelf area exceed 200 m in depth today, and it is shallower near its southern margin. The surface is thought to be a late Cretaceous peneplain that was subsequently submerged as compressional and tensional forces of surrounding plates influenced the Indosinia block during the Tertiary. Up to 800 m of Tertiary sediments have accumulated in basins of the Sunda shelf, and an apron of deltaic sediments 160 m in depth extends outward from the mouth of the Mekong River (Bridges 1990). Ancient river drainage patterns extending southeast across the Gulf of Thailand from Southeast Asia and northeast from Sumatra and Java toward the South China Sea remain apparent in Sunda shelf sediments today.

The primary area of emergent terrain of the Sunda shelf province is the island of Borneo. The backbone of the island is a ridge of high mountains extending from southwest to northeast, where they reach 4101 m at Mount Kinabalu in northern Sabah.. These mountains are structured of a mixture of sedimentary formations of sandstone, shale and limestone of early to mid-Tertiary age that have been uplifted through the Tertiary into Holocene times.

1.2.10 The Indonesian Arc

The islands of Sumatra, Java and smaller islands to the east comprise the Indonesian Arc of Indosinia. The dynamic history of tectonic uplift in this arc has resulted from the influence of the Indo-Australian plate pushing below continental basement rock of the Sunda shelf. Volcanic activity along this arc began as far back as Mesozoic times and continues today (Bridges 1990). There are 70 active volcanoes today along this arc. The

highest peaks include Kerintji (3,805 m) and Leuser (3,381 m) on Sumatra and Slamet (3,428 m) on Java. The Sunda trench which lies about 200 km south of this island arc reaches a known depth of 7,450 m.

1.3 Mekong River System

The Mekong ranks as one of the great rivers in Asia, and indeed of the world. From its origins in the Himalayas of southern China, at about 5,000 m elevation near Dzanag La Pass in the Tanghla Shan Mountains, it flows southward through six countries in its 4,200 km course to the South China Sea. In southern Yunnan Province near the northern border of Burma the headwaters of the Irrawady River, Salween River, Mekong River and Yangtze River all flow in parallel canyons over a distance of only 200 km. In terms of its length, the Mekong rates as the twelfth longest river in the world. It ranks even higher in terms of its mean annual discharge (about 475×10^9 m^3 yr^{-1}) where it is sixth in the world (Pantulu 1986). Of the total area of 783,000 km^2 which lies within the Mekong drainage basin, 22% lies in China and Burma (160,000 km^2 and 12,000 km^2, respectively).

The lower Mekong basin, measured from where the river crosses from the triangular border of Burma-Thailand-Lao, comprises about three-fourths of the total drainage area. The Mekong enters Lao at an elevation of only 500 m after its sharp descent from the Himalayas and forms a broad river with a wandering course and leisurely rate of flow. After a flow for a short distance as the Lao-Thai border, the Mekong turns eastward near Chiang Rai in northern Thailand (about 20^oN lat.) for a 600 km run through Lao. The river again changes direction just north of Luang Prabang and flowing southward. Near Xanakham, about 100 km to the west of Vientiane, the Mekong curves back eastward, again forming the Lao-Thai border. Here it skirts the hills of northeastern Thailand and then cuts a gorge through the sandstone rim of the Khorat Plateau along a line of low hills about 24 km to the west of Vientiane (Pantulu 1986). The Mekong continues to flow eastward until Pak Kading where it turns again to the south. From here to the Cambodian border, the Mekong follows the rim of the Khorat Plateau through low-lying topography of broad valleys and gentle profiles. Natural levees mark much of the boundaries of the river. The Nam Mun and its tributary drain more than half of the Khorat Plateau to the Mekong the Nam Chi. Together, these rivers provide 15% of the total Mekong catchment and 5% of its flow. The boundary of the Mekong basin lies in the Central Highlands along the western margin of the Khorat Plateau separate this drainage from that of the Chao Phraya and central plain of Thailand. To the south, the Dongrack Range separates the Khorat Plateau from the Cambodian lowlands, although both areas fall within the Mekong drainage basin. Several major rivers drain the Lao side of the river, most notably the Nam Ngum and Nam Lik which drain the highlands to the north and east of Vientiane.

The Mekong leaves the Khorat Plateau at its southeastern edge as it plunges over the Khone Falls and the border of Lao with Cambodia. Below the falls, the Mekong passes through a series of rapids before entering the floodplain of central Cambodia. The last major tributary of the Mekong is the Tonle Sap River which drains much of western and northern Cambodia through the great lake of Tonle Sap. The flow in this river, as described in more detail later in this report, reverses direction during the dry season as the

high flows of the Mekong move back up into this lake and increase its size by an order of magnitude. South of the confluence of the Tonle Sap at Phnom Penh, the Mekong divides forming two rivers, the Mekong and the Bassac (Song Hau Giang). At this point, the lower drainage basin of the Mekong reaches its narrowest width of less than 100 km before spreading into a broad triangular delta area in southern Vietnam. The breadth of the delta where it meets the South China Sea has led to a large number of mouths. This area of the river has been called Cuu Long in Vietnamese, meaning the River of the Nine Dragons.

The hydrology of the Mekong povides an interesting pattern of flow that separates this river from smaller Southeast Asian rivers that lack the Himalayan source of its drainage. Although the upper Mekong basin above the Burma-Lao-Thailand border provides only 20% of the annual flow (in 26% of the total drainage basin), the snowmelt source of this flow provides a fairly steady discharge throughout the year. The lower Mekong basin has inputs solely from rainfall, and thus exhibits far sharper seasonal changes in water supply.

Natural flows of the Mekong have the potential to be strongly impacted by a series of dam projects, either projected or in construction. A number of projected dam projects have been the focus of major environmental controversies, particularly in regard to their effect on fisheries and on the sustainability of wetland areas fed by annual overflow from the Mekong. For the upper Mekong basin, Ryder (1994) suggested that there are plans for 15 dams in China, with one of these at Manwar now completed. A blockage of flow during construction of a secondary dam at the Manwar site in 1995 produced record low flows in northern Thailand and Lao, and brought a halt to the movement of large river vessels until this flow was restored. There have been plans proposed over the past three decades for as many as eight dams along the central Mekong, with a planned function to store excess flow, provide irrigation water, and generate hydroelectric power. These plans remain in a state of flux because of unresolved political issues, financing, and environmental controversies. Numerous plans have also been presented for hydroelectric dams along major tributaries of the Mekong.

There is abundant evidence to suggest that the drainage pattern of the Mekong River has changed through geological time (Hutchinson 1989). Sediment deposits in central Thailand and out into troughs in the Gulf of Thailand suggest that the Mekong once flowed directly southward from Chiang Rai along the present course of the Chao Phraya toward Bangkok and the gulf. Late Cenozoic faulting was responsible for diverting the river to its present course. There is also evidence that block-fault movement in Quaternary times may have once pushed the Mekong River to a more direct course across central Cambodia through Tonle Sap to the coast east at Kampot (Fontaine and Workman 1978).

2. Vegetation Patterns in Southeast Asia

2. 1 Regional Forest Formations

Classification systems that have been developed to describe the major forest communities of mainland Southeast Asia have largely been based on a variety of traits:

a. elevational distribution (low or high elevation),
b. dominate phenology (deciduous or evergreen),
c. rainfall pattern (seasonal or year-round),
d. conifer presence,
e. floristic relationships.

The category of *tropical rainforest* or *tropical evergreen forest* used in many vegetation classification systems for Southeast Asia includes tall, evergreen forests with closed canopy structure. Within this structural category, however, are a group of forest formations that are quite disparate in their environmental characteristics, canopy structure, and floristic composition. The most important groups of tropical evergreen forest formations are wet evergreen forest, semi-evergreen forest, freshwater swamp forest, and evergreen montane forest. Mangrove forests provide a fifth important evergreen forest formation. These forests all have similar spectral signatures in aerial photography or satellite images, and are thus difficult to separate without field observations or multispectral images. Classification or forest mapping systems that lump all of these disparate forest types together are inappropriate for ecological interpretations since they represent sharply differing environmental conditions and forest structure.

Under the ecological system of forest classification that will be used in this monograph, forest communities will be divided into lowland and montane communities. In lowlands, luxuriant forest communities with more than about 2,000 mm annual rainfall and only a brief dry season of 1-2 months are termed wet evergreen forest. Mature wet evergreen forests, as described in more detail below, are almost entirely dominated by evergreen tree species. Structurally similar forest communities growing under somewhat lower rainfall regimes and/or a longer drought period are termed semi-evergreen forest because of the presence of variable densities of deciduous forest trees in the canopy. Forests with a dominant deciduous canopy but floristic affinities to semi-evergreen forest can be still classified under this name.

In contrast to these evergreen forest communities, deciduous forests cover large areas of Southeast Asia with climatic regimes characterized by subhumid to dry conditions. The seasonality of water availability in much of this area has led to the evolution of tree species that lose their leaves in the dry season. Deciduousness is typically brought on by drought stress and therefore the period of leaf fall is not synchronous. There are two primary associations of deciduous forest in Southeast Asia which differ sharply in structure and floristic composition. Tall and relatively closed-canopy forests with floristic affinities to the monsoon forests of India and Burma are termed mixed deciduous forest. These forests generally occur in areas with 1,400-2,000 mm of mean annual rainfall, but 5-7 months of dry season. A second association termed deciduous dipterocarp forest forms open forests or woodland communities with a grass understory are. These communities, as described below, occur typically on drier sites of less than 1,500 mm annual rainfall and strong seasonality.

The boundaries between lowland forest associations may be quite sharp with fire-influenced boundaries between deciduous dipterocarp and semi-evergreen forest, with topographic exposures for mixed deciduous and deciduous dipterocarp forest, or at the margins of semi-evergreen forests situated at gallery woodlands along streams. In other area, there may be broad ecotonal areas between these associations, with mixtures of tree species that would not normally be expected to occur together. Human activities related

to fire and land clearance, extending back thousands of years, have further blurred natural boundaries between habitats.

Above about 1,000-1,200 m elevation, or somewhat lower elevations in northern Lao and Vietnam, lowland communities grade into distinctly different montane communities that have been broadly termed montane evergreen forest in Thailand. This change in habitat involves strong floristic turnover in dominant species, and a characteristic difference in forest structure from a more tropical to a more temperate appearance. Typical tropical family affinities in the lowland forest floras such as the Dipterocarpaceae, Lythraceae, Fabaceae, Annonaceae, Sapotaceae, and Myristicaceae give way to dominance by tree species in more typically temperate families such as the Fagaceae, Magnoliaceae, Lauraceae, Betulaceae and Theaceae. Such a turnover between lowland tropical forest and montane tropical forest floras is typical of other tropical mountain areas in Malaysia and throughout the world (Richards 1952, Whitmore 1984).

Structural and floristic difference within individual forest associations in mainland Southeast Asia have often been recognized by designations of subdivisions of forest types with distinctive structural and floristic characteristics. These subdivisions generally fall out along rainfall gradients from those with more mesic to those with less mesic habitats. Thus, as described below, multiple such subdivisions have been described for most forest associations, but these descriptions are reasonably specific to some of the better studied areas of northern Thailand and Burma, and are of less value in describing habitats in Lao, Cambodia and Vietnam.

The forest associations or habitats introduced above are what are termed zonal communities. Zonal communities are habitats that respond to broad patterns of climatic regimes in their evolution and distribution. Also present, however, are azonal forest communities that grow under highly specialized conditions of soil characteristics or water regimes. Important azonal forest communities in mainland Southeast Asia include freshwater swamp forests, seasonal swamp forests, beach forest on dunes, and mangrove forests.

2.2 Lowland Forest Habitats

2.2.1 Wet Evergreen Forest

Wet evergreen rainforest, typical over much of the Indo-Malaysian region to the south, presents classical tropical rainforest forest with multi-storied canopies to heights of 40 m or more and abundant lianas. These forest formations occur in areas of perhumid climate with more than 2,000 mm of rainfall annually. Such forests are found on the steep southwestern-facing slopes of the Cardamom and Elephant Mountains of southwestern Cambodia, in portions of the Annamite Range, and in small local areas of the western Dangrek Range in Khao Yai National Park, Thailand. These are all areas where the topography captures large amounts of rainfall, fog and mists from monsoon winds.

When defined on a floristic basis, the wet evergreen forests of mainland Southeast Asia are distinctly different from the better known wet evergreen forests of Malaysia and Indonesia. Strictly speaking, Indomalaysian forest formations do not extend north of the Kra Isthmus in southern Thailand at latitude of about 6^{o}. While structurally similar to Indomalaysian rainforests, these Indochina communities are less floristically rich and

distinctive in species composition. At the generic level, there is a strong floristic relationship, but at the species level there are obvious differences. While some trees in Indochinese wet evergreen forests represent the northern limit of distribution for Indomalaysian rainforest species, these forests are rich in endemics. Wet evergreen forests extend at least as far north as the northern Annamite Range in Vietnam where rainfall is moderately high and the drought period short. North of Hanoi, there are lowland forest communities with intermediate floristic structure between the wet evergreen forests of the Annamite Range and the subtropical broadleaf evergreen forests of southern China.

Wet evergreen forests of the Cardamom and Elephant Mountains exhibit distinctive floristic differences from similar associations in the Annamite Range. These differences suggest significant evolutionary isolation.

Conifers may occasionally play a significant local role as dominants in areas of lowland wet evergreen forest. The most widespread of these are species of Podocarpaceae which may extend from wet evergreen forest down to 200 m elevations or below as well as their more characteristic role in wet lower montane forests. Two species, *Dacrydium elatum* and *Podocarpus imbricatus*, often dominate the canopy in local dwarf forests on poorly-drained sites in the Cardamom and Elephant Ranges of Cambodia.

2.2.2 Semi-Evergreen Forest

Semi-evergreen forest has been commonly designated as *dry evergreen forest* by many researchers, but this name is misleading because of the often strong presence of deciduous tree species in the forest canopy of this community. The term *semi-evergreen* to describe this forest is much more accurate and will be used here. This forest association has also been termed *seasonal evergreen forest*, *tropical semi-evergreen forest* or *semi-deciduous forest* (Stamp 1925, Champion and Seth 1968, Santisuk 1988).

Semi-evergreen forest generally occurs in humid and subhumid climatic regions where mean annual rainfall is generally between 1200 and 2000 mm and a significant dry period (generally 3-6 months) occurs each year. These forests are often present in mosaics made up of stands of mixed deciduous and/or deciduous dipterocarp communities, with the semi-evergreen formations in areas where soil moisture conditions are most favorable.

Semi-evergreen forests themselves represent a somewhat artificial category of classification. They include typical semi-evergreen forest associations, a unique plant association for mainland Southeast Asia, as well as a variety of riverine or gallery forests occurring along the major rivers and streams. Semi-evergreen forests almost always contain a significant number of tree species that lose their leaves at least briefly during the dry season, and some forms of the forest may even display a dominance of deciduous species. The floristic structure of semi-evergreen forest, however, generally separates this association from mixed deciduous forest.

Semi-evergreen forests are widespread in a band across northern and central Thailand into Lao, Cambodia and Vietnam. These forests comprise one of the most significant forest associations with respect to area covered in northern Thailand and Lao. Together with deciduous dipterocarp forests, semi-evergreen forest form what has been termed the

Central Indochina dry forest bioregion (Wikramanayake et al. 1997). Semi-evergreen forest, adapted to conditions of relatively moderate amounts and highly seasonality distribution of rainfall are unique to mainland Southeast Asia. It is not surprising, therefore, that this association has evolved a large number of endemic species as well as species which extend in to Malaysia only on areas with seasonal climatic regimes. However, regional species endemism within semi-evergreen forests is quite low. Thus, semi-evergreen forest floras in Lao, Cambodia and Vietnam are not strikingly different from those present in Thailand.

While the overall structure of semi-evergreen forests is similar to that of wet evergreen forest in the presence of multi-layered canopy, the canopy is less massive and continuous at about 30-40 m height, and more open in structure. Species richness of forest trees is lower in semi-evergreen forest as well. This reduction in richness can be particularly seen in the rduced numbers of Dipterocarpaceae in individual forest stands compared to the diversity of this family in wet evergreen forest communities.

Buttressed trees are common in semi-evergreen forests among both evergreen trees (e.g. *Ficus* spp., *Dracontomelon dao, Hopea ferrea*) and deciduous trees (e.g. *Tetrameles nudiflora*). Bamboos are often common in the forest, particularly as colonizers of open gaps following disturbance. Palms are present, most notably along watercourses, but less abundant and diverse than in lowland tropical rainforest habitats. Although lianas may be abundant, understory formations are less complex than in wet evergreen forest and their species richness is also lower.

The distribution of semi-evergreen forest habitats across a landscape catena is largely a function of gradients of soil moisture availability, with soil parent material relatively unimportant. Thus, it is common to see semi-evergreen forest on both calcareous and crystalline rock substrates, but with a relatively deep soil profile and good capacity for soil moisture storage as a common characteristic.

In broad valley areas, semi-evergreen forest often occurs as a fringing gallery forest along streams, grading out into deciduous dipterocarp forest on drier sites with shallower soils. Massive trees of species such as *Dipterocarpus turbinatus*, *D. alatus*, and *D. costatus* (at the head of valleys) once formed dense stands in these forests, along with a diversity of other Dipterocarpaceae. Semi-evergreen forest species begin to drop out at about 700 m elevation and are replaced by montane species that form a continuous montane evergreen forest at and above 1,000-1,200 m elevation.

Semi-evergreen forests are generally relatively intolerant of fire. In comparison to species in adjacent deciduous dipterocarp communities, woody species in semi-evergreen forest resprout poorly after fire. Similarly, semi-evergreen forest species are relatively sensitive to drought, apparently due to less well-developed root systems. In regions subject to intense human occupation where wildfires are commonly used for land clearance, with the Khorat Plateau of Thailand as a primary example, large areas of semi-evergreen forest have been converted to deciduous dry dipterocarp savannas.

A distinctive assemblage of tree species often dominates in broad ravines and moist slopes at elevations of 800-1,000 m at the transition from semi-evergreen forest to montnae evergreen forest in northern Thailand (Santisuk 1988). These species include *Acrocarpus fraxinifolius, Erythrina stricta, E, suberosa* and *Parkia leiophylla* (Fabaceae), *Gmelina arborea* (Verbenaceae), *Pentace burmanica* (Tiliaceae), *Canarium subulatum* (Burseraceae), and *Toona ciliata* and *Melia azedarach* (Meliaceae). Two

short-lived successional trees, *Duabanga grandiflora* (Sonneratiaceae) and *Anthocephalus chinensis* (Rubiaceae) are often common.

2.2.3 Mixed Deciduous Forest

Mixed deciduous forest, or *monsoon forest* as it is sometimes termed, forms the most extensive forest cover in a broad belt extending from the Ganges Basin of India through Burma to northern Thailand and Lao. There are scattered occurrences of this formation in northern Vietnam as well. The canopy of mixed deciduous forest is typically closed and high, often reaching 30 m or more. Beneath this canopy, the understory is relatively open despite a diverse assemblage of small trees, shrubs and bamboos. Unlike the evergreen forest formations, lianas and vascular plant epiphytes are uncommon. Where the dry season commences in late November, as in northern Thailand, leaf fall typically begins 1-2 months later and continues until the forest becomes leafless by the end of March. This leafless period extends for four to five months. To the east in the Mekong basin, however, the dry season commences somewhat later and leaf fall is delayed proportionately

The name of this formation derives from the diversity of tree species that characterize mixed deciduous forests. These are arguably the most specie-rich deciduous tropical forests in the world (Elliot et al. 1989). Teak (*Tectona grandis*) was once the dominant tree through much of this formation, but this species has been intensely lumbered over the past century in Burma and Thailand. Other widespread and codominant tree species include members of the Fabaceae (*Xylia kerrii, Pterocarpus macrocarpus, Dalbergia* spp.), Combretaceae (*Terminalia* spp.) and Lythraceae (*Lagerstroemia* spp). Dipterocarpaceae are generally absent except in transitional areas with deciduous dipterocarp forest. Forest classification systems for Burma have recognized three associations within the mixed deciduous formation (Stamp 1925). These are moist teak, dry teak, and dry deciduous without teak.

The southern boundary of mixed deciduous forest across Thailand and Lao is difficult to determine. Teak whose distribution characterizes much of the range of mixed deciduous forest is not present in southern Lao or northern Cambodia. Complicating the matter further is the fact that *Lagerstroemia* may be a natural associate in both mixed deciduous forest and semi-evergreen forest. Areas of semi-evergreen forest in southern Lao and northern Cambodia dominate by deciduous *Lagerstroemia* have often been classified as mixed deciduous forest rather than the more appropriately as a deciduous forest form of semi-evergreen forest. In fact, these two forest associations grade together in this region in a manner that makes it difficult to impossible to clearly characterize the correct forest association. Heavy disturbance by logging of these forests has led to replacement by agriculture or secondary dipterocarp forests and woodlands and further complicated this situation.

Mixed deciduous forest is characterized by tall and diverse canopy structure with an almost complete dominance of deciduous species, and in often situated in intermediate positions along landscape gradients at the edge of semi-evergreen forests or in habitats between semi-evergreen and deciduous dipterocarp forests (Rundel and Boonpragob 1995). The features that distinguish mixed deciduous forests from other habitats are:

a) presence of a closed forest canopy dominated by deciduous tree species;
b) relatively low diversity of lianas and understory species; and,
c) relatively low occurrence or absence of Dipterocarpaceae
d) floristic dominance by *Tectona grandis* and/or members of the Fabaceae, and Lythraceae;
e) regular occurrence of dry season fire as a natural ecological factor.

2.2.4 Deciduous Dipterocarp Forest

Deciduous dipterocarp forest forms a relatively low and open forest or woodland community dominated by deciduous trees. Community structure may range from virtually closed canopy forest of low trees 5-8 m in height, although occasional emergents may reach 10-12 m, to more typical woodland structure with 50-80% canopy cover. In all cases, there is an open understory dominated by grasses. This community differs from more typical tropical dry deciduous forests such as those in India by its open and xeromorphic structure (Champion and Seth 1968). This forest formation has often been termed *dry dipterocarp forest*, but this designation is unfortunate in that it has led to confusion with *dry evergreen forest*. The use of deciduous dipterocarp forest or woodland is the more appropriate designation used here. This community has also been termed *idaing* in Burma (Stamp 1925) and *forêt claire a dipterocarpacées* in Lao (Vidal 1956-60). In some areas, particularly in more arid regions with significant human intervention, deciduous dry dipterocarp forest may attain a true savanna structure with scattered shrubby trees.

Deciduous dipterocarp forest covers more area in mainland Southeast Asia than any other forest type. It extends from northeastern India and Burma (Chapmpion and Seth 1968) through Thailand (Rundel and Boonpragob 1995) to the Mekong River region of Lao (Vidal 1956-60), Cambodia (Rollet 1953, 1972, Aubreville 1957, Pfeffer 1969), and Vietnam (Schmid 1974). Over this range it characteristically occurs in areas with 1,000-1,500 mm rainfall and 5-7 months of drought. Potential evapotranspiration may exceed rainfall for up to nine months per year. Together with semi-evergreen forest communities, deciduous dipterocarp forests and woodlands form the *Central Indochina dry forest bioregion.*

Deciduous species of Dipterocarpaceae form the dominant element of deciduous dipterocarp forests. Only six species of the approximately 550 dipterocarps in the world are deciduous and all of these occur in this formation. Four of these, *Shorea siamensis, S. obtusa, Dipterocarpus obtusifolius,* and *D. tuberculatus*, generally form the dominant biomass and cover. Also present is a reasonable diversity of other small trees, particularly legumes. *Pinus merkusii* may be a codominant.

Deciduous dipterocarp forest exhibits relatively moderate species richness, and a similar floristic structure extends broadly across mainland Southeast Asia. While the forest association itself has endemic species, there are relatively few local endemics.

Fire is a frequent event in most deciduous dipterocarp forests. Areas with regular human impact commonly have fire at intervals of 1-3 years through both deliberate and accidental ignitions. Most fires occur between December and early March in Thailand when forest conditions are driest. Dominant tree species in this formation exhibit

adaptations to fire in the form of thick corky bark to protect cambium tissues and root crowns which readily resprout (Sukwong et al. 1975, 1984, 1986, 1988a,b, Stott et al. 1990).

2.2.5 Savanna Woodland

Under heavy human impact, particularly from repeated fires, lowland areas of deciduous dipterocarp forest may be converted to open savanna woodlands. This process is evident in drier areas with sandy or lateritic soils, as in the Khorat Plateau region of Thailand, portions of northern Cambodia, and drier portions of several provinces in southern Vietnam. The presence of shallow rocky soils promotes such conversions. These savanna woodlands may maintain a few of the hardier tree species from typical dry deciduous dipoterocarp woodlands, particularly fire resistant species such as *Shorea siamensis* and *Pinus merkusii*. Other fire-tolerant tree species include *Careya arborea, Mitragyna parvifolia, Acacia siamensis, A. catechu,* and *Pterocarpus macrocarpus* (Smitinand 1989). The C_4 grassland matrix of these savanna woodlands is commonly dominated by species of *Imperata* and *Vetiveria*, together with *Eulalia, Panicum, Sporobolus, Themeda, Eriochloa* and *Sorghum*. With grazing pressure, thorny shrubs may become important associates in these communities. *Feroniella lucida* and *Carissa cochinchinensis* are two such species.

2.3 Montane Forests

2.3.1 Lower Montane Forests

Montane forests, or *hill evergreen forests* as they are often termed in Thailand, grow under perhumid conditions with cooler temperatures and higher rainfall than that present in adjacent lowland areas. In northern Thailand and Lao, the boundary separating semi-evergreen and/or deciduous forest communities from montane evergreen communities generally occurs at 800-1,000 (rarely 1,200) m elevation, but at lower elevations of 600-700 m in northern Vietnam and Lao. Annual rainfall is typically 2,000 to as high as 4,000 mm or more, and the mean temperature of the coldest month is below 15^{o}C. Frosts may be present at the higher and more northern parts of this formation.

The relatively abrupt lower boundary of montane forest in Southeast Asia is due more to temperature conditions than to moisture availability. This boundary represents a sharp transition not just in forest structure, but also in floristic composition. The Dipterocarpaceae and other lowland groups drop out rapidly, and are replaced by a rich community dominated by tree species of families such as the Fagacaeae, Magnoliaceae, Lauraceae, Theaceae, and Juglandaceae. Overall, these communities exhibit a strong floristic relationship with temperate mountain floras of southern China, as well as with montane forests of Malaysia and Indonesia. There is, however, significant endemism at the species level in the montane areas of mainland Southeast Asia. This endemism is particularly notable in the Annamite Province. The structure of montane evergreen forests, as throughout the tropical mountain regions of the world, are distinctive with an open to semi-open canopy of relatively low and twisted tree forms. Epiphytes are

typically present and often abundant and diverse in these forests. Much of the remarkable diversity of orchids from Southeast Asia is centered in these evergreen montane forests.

In describing the floristic and vegetation patterns of northern Thailand, Santisuk (1988) has subdivided what he terms montane forests into first lower montane at elevations up to about 1,800 m, and then upper montane forests at 1,800-2,000 m and above. This boundary corresponds to an elevation in which frequent cloud cover and mists occur, making these the equivalent of cloud forests that have been described for tropical montane forests in many other parts of the world. Santisuk further divides lower montane forests into three types – lower montane rainforest, lower montane oak forest, and lower montane pine-oak forest. No equivalent attempt has been made to classify montane forests in Lao and Vietnam.

Lower montane evergreen forest is characterized by a a continuous canopy of trees 20-30 m in height, with two to three layers of canopy structure (see Santisuk 1988, Nanakorn n.d.) and a relatively sparse shrub understory. Tall bamboos are rare except for scattered areas of disturbance and along forest edges, but small loose-clumped bamboos (e.g. *Melocalamus, Melocana* and *Teinostachyum*) may be present. The forest floor typically has a relatively well-developed herb flora, and the upper branches of the tree canopy are rich in epiphytic orchids and ferns.

The floristic composition of lower montane forests in northern Thailand has been described in some detail by Santisuk (1988) who separated lower and upper communities of these habitats. On somewhat less mesic valley slopes and ridges from 1,400-1,800 m elevation, where soils nevertheless are rich in organic matter and remain moisture well, mature lower montane forests are dominated floristically in the upper canopy by species of Fagaceae, Theaceae and Magnoliaceae. Although some tropical elements are still present, the absence of Dipterocarpaceae and most Fabaceae at this elevation is notable.

The dominance of Fagaceae in these forests is reduced in shaded ravines that typically support a distictive assemblage of tree species in northern Thailand
It is in such habitats that a few species of lowland palms (e.g. *Caryota urens, Pinanga gracilis* and *Wallichia siamensis*) may reach their upper elevational limit.

The more mesic phase of lower montane forests in northern Thailand are those occurring in fertile gullies and valleys at 1,400-1,800 m elevation. The upper canopy of this habitat reaches 25-35 m, with large trees with intermingled crowns. The floristic composition of these habitats is more mixed than that of the lower elevation montane forests and includes a rich species assemblage that retains a few tropical lowland elements.

Montane evergreen forests at these lower elevations that have been cleared in the past by the swidden agriculture of hill tribes often exist in a successional stage with lower tree diversity and very strong dominance of Fagaceae. Santisuk (1988) terms these habitats as *lower montane oak forests*. He mentions that an abundance of such species as *Castanopsis acuminatissima, C. fissa* and *C. tribuloides* (Fagaceae), *Betula alnoides* and *Carpinus viminea* (Betulaceae), and/or *Engelhardtia spicata* (Juglandaceae) as an indicator of past human disturbance. Such human-impacted forests are typically relatively low in stature with an open canopy structure as a result of frequent fires and cutting. A ground cover of grasses, rare in pristine montane evergreen forest, is common, as is a cover of braken fern (*Pteridium aquilinum*).

A third form of lower montane forest separated by Santisuk (1988) is the lower montane pine-oak forest, often termed simply a pine forest by other workers. These generally stands represent floristically depauperate forms of lower montane forest that have been severely and chronically subjected to disturbance from fire, grazing, cutting and soil erosion. Such forests may occur naturally, however, on nutrient-poor habitats with well-drained sandy soils. The primary species characterizing this community is the widespread *Pinus kesiya*, a three-needled pine. This pine reaches 20-30 m in height and may form anywhere from a minor stand component to community dominant among hardy evergreen species of Fagaceae and Theaceae. With reasonable soil development and protection from fires, hardwood species will outcompete pines for dominance in these forests. However, rocky sites, eroded slopes, or areas subjected to frequent fires all favor pine establishment and success. Such pine oak forests are common under these conditions in northern Thailand from about 700-1,500 m elevation and occasionally higher. Elsewhere in its range, *P. kesiya* frequently reaches its best development at higher elevations of 1,500-2,200 m, higher than its typical distribution in Southeast Asia.

2.3.2 Montane Conifer Forests

Conifers play an important role in many montane forests in Southeast Asia. The most significant of these are the widespread *Pinus kesiya* forests which extend throughout much of northern Thailand into the mountains of Laos and Vietnam. This pine may become a dominant species on drier montane sites with less than 2,000 mm annual rainfall and well-drained or shallow soils at elevations of 800-1,500 m. Frequent fire seems to promote the establishment and maintenance of these pine forests at the expense of hardwoods.

In Laos and Vietnam these drier montane conifer forests often contain another conifer that is absent from Thailand, *Keeteleria evelyniana*. This species shows a wide ecological amplitude, growing on sites with relatively dry conditions to areas with more than 3,000 mm of mean annual rainfall. Like the pines, *K. evelyniana* appears to be much more edaphically controlled than moisture controlled in its distribution. It is more characteristic, however, of drier pine forests. Another drier site conifer, *Calocedrus macrolepis* (Cupressaceae) may also be present in these forests.

The Annamite Range, including its northern extensions in the Fan Si Pan Massif and its southern extensions into the Dalat Plateau, contain unique conifer forests and a rich assemblage of conifer species. Beyond the drier *Pinus kesiya*/*Keeteleria* forests described above, there are wet montane forests with mixed dominance of hardwoods and conifers in areas with more than 2,000 mm annual rainfall. The cool growing season temperatures and short drought period in these habitats promotes the growth of large trees on sites with a strong development of humic soils. The most abundant of these mesic forest conifers are species of Podocarpaceae which often form very large forest trees reaching 1-2 m in diameter and 40 m in height. Two endemic pine species, *Pinus krempfii* and *P. dalatensis* are restricted in distribution to wet montane forests of the southern Annamite Range and dalat Plateau. Also present in scattered sites from southern China down the Annamite Range is the monotypic *Fokienia hodginsii* (Cupressaceae), a large tree much valued for its fragrant wood. Many of the Podocarpaceae and *Fokienia* may occur at lower elevations into wet evergreen forest.

The Fan Si Pan Massif in northern Vietnam reaches suffiently high to promote the development of a montane temeprate conifer forest at elevations above 2,000 m. Here there is a fir/hemlock forest whose typical range is the mountains of southern China. *Abies fansipanensis* and *Tsuga dumosa* dominate this forest, mixed with a variety of temperate hardwood tree species (Nguyen Nghai Thin and Nguyen Tha Thoi 1998).

2.3.3 Montane Cloud Forests

High elevation montane areas exposed to heavy cloud cover and fog drip experience a cool climate and high rainfall with a relatively brief drought period. Areas with this climatic regime support a cloud forest community of low canopy height and abundant epiphytes. The growth form of trees in this community is usually highly branched with a twisted main trunk. The Ericaceae are frequently a major component of the flora of these forests.

2.4 Freshwater Swamp Forests

Areas of seasonal inundation of freshwater along coastal delta areas and inland wetlands often support evergreen forests of tall stature. The saturated soil moisture conditions of these sites provide a strong selective pressure, and thus freshwater swamp forests generally have a distinctive flora. The structure and floristics of coastal freshwater swamp forests in Thailand have been described in detail (Phengklai et al. 1989). Extensive areas of freshwater swamp forest occur within the broad floodplain of Tonle Sap in Cambodia. These forests are unlike typical swamp forests in a number of respects owing to the seasonal pattern of flooding which affects these areas, as well as floodplain margins of areas along the Mekong. The Tonle Sap swamp shrublands and forests are generally low in stature, and have a predominance of tree species which loose their leaves when submerged during the wet season. These species differ floristically from those of more typical swamp forests, and this region contains a number of narrowly distributed endemics.

2.5 Mangrove Forests

Mangrove forests in areas of regular flooding by tidal or brackish water and associated saline gleysols form a special formation of evergreen forest in Southeast Asia. Accurate maps of the distributions of these mangrove forests are generally not available because of the relatively small size of individual stands. These forests have been heavily impacted in recent years by conversion for agriculture, aquaculture and recreational development, and earlier by extensive defoliation in the Mekong delta area during the Vietnam War. Remaining mangrove forests deserve special attention for protection. These formations are extremely significant for the ecosystem services they provide in limiting coastal erosion, maintaining navigable rivers, and serving as critical nurseries for larval and juvenile stages of many marine organisms. In addition, however, they are remarkably diverse for such a habitat. The richness of mangrove tree species in the

Southeast Asian region extending southward to northern Australia is the highest of any area in the world.

Recent estimates of the remaining areas of mangrove formations in mainland Southeast Asia are as follows (Spalding et al. 1997):

Burma	3,444 km^2
Thailand	2,641 km^2
Cambodia	600 km^2
Vietnam	2,723 km^2

Overviews of mangrove ecosystems have been written for Thailand (Silapathong and Blasco 1992) and Vietnam (Phan and Hoang 1993).

LAOS

Hydrology

The Mekong River flows for 1700 km along the length of Laos, forming over much of this distance the border with Thailand. The elevational gradient of the river is slight, entering Laos at about 250 m elevation and leaving to enter Cambodia at about 65 m. From its entrance into Laos from the Chinese-Burmese border to Vientiane, the Mekong flows for about 720 km through narrow valleys in mountainous terrain. This portion of the river is relatively clear and fast flowing, with many exposed rock outcrops and rapids. Two large tributary rivers, the Nam Ngum and Nam Lik, join the Mekong near the capital, forming a broad alluvial plain along the north bank of the river here at the edge of the Khorat Plateau.

Leaving Vientiane, the Mekong flows more placidly with a meandering course through broad lowland valleys for more than 500 km, with its banks delineated by natural levees. The river is much more turbid in this area, particularly in the rainy season when increased flows cause significant erosion of stream banks. Several large rivers (the Nam Theun, Xe Bang Fai, and Xe Bang Hiang) drain the western slopes of the Annamite Range along the Vietnamese border and flow westward into the Mekong, forming broad alluvial valleys on the eastern margin of the Khorat Plateau. South of its confluence with the Xe Biang Hiang, the Mekong narrows and flows over the Khermat Rapids and continues on for 160 km through rocky gorges. River flows can increase very rapidly in this section during the rainy season, raising the height of flow by as much as 20 m (Claridge 1996). The principle tributary river over this length of river is the Xe Done, also flowing out of the Annamite Range. Emerging from these rocky gorges at about 100 m elevation near Pakse, the Mekong enters the lowlands of southern Laos where it meanders slowly before reaching the Khone Falls and passing on to the lower Mekong Plain of Cambodia.

The breakdown of drainage areas and mean annual flows for the largest of the 14 major tributaries of the Mekong in Laos are the following (Claridge 1996):

Tributary	Drainage area (km^2)	Annual flow ($m^3 \times 10^6$)	($m^3 s^{-1}$)
Nam Ngum	16,640	21,000	675
Nam Theun	14,650	24,500	776
Xe Bang Fai	9,470	11,700	369
Xe Bang Hiang	19,600	19,200	607
Xe Done	7,170	7,680	243

The combination of high water velocity, low nutrient levels, turbidity, and unstable bottom sediments makes the Mekong relatively poor in bottom fauna of invertebrates over much of its length. The tributary rivers, however, are generally much richer.

Climatic Regions

Vidal (1956) has divided Laos into nine climatic regions on the basis of their temperature regime, rainfall regime, and drought regime. For temperature, he separated four regimes characterized as follows:

T3/4 Mean annual temperature less than 20°C; mean temperature of the coldest month from 0-10°C (areas above 2,000 m elevation)

T4 Mean annual temperature less than 20°C; mean temperature of the coldest month from 10-20°C (areas 1,000-2,000 m elevation)

T4/5 Mean annual temperature from 20-30°C; mean temperature of the coldest month less than 20°C

T5 Mean annual temperature from 20-30°C; mean temperature of the coldest month greater than 20°C

For rainfall, he separated two zones:

R1 Mean annual rainfall greater than 3,000 mm

R2 Mean annual rainfall less than 3,000 mm

The final climatic characteristic of drought regime was based on an index derived from both the mean annual precipitation and the length of the dry season to separate four categories from X0 (short, cool dry season) to X3 (relatively long dry season).

Combining these climatic characteristics, Vidal (1956-60) designates 10 different climatic regions for Laos and Vietnam:

T5 R2 X3 Mekong valley and its tributaries in southern Laos

T4/5 R2 X2 low elevation areas of northern Laos and northern Vietnam

T4/5 R2 X0 coastal areas

T4/5 R2 X1 " "

T4/5 R1 X2 lower western slopes of the Annamite Range; Paksane

T4/5 R1 X0 inland coastal areas between Vinh and Hue

T4/5 R1 X1 " " " " " "

T4 R2 X2 Mountainous areas of northern Laos from 1,000-2,000 m

T4 R1 X1 Local high rainfall regions of the Annamite Range from 1,000-2,000 m

T3/4 R1 X0 Mountain regions above 2,000 m

Dry Evergreen Forests

Vidal (1960) divides his descriptions of the vegetation of Laos into lower elevation forests, generally those below 800-1000 m, and upper elevation forests. Among the former of these, dry evergreen forests and degraded forms of this habitat comprise the largest area. These lowland forests occur in areas with between 1400 and 2600 mm of mean annual rainfall with five months of dry season. Thgis community has been termed *forêt dense* and *forêt hemi-ombrophile a dipterocarpacées* in the French literature. More recently it has been described as Eastern Indochina Moist Forest (Wikramanayake et al. 1997).

The primary form of dry evergreen forests on siliceous clay soils of alluvial plains is dominated by emergent trees of two Dipterocarpaceae, *Dipterocarpus alatus* and *Anisoptera costata*. These trees may reach 40 m in height. The complexity of this forest is indicated by the diversity of canopy tree species that may be present. The most

important of associated canopy trees are *Lagerstroemia angustifolia* (Lythraceae), *Irvingia harmandiana* (Simaroubaceae), *Dialium cochinchinense* (Fabaceae), *Chaetoarpus castanocarpus* (Euphorbiaceae) and *Walsura robusta* (Meliaceae). In local areas, *Lagerstroemia* may form virtually pure stands. In other areas, *Hopea odorata* (Dipterocarpaceae) may become the dominant canopy tree. Of the important canopy trees, *Irvingia* and *Dialium* are unusually successful at colonizing disturbed areas. Canopy species that are largely restricted to areas of broad forest gaps include the following, all of which are deciduous:

Albizzia lucida (Fabaceae-Mimosoideae)
Cananga latifolia (Annonaceae)
Crypteronia paniculata (Crypteroniaceae)
Elaeocarpus robustus (Elaeocarpaceae)
Holoptelea integrifolia (Ulmaceae)
Sapium discolor (Euphorbiaceae)
Tetrameles nudiflora (Datiscaceae)
Trewia nudiflora (Euphorbiaceae)

Subcanopy gap colonizers, however, are largely evergreen:

Alchornea rugosa (Euphorbiaceae) - evergreen
Alchornea tiliaefolia (Euphorbiaceae) - evergreen
Bambusa tulda (Poaceae) -evergreen
Duabanga sonneratioides (Sonneratiaceae)
Macaranga denticulata (Euphorbiaceae) -evergreen
Zanthoxylum rhetsa (Rutaceae) -deciduous

The understory shrub strata of these forests are rich in species, with such families as the Annonaceae, Arecaceae, Euphorbiaceae and Rubiaceae particularly well represented. *Linociera thorelii* (Oleaceae) and *Rothmannia venalis* (Rubiaceae) were particularly common in stands sampled by Vidal (1960). Ground cover is relatively sparse, largely as a result of low light levels present, with Acanthaceae, Araceae and Zingiberaceae as the dominant families.

In studies of three stands of comparable dry evergreen forest on alluvial soils near Vientiane, Savannakhet and Pakse, Vidal encountered 217 species in 165 genera. These were divided by growth form into 88 tree species, 53 shrubs, 29 herbs 39 lianas and eight epiphytes and parasites. The most important families represented among the canopy trees were the Dipterocarpaceae (9 species), Fabaceae (7 species), Meliaceae (6 species and Sapindaceae (6 species).

Among the tree species, 56% were deciduous, but the presence and dominance of many evergreen species means that this habitat never takes on a leafless appearance. Many of the deciduous species are largely restricted to young forest stands that have colonized old forest gaps, as described above. The phenology of evergreen tree species is heavily weighted toward flowering in the dry season, with 92% of the species having this trait.

For deciduous species, the leafless period is relatively short and only poorly synchronous. Leaf fall always takes place during the dry season and peaks from January to March. Sixty percent of these deciduous species lose their leaves for no more than one month, with leaf fall centered in February and March. The majority (88%) of these species flower in the dry season with leaves present, while he remaining 12% flower in the wet season. Examples of canopy trees in this category with their season of flowering are:

Schleichera trijuga (Sapindaceae) – dry season, with leaves
Shorea thoreli (Dipterocarpaceae) – dry season, with leaves
Holoptelea integrifolia (Ulmaceae) – dry season, with leaves
Sapium discolor (Euphorbiaceae) – wet season
Pterospermum semisagittatum (Sterculiceae) – wet season

Among tree species which lose their leaves for more than a single month, 50% flower during the dry season when leaves are not present, 28% in the dry season with leaves present, and 22% in the wet season. Examples of canopy trees in this category with their season of flowering are:

Spondias mangifera (Anacardiaceae) – dry season, no leaves
Stereospermum fimbriatum (Bignoniaceae) – dry season, no leaves
Garuga pinnata (Burseraceae) – dry season, no leaves
Tetrameles nudiflora (Datiscaceae) – dry season, no leaves
Shorea harmandii (Dipterocarpaceae) – dry season, no leaves
Pterocymbium cf. *dusaudii* (Sterculiaceae) – dry season, no leaves
Gmelina arborea (Verbenaceae) – dry season, no leaves
Trewia nudiflora (Euphorbiaceae) – dry season, with leaves
Dalbergia nigrescens (Fabaceae-Papilionoideae) – dry season, with leaves
Lagerstroemia angustifolia (Lythraceae) – dry season, with leaves
Albizzia procera (Fabaceae) – wet season
Dalbergia cochinchinensis (Fabaceae-Papilionoideae) – wet season
Dialium cochinchinense (Fabaceae-Caesalpinoideae) – wet season

The flora of understory shrubs and forest floor herbs and subshrubs are heavily weighted toward evergreen phenologies, with 83% and 65% presence of this trait among species. All but one of the shrub species and all of the forest floor species flower in the dry season.

Vidal (1960) sampled a second group of dry evergreen forest habitats on *terre rouge* soils derived from basalt parent material. These sites were located in southern Laos at Phuo Chieng to the east of Pakse, at Dong Houa Sao to the south of Pakse, and at Phang Ham in Saravane Province. He distinguished these habitats by the absence of *Dipterocarpus alatus*, the abundance of species of *Lagerstroemia*, and the frequent occurrence of other species which he tentatively identified as *Shorea vulgaris* (Dipterocarpaceae), *Diospyros* cf. *rubra* (Ebenaceae), *Terminalia* cf. *bialata* (Combetaceae) and *Dalbergia* (Fabaceae-Papilionoideae). Based on limited samples, he found an even mix of evergreen and deciduous species in this habitat.

Secondary Forest Habitats

There has been a long history of human impact and exploitation of forest resources, and such impacts have accelerated dramatically in the past few decades. Heavily impacted forests show characteristic patterns of structure and species composition, depending on the nature of the disturbance and the time since disturbance. Extensive timber exploitation of native forests opens up large gaps and promote invasions of species able to rapidly colonize and become established in these open habitats. Such species and the structures formed are very similar to the thickets of vegetation that commonly form along forest edges or roads. When disturbance comes in the form of landscape clearance, a different community typically becomes established, with greater dominance of herbaceous perennial species. Finally, both of these communities, if protected from chronic disturbance, respond to successional changes and form a secondary forest habitat.

The floristic composition of ecological structure of secondary forest communities have been described in some detail by Vidal (1960) on the basis of his field studies of a series of typical sites. Cutover forest areas were studied in four sites near Vientiane, Thakhek, Savannakhet and Pakse. The dominant shrub and tree species found widely in these secondary habitats included two bamboos, *Bambusa arundinacea* and *B. tulda*, which frequently form impenetrable thickets. Low growing thickets of *Combretum quadrangulare* are widespread in areas of seasonal inundation, and Vidal suggests that some of this distribution may be due to their ancient utilization as a host plant for lac insects. *Peltophorum dasyrachis* (Fabaceae-Caesalpinoideae) is a common small tree that rapidly colonizes large forest gaps, while the paper mulberry *Broussonetia papyrifera* (Moraceae) is widespread in many areas, particularly along the Mekong. This latter species was widely cultivated in the Khymer era for the fabrication of paper, and paper mulberry remains the source today of tapa cloth in the western Pacific region. Many other small shrubs and small trees were reported to be of common or very common in the stands studied by Vidal (1960):

Acacia concinna (Fabaceae-Mimosoideae)
Ailanthus malabarica (Simaroubaceae)
Alchornea rugosa (Euphorbiaceae)
Alstonia scholaris (Apocynaceae)
Anthocephalus indicus (Rubiaceae)
Capparis foetida (Capparaceae)
Capparis micrantha (Capparaceae)
Colona auriculata (Tiliaceae)
Duabanga sonneratioides (Sonneratiaceae)
Elaeocarpus robustus (Elaeocarpaceae)
Eugenia zeylandica (Myrtaceae) – moist areas
Ficus hispida (Moraceae)
Grewia paniculata (Tiliaceae)
Mallotus cochinchinensis (Euphorbiaceae)
Micromelum falcatum (Rutaceae)
Pterocymbium javanicum (Sterculiaceae)

Wrightia tomentosa (Apocynaceae)
Vitex tripinnata (Verbenaceae)
Zizyphus cambodiana (Rhamnaceae)

The tangled vegetation of these secondary forest habitats is further structured by a remarkable abundance of lianas and herbaceous vines that thrive in the relatively open light environment of these formations. Vidal (1960) reported 77 species of lianas and vines from the four sites that he surveyed. The most important families for these life forms were the Fabaceae (15 species), Convolvulaceae (10 species), Cucurbitaceae (6 species), Asclepiadaceae (6 species), and Menispermaceae (5 species). There were 19 species found to be common or very common:

Acacia pennata (Fabaceae-Mimosoideae)
Cayratia carnosa (Ampelidaceae)
Calycopteris floribunda (Combretaceae)
Caesalpinia mimosoides (Fabaceae-Caesalpinoideae)
Combretum pilosum (Combretaceae)
Combretum trifoliatum (Combretaceae)
Congea tomentosa (Verbenaceae)
Connarus bariensis (Connaraceae)
Ipomaea chyseides (Convolvulaceae)
Ipomaea eriocarpa (Convolvulaceae)
Melothria heterophylla (Cucurbitaceae)
Omphalea bracteata (Euphorbiaceae)
Oxystelma esculentum (Asclepiadaceae)
Passiflora hispida (Passifloraceae)
Pterolobium platypterum (Fabaceae-Mimosaceae)
Rourea rubella (Connaraceae)
Sphenodesma ferruginea (Verbenaceae)
Thunbergia grandiflora (Acanthaceae)
Tinospora crispa (Menispermaceae)

The herb ground layer of these cutover forest areas is rich in species of Fabaceae, Melastomataceae, Asteraceae and Poaceae, particularly in more open areas. Two tall herb species, *Saccharum arundinaceum* (Poaceae) and the alien *Eupatorium odoratum* (Asteraceae) often form dense stands one meter or more in height over large areas. These species are even more characteristic of secondary habitats that have been cleared of forest cover, as described below.

Cleared areas of forest commonly support a community overwhelmingly dominated by dense coverage of *Eupatorium odoratum*, an invasive alien species introduced from Central America. The dense and almost impenetrable stands of this species may reach 2-3 m in height and cover extensive areas, particularly on siliceous clay laterite soils. Vidal (1960) describes how the widespread distribution of this species within the country has led geographers to name it *l'herbe du Laos*, while Laotians themselves have named it *l'herbe des Français* because its appearance coincided with the arrival of the French in Laos. It appears that *Eupatorium* was first introduced into India and Thailand, and only

became a widespread invasive in Southeast Asia over the past 70-80 years. Older cleared areas with *Eupatorium odoratum* generally show establishment of several colonizing tree species. These are *Trema velutina* (Ulmaceae), *Mallotus cochinchinensis* (Euphorbiaceae), and *Ailanthus malabarica* (Simaroubaceae). *Trema* and *Mallotus* are evergreen, while *Ailanthus* is deciduous.

A third form of secondary community forms with greater successional change after disturbance or under conditions of less severe human impact. Three deciduous tree species, *Holarrhaena antidysenterica* and *Wrightia tomentosa* (Apocynaceae) and *Cratoxylum cochinchinense* (Guttiferae). Often present are scattered remnant trees of the original dry evergreen forest association.

Mixed Deciduous Forests

Mixed deciduous forests in Laos have been described as *forêt semi-dense or forêt mixte caducifoliée*, as well as being subdivided into a number of units on the basis of structure and floristic composition in the French literature (Vidal 1960). It has more recently been termed Central Indochina Moist Deciduous Forest (Wikramanayake et al. 1997). These forest associations are characterized by tall and diverse canopy structure with a large dominance of deciduous species, and are often situated in intermediate positions along landscape gradients at the edge of dry evergreen forests or in habitats between dry evergreen and deciduous dipterocarp forests. The features that distinguish mixed deciduous forests from other habitats are: a) the presence of a closed forest canopy dominated by deciduous tree species; b) a relatively low diversity of lianas and understory species; and, c) a floristic dominance of members of the Fabaceae, Lythraceae and Rubiaceae, together with a relatively low occurrence or absence of Dipterocarpaceae. Dense local stands of bamboo are often present, particularly in areas with significant human impacts.

In his detailed descriptions of the vegetation of Laos, Vidal (1960) treated mixed deciduous forests individually in each of three climatic regions. These correspond geographically with the lower Mekong valley and its tributaries from Vientiane to southern Laos, the lower elevational areas of northern Laos, and the western slopes of the Annamite Range. He suggests that many of these forests represent degraded communities that were once dominated by dry evergreen forests.

For the Mekong valley area, the floristic structure of mixed deciduous forests strongly supports an intermediate ecological condition of this habitat between more mesic dry evergreen forests and more xeric deciduous dipterocarp forests. Vidal (1960) studied five stands of mixed deciduous forest between Vientiane and Paklay, representing areas with lateritic soils, sandstone substrates and black riverine soils over laterite along the Nam Ngum river. Of the 35 species of canopy trees that he found in his survey, 9 species were characteristic of dry evergreen forests and 12 were characteristic dry deciduous dipterocarp forests in the region. Among the 43 species that he sampled among canopy and understory trees, 88% were deciduous, including all of the ecologically common species. Sixty percent of the canopy trees, however, were leafless for less than one month, with the other 40% having a longer leafless period. The leafless period for these forests was largely confined to the period of January through March, with a peak of

defoliation in February. The majority of species of canopy trees (55%) flowered in the dry season when leaves were present while 18% flowered during the leafless period. The final 29% flowered in the wet season. The most common canopy species in the mixed deciduous forest in his samples were:

Afzelia xylocarpa (Fabaceae-Caesalpinoideae)
Xylia xylocarpa (Fabaceae-Mimosaceae)
Peltophorum dasyrrachis (Fabaceae-Caesalpinoideae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae)
Lagerstroemia angustifolia (Lythraceae)

Other species noted as being common or very common in these surveys were:

Bombax kerrii (Bombacacaeae)
Cratoxylon formosum (Guttiferae)
Dalbergia kerrii (Fabaceae-Papilionoideae)
Schleichera trijuga (Sapindaceae)
Spondias mangifera (Anacrdiaceae)

Mixed deciduous forests in northern Laos have a distinctive structure and high species diversity similar to that present in northern Thailand. The canopy of these forests reaches up to 30 m or more, and supports a mixed dominance of species. Vidal (1960) distinguished an upper mixed deciduous forest characterized by an abundance of bamboo and original dominance of teak from a lower mixed deciduous forest on alluvial soils where bamboo is relatively rare and teak less common.

The phenology of canopy trees in these areas of northern Laos showed a complete dominance by a deciduous growth habit, with species almost equally split between those losing their leaves for less than one month and those with a longer leafless period. The period of defoliation was found by Vidal (1960) to be strongly centered on February when 90% of the trees were leafless, with only 15% of the tree species leafless in January and trailing off to 47% of species being leafless in March. The largest proportion of canopy tree species in these habitats (44%) flowered in the dry season when leaves were present, followed by 35% that flowered in the wet season. The final 17% flowered in the dry season during the leafless period. There were species in flower from January through June, with a peak of flowering (35% of species) in April.

A floristic analysis of 56 woody species sampled by Vidal (1960) in four stands of mixed deciduous forest in northern Laos found a strong dominance of Fabaceae (13 species), Verbenaceae (5 species), Poaceae (5 species of bamboo), and Combretaceae (4 species). The most common species were:

Afzelia xylocarpa (Fabaceae-Caesalpinoideae)
Albizzia odoratissima (Fabaceae-Mimosoideae)
Anogeissus acuminata (Combretaceae)
Berrya mollis (Tiliaceae)
Bombax kerrii (Bombacaceae)
Cassia timorensis (Fabaceae-Caesalpinoideae)

Cephalostachyum pergracile (Poaceae)
Cratoxyon prunifolium (Guttiferae)
Dendrocalamus membranaceus (Poaceae)
Eriolaena candollei (Sterculiaceae)
Lagerstroemia balansae (Lythraceae)
Oxytenanthera albociliata (Poaceae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae)
Spondias mangifera (Anacardiaceae)
Tectona grandis (Verbenaceae)
Terminalia nigrovenulosa (Combretaceae)
Xylia xylocarpa (Fabaceae-Mimosoideae)

The historically most significant species in the mixed deciduous forest of Laos has been teak (*Tectona grandis*). While teak may occasionally occur in open dry dipterocarp forest or in closed dry evergreen forest, its characteristic habitat and site of best growth is in mixed deciduous forest habitats. The best stands of teak were reported by Vidal (1960) to occur in the Golden Triangle area, where the borders of Burma and Thailand join that of Laos, and further south in the Mekong valley around Pak Lay. Teak generally is not present on lateritic soils. The natural range of teak extends from northern India and Burma across northern Thailand to northern Laos. The great majority of large teak has been cut out of these forests beginning in Burma in the mid-19th century and extending into Thailand and Laos at the end of that century. Heavy and indiscriminate cutting of teak and other large forest trees began at this time as European and Burmese companies vied for leases over the most favorable areas. Logging practices in this era, described in wonderful detail by Campbell (1935), involved girdling standing trees to allow them to dry for two years before they were felled and hauled by elephant into major rivers for transport in log rafts. Freshly cut teak has too high a density to float. Little merchantable teak remains in these forests today.

Despite poor logging practices, teak is inherently a good colonizing species so long as fire is present to promote seed germination. Many areas that were once heavily logged for teak and other forest trees now support good stands of young teak. The strong seasonality of the mixed deciduous forest environment, and the consequent accumulation of leaf litter on the forest floor during the dry season, promotes flammability in these forests. While teak is deciduous, its extremely large leaves do not readily abscise and remain attached well into the dry season. Although the genetic diversity of teak in northern Laos has been shown to be quite similar to that of northern Thailand, Laotian foresters have traditionally distinguished several forms of teak with specific wood characteristics (Vidal 1960).

Dry Deciduous Dipterocarp Forests

Dry deciduous dipterocarp forests in Laos are largely an extension of the lowland forms of this habitat occurring from the Khorat Plateau in northeastern Thailand eastward over into the lowlands of southern Laos. These communities are termed Central Indochina Dry Forest in the classification of Wikramanayake et al. (1997). These habitats generally represent areas with relatively low levels of mean annual rainfall,

usually less than 1500 mm, and extended drought seasons of 4-5 months. Edaphic sites with xeric environments because of laterites or shallow rocky soil may also support azonal distribution of dry deciduous dipterocarp forest. Such sites are present in northern Laos where annual rainfall may be between 1500 and 2000 mm, as aroun Vientiane, or exceeding 2000 mm to the north of Pakse. Vidal suggests that dry deciduous dipterocarp forest over its entire range is really an edaphic subclimax on shallow, rocky, and nutrient-deficient soils, with dry evergreen forest as a climatic climax community. Human activities over centuries have also acted to promote the expansion of dry deciduous dipterocarp forests and woodlands at the expense of dry evergreen forest. Fire has undoubtedly been the most significant single factor in promoting these changes.

The structure of dry deciduous dipterocarp forest in Laos is similar to that described for other regions of Southeast Asia. The habitat consists of relatively open stands of trees, with only a few species reaching 20 m in height. Many tree species grow only to 5-10 m in height, with twisted or multiple-branched trunks. Canopy cover ranges from virtually closed to sufficiently open to be appropriately termed a woodland or savanna. Increased openness of the canopy is associated both with increased xerophytism of the site and with increased human intervention. A grassy understory is present beneath the open tree canopies, and this strata is rich in herbaceous species. In comparison to dry evergreen forests, the flora of the dry deciduous dipterocarp forest is highly diverse in understory and herbaceous species in comparison to canopy trees and very much poorer in diversity and abundance of lianas.

Although the diversity of tree species may be moderately high in dry deciduous dipterocarp forests, five of the six most dominant species of this habitat in Laos are members of a single family, the Dipterocarpaceae. As described previously, these are *Dipterocarpus intricatus, D. obtusifolius, D. tuberculatus, Shorea obtusa,* and *S. siamensis*. These are the only characteristically deciduous species in the family. A sixth important species is *Terminalia tomentosa* (Combretaceae).

While the general canopy structure of dry deciduous dipterocarp forest is quite consistent throughout the range of this habitat, the floristic structure of individual stands may vary. In Laos, five forms of dry deciduous dipterocarp forest have been designated. As described by Vidal (1960), these five forms are as follows:

Type 1. Mixed dominance of *Dipterocarpus tuberculatus, Shorea siamensis, S. obtusa,* and *Terminalia tomentosa*. This is the most widespread form and grows with a moderately stunted trunks on shallow sandstone or lateritic soils. Similar forests have been termed *scrub indaing forest* or *forêt claire rabougries* in Burma.

Type 2. Primary dominance of *Dipterocarpus intricatus*. This form grows on gravelly laterites or sandy soils. Similar forests have been termed *scrub indaing forest* or *forêt claire rabougries* in Burma.

Type 3. Primary dominance of *Shorea siamensis,* with associated importance of *S. obtusa* and *Terminalia tomentosa*; *Dipterocarpus* absent. This form typically occurs on very thin lateritic or sandstone soils. Similar forests have been termed *scrub indaing forest* or *forêt claire rabougries* in Burma.

Type 4. Primary dominance of *Dipterocarpus obtusifolius*. Typically grows on sandy soils, but rarely also on gravelly laterites subject to seasonal flooding. These have been termed *high indiang forest* or *forêt claire futaies* in Burma.

Type 5. Primary dominance by *Dipterocarpus tuberculatus*. This form is generally found on silica clay alluvial soils. These have been termed *high indiang forest* or *forêt claire futaies* in Burma.

However, as Vidal admits and other researchers have pointed out (Rollet 1952), the distribution of communities within dry deciduous dipterocarp forest is often a complex mosaic of individual forms reflecting soil heterogeneity.

The floristic compositions of 15 stands of dry deciduous dipterocarp forest in southern Laos, reflecting all five forms, were described in detail by Vidal (1960). In these stands he found 207 species of vascular plants, including 56 trees, 45 shrubs, 97 subshrubs and herbaceous species, and four epiphytes and parasites. The tree flora included representatives of 21 families, with the Fabaceae (eight species), Dipterocarpaceae (six species) and Rubiaceae (six species) combing for more than a third of this the tree diversity. Tree canopies were dominated by the six species described above, but eight other tree species were common or very common. These included:

Dillenia baillonii (Dilleniaceae)
Dillenia ovata (Dilleniaceae)
Diospyros ehretioides (Ebenaceae)
Eugenia jambolana (Myrtaceae)
Lagerstroemia macrocarpa (Lythraceae)
Terminalia chebula (Combretaceae)
Vitex pubescens (Verbenaceae)
Xylia xylocarpa (Fabaceae-Mimosaceae)

While there is an absence of a distinctive shrub canopy layer, a diverse assemblage of shrub species was nevertheless present. The flora of shrub layer was strongly dominated by the Rubiaceae (16 species) which alone accounted for more than a third of the shrub diversity. The Fabaceae (six species) and Euiphorbiaceae (4 species) were also well represented. The shrub species found to be very frequent, very common or common included:

Arundinaria ciliata (Poaceae)
Gardinia erythroclada (Rubiaceae)
Melientha suavis (Opiliaceae)
Memecylon edule (Melastomataceae)
Ochna harmandii (Ochnaceae)
Phyllanthus emblica (Euphorbiaceae)
Randia tomentosa (Rubiaceae)
Randia uliginosa (Rubiaceae)
Strychnos nux-blanda (Loganiaceae)
Symplocos racemosa (Symplocaceae)

The diverse assemblage of subshrubs and herbaceous species on the floor of these dry deciduous dipterocarp forests is richly represented in herbaceous monocots which form three of the four most diverse families. Leading these is the Zingiberaceae with 17 species, followed by the Orchidaceae in second place with six species and the Poaceae fourth with five species. Overall there were 36 families represented among the 97 species of subshrubs and herbs sampled. The growth forms of these species were relatively distributed as follows: subshrubs (25%), suffrutescents (12%), herbaceous perennials with rhizomes (23%), herbaceous perennials with tubers (18%), herbaceous perennials with bulbs (1%), and annuals (21%). The large proportion of species that can resprout from underground meristems reflects adaptations to frequent fires in this habitat.

Two species were particularly abundant:

Dillenia hookeri (Dilleniaceae) - subshrub
Holarrhaena curtisii (Apocynaceae) – suffrutescent

Other common species in these life-forms were:

Clitoria hanceana (Fabaceae-Papilionoideae) - suffrutescent
Costus speciosus (Zingiberaceae) – rhizomatous herb
Globba siamensis (Zingiberaceae) – tuberous herb
Helicteres lanceolata (Sterculiaceae) – subshrub
Leea rubra (Leeaceae) – subshrub
Urena rigida (Malvaceae) – subshrub

Two small palms were present in low numbers and classified as subshrubs – *Calamus acanthophyllus* and *Phoenix acaulis*. Similar habitats in Thailand typical have *Cycas siamensis* as a common understory species, but this cycad was not observed by Vidal.

Lianas and epiphytes are poorly represented in dry deciduous dipterocarp forests. Vidal (1960) reported only seven species of vines, one parasite and three identified epiphyes in his surveys. The epiphytes were *Hoya macrophylla* (Asclepiadaceae), a drought adapted species with CAM metabolism, as well as *Schefflera elliptica* (Araliaceae) and *Staurochilus fasciatus* (Orchidaceae). Other unidentified orchid species were also present.

The phenology of dry deciduous dipterocarp forests is strongly to deciduousness during the dry season. Vidal found that 95% of his tree species and 84% of his shrub species were deciduous. Woody species begin to lose their leaves in December and reach a peak of deciduousness in February (85% of species deciduous) and March (60% of species deciduous) before beginning to leaf out in April. Some individual species such as *Dipterocarpus intricatus* begin to lose their leaves in December, while other species such *Shorea siamensis* do not typically begin to drop leaves until February. The timing of leaf fall may highly variable between sites and years, however, depending on soil moisture availability. Herbaceous and subshrub species show a much more pronounced leafless period. All species in this group are generally leafless in December and remain so until the advent of monsoon rains in April. Vidal (1960) found that 62% of the tree species and 44% of the shrub species flowered in the leafy period of the dry season, while 33% of trees and 53% of shrubs flowered in the wet season. Only a very few woody species

flowered in the dry season when trees or shrubs were leafless. There is no sharp peak in seasonal flowering of woody species, with flowering spread in every month of the year except November. Subshrubs and herbaceous species largely flower in the wet season, with a broad peak of flowering in May and June.

Savanna habitats with a dominance of grasses and sedges and a scattered distribution of woody species have become increasingly common in southern Laos with the degradation of dry deciduous dipterocarp forest and woodland. These habitats are not a natural climax component of Laotian vegetation, but rather represent changes from heavy human impacts on forested areas. Vidal (1960) describes three forms of savanna communities for southern Laos. The first of these is a tree savanna where grass cover of *Themeda* is dominant and there are scattered low trees of either *Careya sphaerica* (Lecythidaceae) or *Lagerstroemia macrocarpa* (Lythraceae). Areas with frequent fires that remove tree species from mixed deciduous or dry evergreen forest may support a dominance of *Thysanolaena maxima*, a tall grass 2-3 m in height. Other savannas are dominated by low growth of grasses, sedges and other herbs. Vidal (1960) points out that patterns of low hillocks present in some of these herb savannas are formed by decomposing stumps of deciduous dipterocarps and thus provide evidence of the recent origin of these savannas.

Vidal (1960) describes a distinct form of dry deciduous dipterocarp forest occurring in restricted areas of northwestern Laos on dry mountain slopes northwest of Louang Prabang. Dry deciduous dipterocarp forest is present on rocky skeletal soils at elevations of below 600 m in this area, with a unique mix of lowland species characteristic of this habitat growing with montane floristic elements. The dominant species are *Shorea siamensis* and *Castanopsis indica* (Fagaceae), and there is notable absence of other species of Dipterocarpaceae. No single shrub species is common, while the herbaceous understory is dominated by *Indigofera galegoides* and *Flemingia chappar* (Fabaceae-Papilionoideae), *Croton oblongifolius* (Euphorbiaceae) and *Pogonatherum crinitum* (Poaceae). Overall species diversity is significantly lower here than in dry deciduous dipterocarp habitats in southern Laos. At higher elevations of 500-800 m above the zone of *Shorea siamensis* on these hills there is an open woodland community dominated by *Tristaniopsis burmannica* (Myrtaceae). This community is transitional to stands of *Pinus khesya* at the summit of these hills at about 800 m.

Hill Evergreen Forests

Above about 800 m in northern Laos, forests structure and composition undergoes sharp changes from lowland communities to montane forest types that have generally been termed hill evergreen forest. These have been termed *forêt dense* and *forêt dense humide* in the French literature (Vidal 1960) and more recently Northeast Indochina Montane Forest (Wikramanayake et al. 1997). Rather than a single community type, these montane forests include a variety of forest associations under the general name of hill evergreen forest. Also included in these montane habitats are conifer forests which are treated separately below.

Vidal (1960) has described elevational gradients of montane communities in the Annamite Range north of Vientiane near Xieng-Khouang and in the region of Paksong on the Bolovens Plateau in southern Laos where *terre rouge* basalt soils are characteristic

and annual rainfall commonly exceeds 3,000 mm. Mean annual rainfall changes from about 2,000 mm lower on these gradients to more than 3,000 mm at 2,000 m elevation.

Transitional Forest Communities

Beginning at about 800 m elevation near Xieng-Khouang, there is a transitional community of humid evergreen forest with *Dipterocarpus turbinatus* and *Rhus* cf. *succedanea* (Anacardiaceae) as the dominant canopy trees. This former species is closely related to *D. alatus* and *D. costatus* which occur in dry evergreen forests at lower elevations. Also characteristic are a diversity of palms including *Arenga saccharifera, Caryota,* and species of *Calamus*. Around 1000 m elevation, Vidal encountered a bamboo forest dominated by stands of *Cephalostachyum virgatum* 6-8 m in height. He suggested that this community represented a degraded stage of forest following clearance. Pure stands of *Cephalostachyum* in this area have also been described for this region by Kerr (1932). *Dipterocarpus turbinatus* is lkikewise the dominant tree in transitional forest communities at middle elevations on the Bolovens Plateau in southern Laos.

Forests of Fagaceae and Lauraceae

Between 1000 and 2000 m elevation near Xieng-Khouang forest structure changes to hill evergreen community dominated by species of Fagaceae and Lauraceae. Characteristic evergreen montane species at this site (Vidal 1966) included:

Bischoffia javanica (Euphorbiaceae)
Castanopsis fleuryi (Fagaceae)
Castanopsis hystrix (Fagaceae)
Castanopsis indica (Fagaceae)
Cinnamomum cassia (Lauraceae)
Litsea sebifera (Lauraceae)
Machilus odoratissima (Lauraceae)

Also present were a series of light-demanding species suggesting that human activity had opened large gaps in this forest. These species included *Betula alnoides* (Betulaceae), *Archidendron clypearia* (Fabaceae-Mimosaceae), and *Sapium discolor* (Euphorbiaceae). *Betula* and *Sapium* are deciduous unlike the evergreen dominants of undisturbed hill evergreen forest.

Dense hill evergreen forests of Fagaceae and Lauraceae on *terre rouge* soils of the Bolovens Plateau are structurally similar to those in northern Laos but have pronounced floristic differences. Vidal (1966) suggested that these Bolovens habitats in comparison to similar forest in northern Laos were richer in understory shrub species diversity but poor in tree species diversity. Common species in this habitat identified by early researchers (Poilane in Vidal 1966) included:

Adinandra integerrima (Ternstroemiceae)
Castanopsis indica (Fagaceae)
Elaeocarpus floribundus (Elaeocarpaceae)

Elaeocarpus parvifolius (Elaeocarpaceae)
Elaeocarpus sylvestris (Elaeocarpaceae)
Eugenia cymosa (Myrtaceae)
Manglietia chevalieri (Magnoliaceae)
Manglietia duclouxii (Magnoliaceae)
Paranephelium chinense var. *laoticum* (Sapindaceae)
Picrasma javanica (Simaroubaceae)
Quercus chrysocalyx (Fagaceae)
Quercus macrocalyx (Fagaceae)
Sloanea kerrii (Tiliaceae)
Ternstroemia japonica (Ternstroemiaceae)

From his own field studies, Vidal (1966) reported a dominance of the following trees:

Lithocarpus microlepis (Fagaceae)
Lithocarpus vidaliana (Fagaceae)
Lithocarpus sp. (Fagaceae)
Litsea sebifera (Lauraceae)
Phoebe cuneata (Lauraceae)
Pirus granulosa (Rosaceae)

Forest edges and large gaps frequently contained *Betula alnoides* (Betulaceae) and *Rhus semialata* (Anacardiaceae).

Mixed Hardwood-Conifer Forests

The communities of Fagaceae and Lauraceae give way at about 2000 m elevation around Xieng-Khouang to a mixed hardwood-conifer forest populated almost entirely by evergreen tree species. Present as dominant trees are *Fokienia hodginsii* (Cupressaceae) and *Podocarpus neriifolius* (Podocarpaceae), along with *Castanopsis gamblei* (Fagaceae), *Manglietia duclouxii* and *Michelia floribunda* (Magnoliaceae), *Acer heptaphlebum* (Aceraceae) and *Elaeocarpus integripetalus* (Elaeocarpaceae) (Kerr 1932, Vidal 1966). Woody lianas of *Gnetum montanum* may also be present. Under relatively undisturbed conditions, this humid community accumulates thick layer of moist humus over the ground surface. Because these sites have been populated by hill tribe villages for many years, most forest areas have been heavily degraded. An abundance of cool-environment epiphytes indicate the humid environment present. Among these are mosses, lichen species of *Usnea*, various orchids and *Agapetes poilanei* (Ericaceae). Mixed hardwood-conifer forest in the Annamite Range of southern Laos has not been well described, but here Fagaceae and Lauraceae are similarly dominant, with *Podocarpus imbricatus* as the common conifer associate.

Open Montane Forests

Open hill evergreen forests are also present between 1,000 and 2,000 m around Xieng-Khouang, primarily on thin sandy soils in areas with less than 2,000 mm annual rainfall. Vidal (1966) identified three forest communities of this structure that had resulted from differing combinations of human intervention and specific edaphic conditions. The first of these found at 1,300 m near Phou Khe was an open forest of *Castanopsis hystrix* (Fagaceae), with *Phyllanthus emblica* (Euphorbiaceae) as a codominant and *Antidesma collettii* (Euphorbiaceae), *Helicia balansae* (Proteaceae) and *Wendlandia paniculata* (Rubiaceae) as important associates. The low stature of trees in this community, less than 10 m height, and open understory with an abundance of broad-leaved monocots and grasses led Vidal to suggest that this community was degraded by fire from hill evergreen forest originally dominated by mixed Fagaceae.

A second form of open hill evergreen forest in this region is an open oak-conifer forest. Vidal (1966) sampled four stands of this community and identified *Quercus griffithii*, *Q. serrata*, and the conifer *Keteleeria evelyniana* (Pinaceae) as the domonant tree species. Associated with these dominants were many of the same species from the *Castonopsis* community:

Anneslea fragrans (Ternstroemiaceae)
Aporosa villosa (Euphorbiaceae)
Crabiodendron stellatum (Ericaceae)
Engelhardtia colebrookiana (Juglandaceae)
Helicia balansae (Proteaceae)
Phyllanthus emblica (Euphorbiaceae)
Pieris ovalifolia (Ericaceae)
Schima wallichii (Ternstroemiaceae)
Styrax cf. *caserifolius* (Styracaceae)
Vaccinium exaristatum (Ericaceae)

This community can occur either as an open forest or low and relatively stunted woodland, often with relatively pure populations of *Quercus*, *Keteleeria* or *Engelhardtia*. Grasses dominate the herbaceous understory. Vidal (1966) suggested that this community represents a pseudoclimax resulting from both special edaphic conditions and human influence through fire. Similar communities dominated by *Quercus griffithii* and *Q. serrata* are present on the Bolovens Plateau of southern Laos.

The third form of open hill evergreen forest characterized by Vidal (1966) is a community overwhelmingly dominated by *Engelhardtia colebrookiana* (Juglandaceae), with an understory cover of braken fern, *Pteridium aquilinum*. This clearly appeared to be an edaphic climax on skeletal granitic soils.

Long histories of human impact on the slopes of the Annamite Range in Laos has led to the degradation of large areas of what were once hill evergreen forest. Such forests have been replaced by thickets or savannas with diverse structure depending on the degree of degradation and the time for successional recovery since major disturbance. Thickets may include diverse assemblages of woody species or be dominated by relatively pure stands of a single colonizing species. Tree species that are common in such thickets include:

Broussonetia papyrifera (Moraceae)
Croton cavaleriei (Euphorbiaceae)
Celtis cinnamomea (Ulmaceae)
Dalbergia sp. (Fabaceae-Papilionoideae)
Duabanga sonneratioides (Sonneratiaceae)
Erythrina stricta (Fabaceae-Papilionoideae)
Styrax tonkinense (Styracaceae)
Trema angustifolia (Ulmaceae)
Trema velutina (Ulmaceae)
Vaccinium exaristatum (Ericaceae)

These are largely deciduous species, unlike the evergreen dominants of natural hill evergreen forest. Many other tree and shrub species may also dominate local areas. Overall, there is a rich assemblage of shrub and liana species present in these thickets.

Shrub and tree thickets are also widespread in degraded montane forest habitats of the Bolovens Plateau of southern Laos, but appear to often support different pioneer species. For these thickets Vidal (1966) reported a dominance of the following woody species:

Capparis sepiaria (Capparidaceae)
Debregeasia velutina (Urticaceae)
Rosa tunquinensis (Rosaceae)
Rubus alceaefolius (Rosaceae)
Rubus ellipticus (Rosaceae)
Sambucus javanica (Caprifoliaceae)
Solanum torvum (Solanaceae)
Trema velutina (Ulmaceae)

The introduced *Eupatorium odoratum* (Asteraceae) may be present in great abundance in the tall herb strata.

Open savannas, commonly dominated by the grass *Imperata cylindrica*, are present in these montane habitats in areas totally denuded of forest vegetation, but also in areas of unusual edaphic conditions. Under conditions of repeated fire, woody species are not able to colonize these savannas and the community structure becomes converted to a pseudo-steppe dominated by grasses and sedges (Vidal 1966). Natural pseudo-steppe grasslands may occur in areas of poor drainage.

Open tree savannas are also widespread in northern Laos, representing both a degraded stage of open forest and a colonization of open landscapes by pioneer tree species. The most frequent woody species in these tree savannas are:

Albizzia stipulata (Fabaceae-Momosoideae)
Bauhinia variegata (Fabaceae-Caesalpinoideae)
Callicarpa arborea (Combretaceae)
Eriolaena candollei (Sterculiaceae)
Erythrina lithosperma (Fabaceae-Papilionoideae)
Grewia bulot (Tiliaceae)
Helicia balansae (Proteaceae)

Phyllanthus emblica (Euphorbiaceae)
Schima wallichii (Ternstroemiaceae)

Vidal describes tree savannas of similar structure for the Bolovens Plateau with *Crabiodendron stellatum* and *Pieris ovalifolia* (Ericaceae) as woody dominants and an herbaceous understory dominated by *Imperata cylindrica* and *Hyparrhenia eberhardtii* (Poaceae).

Conifer Forests

Vidal (1966) divided forest habitats dominated by conifers into first categories of open forest/woodlands and dense humid forests. The open forests are the lowland communities dominated by *Pinus merkusii* and montane areas from about 800 –1,500 m dominated by *Pinus kesiya* and/or *Keteleeria evelyniana.* Dense conifer forest communities above 1,600 m elevation are characterized by a dominance of *Dacrycarpus (Podocarpus) imbricatus, Fokienia hodginsii* or *Cunninghamia lanceolata.*

Lowland Conifer Woodlands

Lowland areas below 1,000 m elevation with skeletal soils formed of schist or sandstone often support woodland communities dominated by a two-needled pine, *Pinus merkusii*. This is a widespread and ecologically plastic pine species that may occur over a variety of soil substrates and rainfall regimes. Depending on soil moisture availability, this species reaches maximum heights of up to 25-30 m. Frequent understory fires help to maintain dominance of this pine over hardwood species with lower resistance to burning. In many cases *P. merkusii* is associated with degraded communities of dry deciduous dipterocarp forest where *Dipterocarpus obtusifolius* is a codominant. It may also occur at its upper elevational limits on skeletal soils in wetter areas with species of *Quercus* and *Keteleeria evelyniana*.

Open Montane Conifer Forests

Open forests dominated by *Pinus kesiya*, a widespread species in Southeast Asia, is found throughout Laos on skeletal soils of schist or sandstone at elevations of 800-1,500 m in areas with less than 2,000 mm mean annual rainfall. This is a three-needled pine contrasting with the two-needle fascicles of *P. merkusii* that typically occurs at lower elevations. Only rarely do the two pines overlap at elevations of 800-1,000 m. Under reasonable growing conditions, P. kesiya reaches 20-30 m in height. The most common tree associates of *P. kesiya* are *Keteleeria evelyniana, Pieris ovalifolia* (Ericaceae), *Schima wallichii* (Ternstroemiaceae) and *Tristania merguensis* (Myrtaceae). Frequent fire seems to promote the establishment and maintenance of these pine forests at the expense of hardwoods.

A second community of open conifer forest in montane areas of Laos is dominated by *Keteleeria evelyniana* which may occur in relatively pure stands or mixed with *Pinus kesiya, P. merkusii*, or species of *Quercus*. This species species may reach up to 35 m in height and occurs from subtropical areas of southern China southward into Laos and

Vietnam. It does not occur in northern Thailand. Over this range, *K. evelyniana* shows a wide ecological amplitude, growing on sites with relatively dry conditions to areas with more than 3,000 mm of mean annual rainfall. Like the pines, it appears to be much more edaphically controlled than moisture controlled in its distribution. Vidal (1966) suggests on the basis of stand composition that these *Keteleeria* forests may represent a transitional stage of succession between pine forests and open montane oak forests.

Dense Montane Conifer Forests

Dense montane forests dominated by one of three conifer species are present in scattered areas of Laos. One such community is dominated by *Dacrycarpus (Podocarpus) imbricatus* (Podocarpaceae) which may occur in relatively pure stands, but more commonly mixed with Fagaceae and Lauraceae. These stands are best represented on deep clay soils formed over crystalline parent rock in very humid areas of the Bolovens Plateau and the Annamite Range. Individual trees reach 30 m in height.

A second community forming dense conifer stands is dominated by *Fokiena hodginsii* in humid habitats at 1,500-2,400 m elevation in northern Laos. Vidal (1966) reported that these imposing trees may reach as much as 40-50 m in height, although Hiep and Vidal (1996) suggest a height limit of 3-35 m. These humid forests receive more than 3,000 mm rainfall annually, and support a lush understory layer of mosses and ferns growing over 50-60 cm of humus. Mists often cover these forests during the dry season, helping protect them from desiccation.

The final form of dense conifer forest in northern Laos is dominated by *Cunninghamia lanceolata* (Taxodiaceae). This tall tree, reaching 30-40 m (or even 50 m) in height, is more typical of temperate mountain regions of Japan and China, but extends its range southward into the Annamite Range of northern Laos and Vietnam. Its habitat preference is for wet humid conditions with high rainfall and deep humus, as described above for *Fokiena hodginsii.*

Wetlands

The total area of wetlands existing in Laos is very poorly known, with estimates ranging from 590 to 21,800 km^2 (Claridge 1996). A recent mapping of wetland land use in a corridor within 50 km of the Mekong in Laos, made using 1:250,000 Landsat images but with little ground-truth verification, provides a preliminary quantitative estimate of the extent and types of wetlands along this corridor. These data indicate the presence of nearly 60,000 ha of seasonally-flooded shrubland, 27,000 ha of permanently-flooded swamp forest, and just 120 ha of seasonally-flooded forest (Table x). While little has been published in peer-reviewed journals on the ecology of Laotian wetlands, there is now a relatively large body of gray literature on bird and fish diversity in such habitats (see Claridge 1996).

Vidal (1966) described the floristic structure of a number of wetland communities in Laos.

On the basis particularly of vertebrate species diversity, Claridge (1996) has identified a number of wetland areas of international significance within Laos. These

include the Mekong River wetlands, the Xe Champhon – Nong Louang wetlands, the Bung Nong Ngom - Xe Pian - Xe Khampho complex of wetlands, the Khone Falls-Seephandon cataracts, the Xe Kong Plains, the Soukhoum wetlands, and the Nam Theun wetlands (Nakai Plateau).

The Nong Louang and Xe Champhon regions form a contiguous area of diverse wetlands located about 45 km southeast of Savannakhet. The former area is most notable for the presence of a number of permanent lakes extending over an area of about 90 km^2. The largest lake which is approximate 4 km^2 in area, thus making it one of the largest permanent bodies of water in Laos. Scattered trees, rice paddies and forest area border these lakes. Extensive areas of deep water in open woodland with a grassy understory provide what should be excellent crocodile habitat. The Xe Champhon wetlands are geomorphologically distinct, forming a 240 km^2 area of oxbow lakes and incised meanders along the Xe Champhon river and its tributaries. Swamp forests and open deciduous woodlands around these wetlands exist today in only a semi-natural to highly disturbed state because of human impacts. Some semi-protected area of swamp forest are present, however, as at Bung Sangha, Nong Lampong and Kout Xe Lat (Claridge 1996). Floating vegetation mats cover much of the area of the oxbow lakes, providing good crocodile habitat. *Mimosa pigra* invasions in the southern area of this area present a significant threat to native habitats.

The Bung Nong Ngom - Xe Pian - Xe Khampho complex of wetlands represent a mosaic of forest-woodland-wetlands in southern Laos beginning 25 km southeast of Champasak. The wetlands are made up of scattered small ponds that include both seasonal and permanent water bodies, with much of this area lying on old volcanic flows. The woodland areas have not been described in detail but these are seasonally-flooded communities surrounding wetland grasslands and ponds which support an important diversity of wildlife. The wetland marsh communities include aquatic vegetation dominated by *Cissus repens* (Vitaceae), *Monochoria hastaefolia* (Pontederiaceae), *Echinochloa stagnina* (Poaceae) and species of *Cyperus* (Cyperaceae). The total area of wetland marshes and ponds is probably less than 40 km^2, scattered over an area of 300 km^2 (Claridge 1996). The Soukhoum wetlands 50 km south-southwest of Champasack comprise over 160 small bodies of water scattered over a flat terrain of dry deciduous dipterocarp woodland at about 100 m elevation. This area has not been well surveyed.

The wetlands of the Khone Falls, or Seephandon wetlands, comprise a complex area of braided channels of the Mekong just above the Cambodian border where hundreds of small islands fringed with tracts of seasonally flooded forest. This is the only area of major waterfalls and rapids on the lower and middle Mekong. These swamp forests apparently play an important role in the ecology of local fish species that enter these forests in the wet season to breed. Roberts (1993) lists 34 plant species that are eaten by fish in this area. Surrounding slopes near the wetlands still contain deciduous forest communities and scattered areas of dry evergreen forest. Invasions by *Mimosa pigra* (Fabaceae-Mimosoideae) are also present here.

The Xe Kong plains lie north of the Xe Kong River about 65 km southeast of Champasack near the Cambodian border. Here, a complex of small ponds and marshes occurs at low elevations of 50-100 m over an area of about 350 km^2 within a matrix of dry deciduous dipterocarp forest. Local areas of mixed deciduous forest and dry evergreen forest are also present along river courses. These wetlands have been described

as a significant and rare example of lowland riverine ecosystem for Southeast Asia (Claridge 1996). Forest areas along the Xe Pian river to the north of the Xe Kong plain have been heavily degraded by logging and burning, and the fringes of some of the wetlands have been used for cultivation and grazing.

The Nam Theun wetlands lie 50 km northeast of Khammuane over an area of approximately 100 km^2 on the Nakai Plateau at an elevation of 500-550 m. The plateau area has numerous wetlands which appear to have formed as subsidence structures formed from the dissolution of underlying salt layers. Much of this area is a mosaic of wetland, grassland, savanna woodland and bamboo stands. Approximately 90% of the Nakai Plateau was still forested in 1993, and the Nam Theun catchment on the eastern margin of the plateau contains virtually the only extensive stand of *Pinus merkusii* in the entire Annamite Chain (Claridge 1996). Commercial logging on the plateau began as early as 1982 and is expanding. The Nam Theun 2 dam project will flood approximately 34,000 ha of the plateau area.

Table x. Estimated areas in hectares of wetland land-use types within 50 km of the Mekong in Laos. Datya collected for the Wetland Management Program of the Mekong Secretariat (Anonymous 1993, in Claridge 1996).

Province	Rice cultivation	Dam/resevoir	Lake	Floodplain grassland	Permanently flooded grassland	Seasonally flooded grassland	Floodplain shrubland	Swam fores
Vientiane Pref.	92,886	38,376	376	702	541	1,404	2,964	
Vientiane	27,342	45,000						
Sayabouri	9,930							
Louang Prabang	1,716							
Hongsa	4,857							
Ourdomsai	3,541							
Bokeo	4,563							
Louang Namtha	8,502							
Bolikhamsai	47,324							
Khammouane	56,863		8,502					
Savannakhet	192,654		2,964					18,
Champasak	251,728		1,092	6,552			42,510	7,
Saravane	68,172						13,884	
Total	770,078	83,376	12,934	7,254	541	1,404	59,358	27,

CAMBODIA

1. Physical Geography

Cambodia is positioned between Thailand and Vietnam in Southeast Asia, straddling a length of the Mekong River. The northeast margin of Cambodia abuts Laos, and the southern margin lies along the Gulf of Thailand. The total area of Cambodia is 181,035 km^2, just over half the size of Vietnam. The coastline of Vietnam along the Gulf of Thailand extends for 443 km.

Following Wharton (1968), Ashwell (1997) divides Cambodia into ten physiographic units. Half of these are lowlands lying below 100 m elevation that dominates most of central Cambodia, while half are areas of greater relief. The largest areas of lowlands are the extensive flat sandstone plains and rolling terrain that covers much of northern and northeastern Cambodia. These plains are composed of continental and marine sediments of Upper Mesozoic age. This terrain is broken by scattered flat-topped sandstone hills and rounded hills formed of andesite or basalt.

A large area of alluvial plains surrounding Tonle Sap and the Mekong River form a second physiographic unit, with these low-lying wetlands at 5-30 m elevation receiving annual flooding and associated deposition of silt. Quaternary sediments of 15-30 m cover much of these alluvial plains. The upper deltaic region of the Mekong River in southern Cambodia forms the third largest area of lowlands and has also received alluvial deposition in the past. The final two lowland areas are the Battantang plain of western Cambodia, with its fertile soils, and the basaltic areas near Kompong Cham in eastern Cambodia. Together, these five lowland regions cover more than 75% of Cambodia.

The coastal ranges of southwestern Cambodia comprises the largest and highest upland unit of the country. The Cardamom Mountains (Chuor Phnum Krâvanh) and Elephant Mountains (Chuor Phnom Damrei) form these coastal mountains, reaching to 1,150 m elevation in the latter. The orientation of their topography along the Gulf of Thailand produces unusually wet conditions on the southwestern slopes of these ranges. These ranges are largely Mesozoic sandstone, with localized areas of limestone and volcanic rock. Younger basalts in these ranges have produced rich supplies of gemstones – rubies, sapphires and zircons (Fontaine and Workman 1978). Also included to the northeastern part of this mountain unit are granite ridges that reach a maximum elevation of 1,813 m at Phnom Aural, the highest point in Cambodia. These ranges fringe the plain and extend southward to near the coast, leaving only a narrow coastal plain, and gently grade down into the interior lowlands to the north and northeast.

The broad colluvial slopes along this transition from the Cardamom and Elephant Mountains to the central lowlands form the second upland unit. The Dangrek Range (Chuor Phnum Dângrêk) forms the northern border of Cambodia with Thailand. These low sandstone hills reaching to 400-755 m elevation. This narrow range with steep escarpments separates the northern plains of Cambodia from similar sandstone sediments that form the Khorat Plateau in northeastern Thailand. The fourth upland unit of Cambodia comprises the northeastern mountains that represent a westward extension of the granitic and sedimentary rocks of the Kontum Plateau of southern Vietnam. Thus, this area forms a small part of the Annamite Ranges. Although higher peaks occur just across

the border into Laos and Vietnam from this northeastern area, the highest hills here in Cambodia reach only 700- 800 m in elevation.

The final physiographic unit of Cambodia is made up of basalts of the Rattanakiri and Chhlong Plateaus that lie along the northeastern border of Cambodia with Vietnam and form a transition to the Annamite Range. The former lies between the Se San and Srepok tributaries of the Mekong, while the latter lies further south in Louang Prabang Province opposite Dac Lac Province, Vietnam. These plateau areas are relatively low in elevation, with only a few points reaching over 400 m.

2. Hydrology

The Mekong River flows from north to south through Cambodia, bisecting the eastern half of the country. Entering northeastern Cambodia, the Mekong flows southward until its course is deflected sharply westward by basalt formations near Kompang Cham. After cutting thriugh these basalts, the river continues its flow westwards to Phnom Penh and then turns southeastward through Vietnam to its delta on the South China Sea. Estimates have been made that only about 10% of the total flow of the Mekong River originates within Cambodia from nine rivers which drain into Tonle Sap. Another 20% of the flows come from the Sekong River that drains northeastern Cambodia and large areas of the western slopes of the Annamite Range. One quarter of the Mekong's flow is derived from the mountains of China and Tibet, while about half comes from adjacent parts of Laos, Thailand, and Vietnam (Pantulu 1986).

Three tributaries of the Mekong - the Sekong, Sesan and Srepok Rivers - drain northeastern Cambodia and adjacent areas of Laos and Vietnam. The Stung Sen and Stung Chinit that flow into Tonle Sap drain much of northern Cambodia. Also flowing into Tonle Sap are the Stung Sangke and Stung Poutisat that drain western Cambodia and the northern slopes of the coastal ranges. The overall drainage basin of Tonle Sap is 67,600 km^2 (Pantulu 1986). Short rivers with steep gradients drain the south slope of the Cardamom and Elephant Mountains flow directly into the Gulf of Thailand.

Tonle Sap covers about 2,580 square kilometers (about 1,000 square miles) in the dry season, but as much as 10,400 square kilometers (4,015 square miles) in the rainy season. It is Southeast Asia's largest lake. Despite its large size, the depth of Tonle Sap is only 1-2 m in the dry season and 8-10 m in the wet season. Its volume changes from about 1.3 x 10^9 m^3 in the dry season to 72 x 10^9 m^3 in the wet season (ORSTOM and BCEOM 1993). The outlet of Tonle Sap is the Tonle Sap River, which flows south into the Mekong during the wet season. During the rainy season, the floodwaters of the Mekong flow the reverse direction into Tonle Sap, expanding the area of the lake and inundating large areas of central Cambodia. Hydrological studies have found that 62% of the water input to Tonle Sap comes in this dry season input from the Mekong River, while only 38% comes from its hydrologic basin, particularly from the rivers (ORSTOM and BCEOM 1993). Because of this importance of the reverse Mekong flow, peak water levels in Tonle Sap lag 1-2 months behind the peak of seasonal rainfall.

The dynamic nature of sediment movement into and out of Tonle Sap has been the subject of much speculation. The shallow structure of the lake makes its longevity highly dependent on rates of sediment deposition. However, a good database does not exist to evaluate this question. The waters of the lake are highly turbid, indicating the possibility

of heavy sediment inputs, erosion along the banks of the lake, and/or disturbance and remixing of lake sediments. Early studies carried out in 1949-53 suggested an input of 5.7 million tons of sediment annually, offset by 4.7 million tons of sediment output (Bardach in Cambodian National Mekong Committee 1998). These data would indicate an annual rate of sediment deposition of 0.3-0.5 mm per year. Other workers, however, have suggested that a much higher rate of sedimentation may be occurring (Csavas 1990 and Woodsworth 1995 cited in Cambodian National Mekong Committee 1998). Much of the sediment input appears to come not from the Mekong but from the Stung Sen and Stung Chinit rivers. Accelerating rates of deforestation within the drainage basins of these rivers has the potential to significantly increase sediment inputs in the future.

Low plains bordering the Mekong River in south and southeastern Cambodia are divided into a complex pattern of braiding river channels. These areas are seasonally flooded by up to several meters of water.

3. Climatic Patterns

The seasonal rainfall pattern of Cambodia, as with other parts of Southeast Asia, is dominated by the influence of the monsoon climatic regime. Southwest monsoon winds from mid-April or May through October bring moist air masses from the Gulf of Thailand and heavy rains. The continental monsoon winds from the northeast bring dry conditions between November and March. Overviews of climatic patterns in Cambodia have been presented by Gaussen et al (1967), and Legris and Blasco (1972).

The topographic situation on the southwest-facing slopes of the Cardamom and Elephant Mountains adjacent to the Gulf of Thailand bring unusually high levels of rainfall. Koh Moul, Sihanoukville (Kompong Som) Veal Renh, and Tuk Sap at low elevations near the coast receive annual mean rainfall of 3,692, 3,825, 4,073, and 4,102 mm, respectively (Khuong, 1971, Tixier 1979). Bokor at an elevation of 850 m has an annual rainfall of about 4,420 mm, while the nearby Emerald Valley where moist winds from the coast funnel upward has about 5,380 mm with approximately a meter of rain falling in each of July and August (Anonymous 1999). These stations receive an average of 170 and 223 days a year of rainfall, respectively. The dry season in these stations is restricted to 2-3 months from December through February. Moving to northward to the Kirirom Plateau, rainfall drops to about 2,045 mm annually (Anonymous 1999).

Relatively high levels of rainfall are also present in the western foothills of the Annamite Range and other hills to the east of the Mekong where 3-4 months of dry season are typical. Mean annual rainfall in Ratanakiri Province is about 2,675 mm (Anonymous 1997).

North-central Cambodia, the northern slopes of the Cardamom and Elephant Mountains, and the river valleys of the Mekong and its tributaries north of Phnom Penh receive 1,500-2,000 mm of rainfall annually. The northern lowlands south of the Dangrek Mountains experience 5-6 months of seasonal drought, while the other areas of intermediate rainfall have a shorter dry season of 3-4 months. Examples of rainfall for cities in this region are Stung Treng with 1,855 mm and Kratie with 1,856 mm (Crocker 1962). The driest areas of Cambodia are the Tonle Sap basin with lowland areas to the west and the lower Mekong basin southeast of Phnom Penh. These areas receive less

than 1,500 mm of annual rainfall, with a mean of of 1,403 mm at Phnom Penh, 1,477 mm at Siem Reap, 1,350 at Battanbang, and 1,292 at Kompong Speu (Crocker 1962).. The dry season here is typically 5-6 months in length.

Mean monthly maximum and minimum temperatures occuring at Sihanoukville along the south coast of Cambodia are very constant. The mean monthly high temperatures range only from 31-33^{o}C, while mean monthly minimums vary from 19-23^{o}C (Department of Nature Conservation and Protection 1996). In the cooler uplands of Ratanakiri Province in northeastern Cambodia, these maximum and minimum monthly temperature means are 28.5-38.7 ^{o}C and 17.9-26.2 ^{o}C, respectively (Anonymous 1997). The Kirirom Plateau in the Elephant Mountains presents some of the coolest temperatures in cambodia. The mean maximum temperature in April, typically the warmest month of the year, is 31.7 ^{o}C, while the mean minimum temperature in January 1s 11.4 ^{o}C (Lay and Taylor-Hunt 1995).

4. Flora

No accurate assessment of the size of the Cambodian flora is available. Dy Phon (1982) suggested a known flora of 2308 species of seed plants, but this total seems far too small given more reasonable estimates of about 12,000-15,000 species for Laos, Cambodia and Vietnam combined (Schmid 1989). Given the absence of strong biogeographic barriers of topography or habitat between Cambodia and neighboring countries, one would not expect to find a high level of endemism within the Cambodia ovberall. Areas that might be expected to harbor locally distributed species would be the wet forests of the Cardamom and Elephant Mountains and swamp forests of the Tonle Sap floodplain. Adequate field studies have not been made, however, to determine what level of endemism might be present. The flora existing on the slopes of the Phnom Dangrek Mountains has not been studied, but the semi-evergreen forests of this region would not be hypothesized to harbor large numbers of endemic species becausae this forest type ocurs so broadly.

Based on those species that she did include, Dy Phon (1982) estimated that 10% of the Cambodian flora was endemic within the national political borders. This figure seems higher than what might be expected. Selecting a subset of 216 woody species, with about one quarter of these upland and three-quarters lowland species, Dy Phon came up with figures of 5% endemism for Cambodia and a further 26% endemic to mainland Southeast Asia (Laos, Cambodia, Vietnam, Thailand and Burma). Species characteristic of southern China comprised 4% of this woody flora, and these species were largely distributed in upland areas.

For the generic level, Dy Phon suggested the following biogeographic affinites for the Cambodian flora:

Indomalesian/Sino-Indomalesian genera	30%
pantropical genera	24%
Australian/Pacific genera	15%
African/Malagasy genera	14%
cosmopolitan genera	10%
continental Asian genera	7%

Although the flora of the Cambodian lowlands shows Indomalesian affinities, as indicated in part by the lack of endemic genera (Dy Phon 1982), the floodplains of Tonle Sap exhibit a flora rich in species unique to the Indochinese floristic region. These species include many shared more broadly through the Mekong basin, as well as others entirely restricted in distribution to the Tonle Sap floodplain. Indochinese endemics of the Mekong basin include *Coccocera anisopodum* (Euphorbiaceae), *Diospyros bejaudii* and *D. cambodiana* (Ebenaceae), *Samandura harmandii* (Simaroubaceae), *Garcinia loureiri* (Guttiferae), *Acacia thailandica* (Fabaceae-Mimosoideae) and *Hydnocarpus saigonensis* (Flacourtiaceae) (Dy Phon 1982, McDonald et al. 1997). These species are widespread locally along river channels, but exist today as relatively small and fragmented populations.

The endemic flora of the Elephant Mountains has been discussed by Dy Phon (1970). She listed 36 species as endemic to these mountains, amounting to about 9% of the known flora. Several of these species have since been collected out of this region, lowering the rate of endemism, but limited botanical collecting suggesting that both the total number and number of endemic species will likely riseas the flora becomes better known. Endemic species in the Elephant Mountains have their greatest abundance not in the lowland wet evergreen forest but in the submontane transitional forests at 600-900 m elevation. Notable endemic trees from the Elephant Mountains include *Castanopsis cambodiana* and *Quercus cambodiensis* (Fagaceae), *Cinnamomum cambodianum* and *Neolitsea cambodiana* (Lauraceae), and *Madhuca bejaudii* and *M. cambodiana* (Sapotaceae).

McDonald et al. (1997) point out that many of the broadly distributed endemics of the Mekong basin appear to be restricted around Tonle Sap to the Steung Sen catchment at the mouth of the lake where they occur as secondary or upper floodplain species. Their field studies suggest that the swamp forest communities of the Tonle Sap floodplain are unique both in structure and floristic composition, and contain a number of narrow endemic species. Although Tonle Sap is a freshwater lake, some elements of its floodplain flora show indications of relationships with coastal mangrove habitats. The endemic *Terminalia cambodiana* (Combretaceae), for example, is restricted in distribution to Tonle Sap and the southern coastal zone of Cambodia and adjacent Thailand. Species relationships in the genera *Diospyros* and *Barringtonia* also show this pattern. McDonald et al. (1997) reported the collection of what appeared to be a new species or variety of the mangrove *Lumnitzera racemosa* (Combretaceae) in the upper floodplain of Tonle Sap.

5. Vegetation Mapping

There are a variety of vegatation and land use mapping programs that have recently been completed for Cambodia (Table 1). These efforts have been based on a number of differing perspectives of land use questions and resource managment, and thus apply divergent schemes of classification for images from satellite and aerial photography that have been used in their construction.

The most ecological of these efforts is a detailed vegetation map of Cambodia has recently been published by Blasco et al. (1997) as an updated revision of an earlier map

by Legris and Blasco (1970). This map uses environmental characteristics of rainfall regime, elevation and forest structure to separate out map units.

Kunneke (1997) has provided a Cambodian Land Use and Cover Classification System (CLUCCS) for Cambodia through the United Nations Development Program using Landsat data. Defintions for the CLUCCS mapping units are described in some detail in this study. To date this mapping sysytem has been used to develop 1:50,000 scale maps of specific natural areas and national parks of conservation interest.

A mapping system of land use and habitat mapping for the Tonle Sap region has been published by FAO (1996). They defined woody vegetation cover categories as based on criteria of canopy height, canopy cover, and leaf phenology.

Several versions of land use and land cover maps have been produced by the Mekong Secretariat (1991, 1993, 1994). These cover simple categories of vegetation cover for Cambodia in 1973-76 (1:2,500,00 scale), 1992-93 (1:500,000 scale), and 1988-89 (1:500,000 scale).

A bioregions approach to mapping the vegetation of Cambodia has been published by Wikramanayake et al. (1997) who mapped eight vegetation units. The major portion of lowland areas of Cambodia were mapped as *Eastern Indochina Moist Forests* (= Semi-evergreen Forests) or *Central Indochina Dry Forests* (= Deciduous dipterocarp Forests). The broad region of the Cardamom and Elephant Mountains in southwestern Cambodia were designated as *Cardamom Mountains Wet Forest.* This region is classified as a mixture of Tropical Evergreen Forest, Semi-evergreen Forest and Montane Forest in this report. Small upland areas in eastern Cambodia were classified as *Bolavens-Kon Tum Montane Forests* and *Da Lat-Phnom Lyr Montane Forest* (= Montane Forests). Azonal wetland forests habitats in Cambodia were mapped by Wikramanayake et al. (1997) as *Tonle Sap-Mekong Peat Swamp Forests, Tonle Sap Freshwater Swamp Forests* and *Gulf of Thailand Mangroves.*

6. Forest Habitats

Forest habitats in Cambodia can be divided into three broad groups: lowland habitats, montane habitats, and azonal habitats where factors other than the regional climatic regime are the primary determinants of community structure.

6.1 Lowland Forest Habitats

6.1.1 Characteristics of Lowland Forest Habitats

Soil structure and characteristics are often a strong predictor of vegetation structure. Of course, climate is a strong co-variant as well in the relationship between soil pedogenesis and climatic history, as is soil moisture holding capacity. Areas with the same climatic regime of 1,400-2,000 mm of annual rainfall and 3-4 months of drought, which characterize much of Cambodia can support a range of vegetation structure from semi-evergreen forests of several forms to deciduous dipterocarp forests to pine woodlands to open savannas or thickets. History of human impact, of course, is also a critical factor in determining vegetation structure and composition.

Deep and well-drained soils that occur in alluvial basins and on older basalt areas generally support the largest stature trees and moist evergreen forests, while at the other extreme young or skeletal soils support open deciduous diptercarp woodlands. Not only substrate material but also degree of weathering in the same area can have a profound effect on vegetation dominance. This can be readily seen in the areas of basalt parent material to the east of the Mekong. Old basalt substrates weather into deep and fertile soils which originally supported tall semi-evergreen forests, while nearby geologically young flows of basalt have only skeletal soil development and support open woodlands dominated by the deciduous *Shorea siamensis*

The extensive lowlands of Cambodia with their mean annual rainfall of about 1,400 mm and 5-6 months of dry season, originally supported a mosaic of semi-evergreen forest on deeper or more mesic soils and deciduous dipterocarp forest and woodlands on more arid sites with skeletal soils. These areas of semi-evergreen forests and deciduous dipterocarp woodlands covered much of western and northern Cambodia, the northern and eastern slopes of the Cardamom and Elephant Mountains, and lowlands east of the Mekong River. However, lumbering, shifting agriculture, fire and other disturbances have heavily degraded large parts of this area into open savanna and savanna woodland.

Evergreen forest communities remain the dominant habitat over areas of Cambodia with higher rainfall and/or a shorter dry season. Semi-evergreen forest, with elements of wet evergreen forest in the wettest areas, still dominate the moist western slopes of the Cardamom and Elephant Mountains and scattered areas of northern and eastern Cambodia. Habitats with montane evergreen forest are present on the higher areas of the Cardamom range above 700-1,000 m elevation. This area of Cambodia has had only light population densities and has remained relatively free of historical disturbance from swidden agriculture. Commercial logging in these ranges, however, has accelerated at an alarming rate in the past decade.

As in other parts of Southeast Asia, fire has always been an important component of the environment in seasonal forest communities and savannas in Cambodia. This impact has been greatly increased, however, by two thousand years of human settlement. Over this period extensive areas of semi-evergreen forest, as described in more detail below, have been converted to savannas and savanna woodlands. Wharton (1966) describes this history of human use of fire to clear forestland for agriculture and the production of grazing land for domestic cattle and water buffalo.

6.1.2 Wet Evergreen Forest

6.1.2.1 Wet Evergreen Forest Habitats

Wet evergreen forest in Cambodia is found principally on the south-facing slopes of the Cardamom and Elephant Mountains, particularly in the area around Kompong Som Bay, where the southwestern monsoon produces unusually heavy rainfall. This association is in many ways a somewhat depauperate form of Indomalaysian rainforest, but has a distinctive floristic character with a notable number of endemic tree species. Here this forest association originally extended from the coast up to 600-700 m elevation. It is very unusual to have such wet rainforest ecosystems occurring at elevations below 600 m in mainland Southeast Asia. The special conditions of the Cardamom and

southern Elephant Mountains results from their geomorphology, with steep mountain slopes occurring directly back from the coast.

Lowland evergreen rainforest in Cambodia has been termed *forêt dense humide sempervirente* in the French literature, and more recently *Cardamom Mountains Moist Forest* by Wikramanayake et al. (1997). The latter authors lump both evergreen rainforest and elements of semi-evergreen forest in their characterization of this ecoregion. These wet evergreen forests along the coast have been significantly degraded in recent years by logging (Department of Nature Conservation and Protection 1996, Feil 1998).

Acid lithosols develop over the sandstone parent material that characterizes much of the Cardamom and Elephant Mountains. These thin soils, easily eroded under conditions of disturbance, allow the development of a dense but relatively low rainforest community. A similar form of evergreen rainforest has been described for KhaoYai National Park in south-central Thailand where topographic conditions with southwest-facing mountain slopes also produce very high levels of rainfall (Smitinand 1968, 1977).

The upper canopy of this evergreen rainforest averages 20-45 m in height, but is irregular in continuity and coverage. Rather than having broad arching canopies, individual trees are typical more cylindrical in canopy form with crown diameters of 20-25 m and crown depths of about 20 m (Hozumi et al. 1969). Beneath the irregular upper canopy, there exists a second stratum at a height of 10-20 m. Light penetration is sufficient to this subcanopy and to the understory below to allow the development of a rich abundance of palms and lianas of all sizes. A diverse assemblage of Dipterocarpaceae forms much of the upper canopy of this community, but other large forest trees are also present. Tree trunks with small buttresses or stilt roots are relatively common, but broad buttresses are relative infrquent. There are two exceptions to this with *Palaquium obovatum* (Sapotaceae) and *Heritiera javanica* (Sterculiaceae) boith exhibiting very large buttresses.. The former of these species is considered to be a vicariant of *P. ellipticum*, a species endemic to evergreen rainforests in southern India (Blasco 1971).

6.1.2.2 Tall forest in the Cardamom and Elephant Mountains

Qualitative descriptions of wet evergreen forests have been provided by for the Cardamom Mountains (Martin 1973) and for the Elephant Mountains (Dy Phon 1970). Also existing is a broad mapping of forest units in the lowland wet evergreen forest on the coastal margins of the Cardamom Range (FAO 1971), and description of forest resources on the west slopes (Monney and Huber 1970), and forest vegetation mapping of the Bokor National Park is currently in progress.

In the wet evergreen forests of the Elephant Mountains which extend up to 400-500 m on their ocean-facing slopes, the following are dominant species:

Anisoptera costata (Dipterocarpaceae) - dominant
Anisoptera scaphula (Dipterocarpaceae)
Dipterocarpus costatus (Dipterocarpaceae)
Dipterocarpus intricatus (Dipterocarpaceae)
Heritiera javanica (Sterculiaceae)

Hopea ferrea (Dipterocarpaceae)
Hopea odorata (Dipterocarpaceae)
Palaquium obovatum (Sapotaceae)
Parkia streptocarpa (Fabaceae-Mimosoideae)
Shorea guiso (Dipterocarpaceae) - dominant
Shorea hypochra (Dipterocarpaceae) - dominant
Swintonia pierrei (Anacardiaceae) - dominant
Szygium cinereum (Myrtaceae)
Tetrameles nudiflora (Datiscaceae)

The upper tree canopy is highly variable in both height and trunk diameter, yet forms a generally continuous albeit irregular cover. The lower canopy stratum is dense but less continuous. Tree trunks are typically straight and cylindrical and, as described above, generally without buttresses. Surprisingly, Martin (1973) reported that over many areas one quarter to one third of the lower canopy trees were leaning. Hozumi et al. (1969) described a forest stand density of 356-412 trees ha^{-1} having diameters of 10 cm above, and 12-16 of these with diameters of one meter or more. They further calculated that the wet evergreen forest used in their studies had a basal area of 31.9 m^2 ha^{-1}, a total dry weight biomass of 382 tons ha^{-1} (321 tons ha^{-1} above-ground), and a leaf area index of 7.4 m^2 m^{-2}. This leaf area index is relatively low in comparison of that present in Indomalaysian and Neotropical wet evergreen forests where values of 10-12 are commonly reported.

The ecological and floristic composition of these evergreen rainforest communities is poorly studied, and there would undoubtedly be recognizable communities within this association were it better known and investigated. Overall, however, these habitats appear to have a strong floristic relationship to rainforests of the Indo-Malyasian region. An unknown but significant degree of local endemism is also present, and far greater identified endemism will likely be found to be present once the flora of this region is better known.

An early inventory of tree densities in the area of Kompong Som Bay (FAO in Rollet 1972) reported the following average densities of family composition for a one-hectare area of evergreen rainforest:

	Diameters 10-29 cm	Diameters > 40 cm
Dipterocarpaceae	49.9	7.0
Guttiferae	22.1	1.0
Myrtaceae	20.4	2.8
Ebenaceae	15.2	-
Theaceae	14.6	1.2
Sterculiaceae	9.7	1.5
Sapindaceae	6.0	-
Fabaceae	-	1.0
Anacardiaceae	-	1.0

Several other families in this forest habitat are less abundant in number of individuals but important in the diversity of common species represented. These include the Anacardiaceae (*Bouea oppositifolia, Mangifera longipes, M. macrocarpa* (?), *Melanorrhoea laccifera* and *Swintonia pierrei*) and Lauraceae (*Cinnamomum iners, C. cambodianum* and *Dehaasia cuneata*).

One of the most abundant subcanopy species in the Elephant Mountains is *Hopea pierrei*, a small tree of limited distribution outside of this area. It seldom is found above 300 m elevation in the Elephant Mountains, but occurs with a limited distribution up to 1,000 m elevation in hill evergreen forests of northeastern Cambodia. In many stands, *H. pierrei* may comprise 50-70% of the tree stems (Legris and Blasco 1972). This species is also notable for the common abundance of aerial roots extending from the lower meter of trunk. Several species of another dipterocarp genus, *Vatica* may also be common, particularly *V. odorata*, as well as *Quercus chrysocalyx* (Fagaceae) and a species of *Anthocephalus* (Rubiaceae) (Martin 1973).

Although evergreen rainforests are largely populated by evergreen tree species, a few deciduous tree species may be present, particularly in areas that have been disturbed. Such deciduous or semi-deciduous species may include *Tetrameles nudiflora* (Datiscaceae), *Dipterocarpus costatus, D. intricatus*, *Sterculia lynchnophora* (Sterculiaceae) and *Irvingia malayana* (Simaroubaceae). These species show a general floristic relationship to semi-evergreen forest habitats of Southeast Asia.

Two large palms, *Caryota urens* and *Oncosperma tigillarium*, are common in the canopy of the evergreen rainforest. The latter is considered an indication of disturbance (Dy Phon 1969, 1970). A diverse assemblage of smaller palms are present in the understory, including *Pinanga duperreana, Areca triandra, Arenga pinnata* and *Licuala spinosa*. Forest edges support an abundance of rattans as well – *Calamus palustris* var. *cochinchinensis, C. rudentum, C. viminalis* and *C. salicifolius*. Many of these occur as understory species, but may become lianas when they are mature.

Lianas and perennial vines are an important component of the evergreen rainforest habitat. Two large woody lianas with a widespread distribution are *Spatholobus parvifolius* (Fabaceae-Papilionodieae) and *Entada phaseoloides* (Fabaceae-Mimosoideae). Herbaceous vines and semi-woody lianas are represented by genera such as *Pothos* (Araceae), *Piper* (Piperaceae), *Dioscorea* (Dioscoreaceae), *Smilax* (Smilacaceae) and *Argyreia* (Convolvulaceae). In addition to *Calamus*, particularly *C. viminalis*, the palms are represented as lianas by *Daemonops pierreanus*.

The evergreen rainforest understory is also populated by a diverse assemblage of shrubs and small trees, with an abundant representation from the Euphorbiaceae (*Antidesma cochinchinensis, A. ghaesembilla, Aporosa planchoniana* and *Croton*), Myrsinaceae (*Ardisia* spp.), and Rubiaceae (*Anocephalus chinensis*, *Chasalia curviflora*, *Pavetta indica, Lasianthus* spp. and *Psychotria* spp.). Many of these understory elements have a widespread distribution through Southeast Asia and Malaysia.

The herbaceous understory vegetation appears to be poorly developed in these evergreen rainforests. Legris and Blasco (1972) note the presence of two important monocot families, the Araceae (e.g. *Agloanema pierreanum* and *A. simplex*) and the Zingiberaceae (e.g. *Amomum* species, *Costus speciosus* and *Zingiber zerumbet*). Grasses are rare.

Epiphytes of the evergreen rainforest are rich in abundance but little is known about their diversity. The most important groups of epiphytes are the ferns and fern relatives (e.g. *Vittaria flexuosa, Drynaria quercifolia* and *Lycopodium phlegmaria*) and orchids.

6.1.2.3 Dwarf Evergreen Forest in the Cardamom and Elephant Mountains

In addition to typical wet evergreen forests, scattered areas in the Cardamom and Elephant Mountains from near sea level to moderate elevations support an unusual dwarf rainforest community reaching no more than 12-15 m height in areas of poorly-drained depressions. Although differing in floristic composition, these dwarf evergreen forests share many ecological features with the better-known kerangas heath forests of Borneo (Bruenig 1974). Dwarf evergreen forests can occur at any elevation, but are most typical of depressions on the summits of hills where they are found in a matrix of wet evergreen forest on better-drained sites (Dy Phon 1970, Rollet 1972). The dominant species in these waterlogged sites are typically *Dacrydium elatum* (Podocarpaceae) and *Tristania merguensis* (Myrtaceae). A mixture of other tree species may be present, most commonly *Podocarpus neriifolius* and *P.* (*Dacrycarpus*) *imbricatus*. Forest canopies here are described as only two-layered, with buttresses rare. The development of pneumatophores is present in some species, however (Legris and Blasco 1972). Lianas are uncommon.

An abundance of palms is characteristic of the canopy composition, and they often provide the largest number of stems. On the wettest sites, three palms (*Oncasperma tigillaria, Areca triandra,* and *Licuala spinosa*) may dominate the canopy reaching 20 m in height.

A subset of tree species from the taller wet evergreen rainforest community may also be present. The most important of these are *Hopea odorata* and *H. pierrei* (Dipterocarpaceae), *Syzgium zeylandica* (Myrtaceae), *Parinari annamensis* (Chrysobalanaceae), and *Calophyllum saigonensis* (Guttiferae). With the abundance of low palms, the understory of these dwarf forests is largely lacking in herbs. Some Zingiberaceae may be locally abundant with *Alpinia oxymitra* as an example, and terrestrial orchids are common. Notable components among epiphytes are the presence of the ant-plants *Hydnophytum* and *Myrmecodia* (Rubiaceae) and carnivorous *Nepenthes* (Nepenthaceae). Such epiphytes are strongly indicative of oligotrophic habitat conditions.

Hozumi et al. (1969) sampled a low elevation stand of dwarf evergreen forest in the Cardamom Mountains and estimated a density of trees with diameters of 10 cm or more as 76 trees ha^{-1}, but 2,570 trees ha^{-1} when diameters down to 4 cm were used. They found a basal area of 23.9 m^2 ha^{-1}, a leaf area index of 7.1 m^2 m^{-2}, and a dry weight biomass of 172 tons ha^{-1} (154 tons ha^{-1} above-ground).

6.1.2.4 Submontane Wet Evergreen Forest

A distinctive wet evergreen forest community occurs at elevations of about 500-800 m in the Elephant Mountains and likely in the Cardamonm Mountains as well, forming a transitional association between lowland wet evergreen forest and montane forest. This community occurs here at lower elevations than similar communities in the Annamite Range to the east. The characteristics of this transitional wet evergreen forest are notable

in its floristic structure. Notable is an abundance of species of Fagaceae (*Lithocarpus* and *Castanopsis*), Lauraceae (*Litsea, Neolitsea*, and *Cinnamomum*) and Myrtaceae (*Syzgium* and *Tristania*) in the canopy. These elements are more characteristic of montane forests. Also notable is the high frequency of four species of conifers – *Podocarpus* (*Nageia*) *fleuryi, P. neriifolius, P.* (*Nageia*) *wallichianus* and *Dacrydium elatum*. Conifers may occur in a variety of wet forest associations but are notable common on poorly drained soils, as described above. Despite the large number of montane floristic elements, many typical lowland rainforest elements are also present despite a minimal presence of Dipterocarpaceae.

The structure and floristics of a transitional wet evergreen forest on the slopes of Bokor National Park have been described by Dy Phon (1970). This canopy structure of this community differed from that of lowland wet evergreen forests in having only a single discontinuous tree stratum reaching to 30 m in height. This canopy is rich in Cambodian endemics. The dominant canopy species in this area were:

Aglaia roxburghiana (Thymeleaceae)
Aquilaria baillonii (Sterculiaceae)
Baccaurea sapida (Euphorbiaceae)
Bouea oppositifolia (Anacardiaceae)
Castanopsis cambodiana (Fagaceae)
Cinnamomum cambodianum (Lauraceae)
Cinnamomum litseaefolium (Lauraceae)
Cynometra polyandra (Fabaceae-Caesalpinoideae)
Dysoxylum cauliflorum (Meliaceae)
Garcinia merguensis (Guttiferae)
Gironniera subaequalis (Ulmaceae)
Guioa pleuropteris (Sapindaceae)
Heritiera javanica (Sterculiaceae)
Hopea ferrea (Dipterocarpaceae)
Hopea helferi (Dipterocarpaceae) - up to 600-700 m
Lithocarpus cambodiensis (Fagaceae)
Lithocarpus farinulenta (Fagaceae)
Lithocarpus guinieri (Fagaceae)
Lithocarpus harmandii (Fagaceae)
Litsea cambodiana (Lauraceae)
Litsea pierrei (Lauraceae)
Lophopetalum duperreanum (Celastraceae)
Mangifera longipes (Anacardiaceae)
Neolitsea cambodiana (Lauraceae)
Palaquium obovatum (Sapotaceae)
Parkia streptocarpa (Fabaceae-Mimosoideae) - up to 600 m
Pterospermum grewiaefolium (Sterculiaceae)
Quercus cambodiensis (Fagaceae)
Sapium baccatum (Euphorbiaceae)
Saraca biglandulosa (Fabaceae-Caesalpinoideae)
Sterculia lychnophora (Sterculiaceae) - up to 800 m; deciduous

Swintonia pierrei (Anacardiaceae)
Syzygium lineatum (Myrtaceae)
Syzygium zeylandicum (Myrtaceae)
Tetrameles nudiflora (Datiscaceae) - up to 600 m; deciduous

The dense understory shrub stratum in this community reaches from 2-8 m in height. It consists virtually entirely of evergreen species, with Euphorbiaceae, Lauraceae and Rubiaceae as dominant elements. Monocots form a significant element of this understory with *Dracaea gracilis* (Liliaceae), *Arenga saccharifera* and *Pinanga cochinchinensis* (Arecaceae), and *Pandanus capusii* and *P. cupribasalis* (Pandanaceae). Also present is a diverse and herb strata characterized by tree ferns (*Cyathea* and *Cibotium*), Zingiberaceae and terrestrial Orchidaceae as major elements. Epiphytes are also abundant and diverse, with 35 species mentioned by Dy Phon (1970) as present. Ferns and orchids make up most of the epiphytes.

Hilltop ridges and steep slopes of the maritime face of the Cardamom and Elephant Mountains contain local communities dominated by pure stands of woody bamboos. These stands, which have not been studied, appear to be relatively stable although they may represent some intermediate stage of forest succession following natural disturbance (Legris and Blasco 1972).

6.1.3 Semi-Evergreen Forests

6.1.3.1 Structure of Semi-Evergreen Forests

Semi-evergreen forests in Cambodia, as elsewhere in Southeast Asia, represent a highly heterogeneous group of communities whose classification together derives from the parallel climatic and edaphic regimes that promote their formation. The diversity of names for this community, for example with the French term *forêt dense semi-decidue* and the widely used *dry evergreen forest* are an indication of the range of phenological structure that may be present in semi-evergreen forest habitats. Given the highly variable proportion of evergreen and deciduous tree species that may be present in such communities, we prefer the term *semi-evergreen* to other names. This terminology avoids problems that have commonly existed in the past when semi-evergreen forest communities dominated by deciduous species such as *Lagerstroemia calyculata* (Lythraceae) and *Irvingia malayana* (Simaroubaceae) have been incorrectly designated as mixed deciduous forests.

These communities may range from forest canopies dominated by largely evergreen forest species to associations dominated by deciduous or semi-deciduous trees. These variations relate in part to edaphic conditions and related soil moisture availability during the dry season, as well as to history of disturbance. The wide distribution and rich diversity of tree species in semi-evergreen forests makes it impossible to characterize these communities by a single suite of dominant species.

Semi-evergreen forests have a characteristic tall and multi-layered forest structure similar to those of lowland evergreen rainforest, but grow in areas of lower and more seasonal rainfall regimes. In contrast to evergreen rainforests, species diversity is lower and both canopies and understory more open. While semi-evergreen forests have floristic

relationships to lowland Indomalaysian forest communities, they exhibit a unique floristic structure that is relatively rich in species endemic to mainland Southeast Asia. With the broad distribution of these types of communities across Thailand and Laos, however, there are few Cambodian endemics.

6.1.3.2 Typical Semi-Evergreen Forest

Legris and Blasco (1972) suggest that semi-evergreen forests are the most beautiful and diverse of all forest habitats in Cambodia, with a majestic appearance including trees up to 2 m or more in diameter and a rich structure of lianas through the canopy. When these habitats are undisturbed, they include a complex canopy structure beginning with an irregular cover of emergent canopies reaching 40-50 m in height. Dipterocarpaceae are a major component of these emergent tree canopies with such species as *Dipterocarpus alatus, D. costatus, Hopea odorata, Shorea guiso, S. hypochra* and *Anisoptera costata*. Other giant emergents are species of *Ficus* (Moraceae), *Tetrameles nudiflora* (Datisciaceae), and *Heritiera javanica* (Sterculiaceae) forming large buttresses.

The primary forest canopy, extending between these giant emergents at a height of 20-30 (35) m, has a diverse composition of associated species. These include *Lagerstroemia calyculata* and *L. floribunda* (Lythraceae), *Irvingia malayana*, (Simaroubaceae), and a variety of legumes including *Sindora siamensis*, *Pterocarpus macrocarpus*, and *Afzelia xylocarpa.* Other genera well represented in the canopy may include *Diospyros* (Ebenaceae), *Wrightia* and *Alstonia* (Apocynaceae), *Litsaea* and *Cinnamomum* (Lauraceae), Eugenia (Myrtaceae), and *Adina cordifolia* (Rubiaceae). Notable among these are deciduous trees which at least briefly lose all of their leaves (*Lagerstroemia calyculata, Irvingia malayana, Pterocarpus macrocarpus*, and *Afzelia xylocarpa).*

Tree diversity is moderately high in semi-evergreen forests. Rollet (1972) reported a total of 148 tre species sampled in a survey of 49 ha of semi-evergreen forest near Damrey Phong in northeast of Phnom Penh.

The understory layers of semi-evergreen forest are commonly relatively diverse in species composition. Families providing significant contributions to this woody understory flora include the Rubiceae, Araliaceae, Annonaceae (diverse species of *Polyathia* and *Xylopia*), Euphorbiaceae (e.g. *Baccaurea* and *Paracleisthus*), and Arecaeae (*Plectocomia, Licuala* and *Caryota*). The most ecologically important groups of herbaceous species in the understory are typically Zingiberaceae, Araceae and Musaceae. Grasses are rare in this shaded understory, although woody bamboos may become important with disturbance.

As in semi-evergreen forests of other parts of Southeast Asia, woody lianas are abundant. Legris and Blasco (1972) mention species of *Calamus* (Arecaceae), *Melodorum thorelii* (Annonaceae), and *Ancistrocladus* cf. *extensus* (Ancistrocladaceae) as important woody lianas in the semi-evergreen forests of Cambodia. Many more woody lianas are also present. Epiphytes are less rich in semi-evergreen forests than in the hill evergreen forest, but nevertheless diverse. Orchids occurring high in the canopy account for much of this diversity but pteridophytes are also important with large shield ferns (*Platycerium grande* and *P. coronarium*) often present.

6.1.3.3 Semi-Evergreen Forest with *Lagerstroemia* Dominance

Extensive areas of semi-evergreen forest north of Tonle Sap and largely (but not exclusively) east of the Mekong exhibit a dominance or co-dominance by deciduous species of *Lagerstroemia*. These forest represent a stage in the transition from mixed deciduous forest to semi-evergreen forest, but are classified here with semi-evergreen forest because of the significant contribution of Dipterocarpaceae to these stands.

Large trees reaching 40 m in height and more than one meter in diameter were originally common in areas of baslatic soils of eastern Cambodia on the Ratanakiri and Chhlong plateaus. Here the soils are typically deep, well drained and fertile and thus have been heavily impacted for agricultural and agroforestry uses. Many of these areas have traditionally supported rubber plantations of *Hevea brasiliensis* and extended Hill Tribe agriculture, and were likely heavily utilized for centuries in the past by the Khymer.

Rollet (1972) provided a quantitative description of two such communities located between Krek and Mimot on two forms of basaltic soils. One of these was growing on *terre brune* soils that appeared to be moderately waterlogged during the wet season. Nearly one-third of all the trees in this community were *Lagerstroemia*. The 4-ha stand sampled had a density of 338 trees ha^{-1} greater than 10 cm diameter, with 12 trees ha^{-1} reaching 1 m or more in diameter. *Lagerstroemia* species formed 30% of these large trees, while *Dipterocarpus dyeri* comprised another 54%. Other species reaching diameters of 1 m included *Anisoptera costata* and *Shorea vulgaris* (Dipterocarpaceae), *Toona febrifuga* (Meliaceae), *Ficus* sp. (Moraceae), and *Irvingia malayana* (Simaroubaceae). Also important among canopy trees were *Peltophorum dasyrachis* (Fabaceae-Caesalpinoideae), *Cratoxylon formosum* (Guttiferae), and *Anogeissus vulgaris* (Combretaceae). The understory of this forest was evergreen with *Corypha* (Arecaceae) and bamboos notably common.

In the second forest community on *terre rouge* soils, *Lagerstroemia* species formed 21% of the trees reaching 10 cm or more diameter. There was a density 256 trees ha^{-1}, with 5.5 trees ha^{-1} reaching above 1 m diameter. Additional canopy species of importance were similar with *Dipterocarpus dyeri*, *Anogeissus vulgaris*, *Sterculia campanulata* and Ficus. Schmid (1979) has described similar forest structures and composition on basalt substrates in southern Vietnam.

6.1.3.4 Semi-Evergreen Forests in the Cardamom and Elephant Mountains

Semi-evergreen forests are widespread on the northern exposures of the cardamom and Elephant Mountains, but forest structure in these areas has not been well characterized, although some descriptions have been made by Schmid (1969) and Dy Phon (1970). Maxwell (1980) described the structure and floristic composition of semi-evergreen forests of the Khao Khieo Wildlife Reserve, an area of low moist hills in western Thailand 150 km west of the Cardamom Mountains. Here, semi-evergreen forest occurs up to 700 m elevation with *Dipterocarpus alatus*, *Walsura angulata* (Meliaceae), *Radermachera hainanensis* (Bignoniaceae), *Pterosperma diversifolium* (Sterculiaceae), *Irvingia malayana* (Simaroubaceae), and *Ficus* species (Moraceae) as dominants.

6.1.3.5 Semi-Evergreen Forest on Alluvial Plains

A distinctive form of semi-evergreen forest develops on alluvial plains in Cambodia where soils are deeper and more fertile. Such habitats occur to the north of the flood basin of Tonle Sap and west of the Mekong, as at Thlong Tuk. The dominant species of such habitats are typically Dipterocarpaceae. The most important of these is *Dipterocarpus alatus*, which may reach up to 3 m diameter at breast height, *Dipterocarpus costatus*, and *Anisoptera costata*. Also important are diverse species of *Vatica*, *Shorea roxburghii* and *Dipterocarpus intricatus* (Dipterocarpaceae), *Sindora siamensis* (Fabaceae-Caesalpinoideae), *Lagerstroemia* (Lythraceae), *Diospyros* (Ebenceae), *Syzygium zeylandicum* (Myrtaceae), *Parinari annamense* (Chrysobalanaceae), *Schleichera oleosa* (Sapindaceae), and *Toona febrifuga* (Meliaceae). The latter form huge trees that may reach 2 m in diameter. Deciduous species among these include *Dipterocarpus intricatus, Lagerstroemia, Scheicheria* and *Toona*. A survey of 22 ha of such an alluvial forest at Thlong Tuk found an average of 412 trees greater than 10 cm dbh per hectare, with 59 of these having diameters of >50 cm and 1.4 with diameters over 1 m (Rollet, cited in Legris and Blasco 1972).

6.1.3.6 Semi-Evergreen Forests of Northeastern Cambodian Uplands

The composition of semi-evergreen trees changes on alluvial and riparian sites at higher elevation along the hills of northeastern Cambodia where a different set of dipterocarps may be dominant (*Dipterocarpos dyeri*, *Shorea vulgaris* and *Hopea odorata*). Semi-evergreen forest may also occur on rocky outcrops with *Heritieria javanica* and *Tetrameles nudiflora*.

6.1.3.7 Human Impacts on Semi-Evergreen Forests

Legris and Blasco (1972) suggest that the great majority of the landscape in Cambodia, with the exception of the wetland areas around Tonlé Sap and the Mekong River, would have supported semi-evergreen forests before the impact of human populations. They felt that fire and swidden agriculture was reasonable for a gradual degradation of extensive areas from evergreen to semi-evergreen to deciduous woodland to dry savanna through a process that might be termed savannization.

The modern composition of semi-evergreen forests may well have been heavily influenced by past human activities. Such activities include preferentially felling or retaining certain species, creating favorable habitats for certain species, or actively planting or encouraging the growth of economically useful species. Large individuals of *Dipoterocarpus dyeri*, for example have been eliminated from extensive areas by cutting, as around Angkor, while *D. alatus* which requires high levels of soil moisture has increased its abundance in the past by colonizing areas of soils irrigated by the Khmer. *Dipterocarpus alatus* is valued for a resin that is bled from wounds in the trunk, and thus this species is less likely than others to be cut. A number of tree species such as *Toona febrifuga* (Meliaceae) have small wind dispersed seeds and readily colonize forest gaps caused human activities. Such species, many of which are deciduous and reach very large size, do not re-establish themselves in the absence of large gaps and are thus an

indication of secondary forest structure. Exotic tree species such as *Nephelium chinensis* (litchi; Sapindaceae), valued for their fruit, have been widely planted and become established in some semi-evergreen forest areas.

6.1.4 Mixed Deciduous Forests

Areas with relatively high rainfall above 1,500 mm annually and a strong drought season of 5-6 months commonly support a habitat of mixed deciduous forest in northern Thailand and Laos. These are diverse forest communities with complex canopy structure, high biomass, and multiple species dominance. Teak, *Tectona grandis* (Verbenaceae), the characteristic species of mixed deciduous forests over much of Southeast Asia, is not naturally present in Cambodia. The other most faithful of the mixed canopy dominants of this community are species of *Lagerstroemia* (Lythraceae), *Xylia xylocarpa* (Fabaceae-Mimosoideae), *Pterocarpus macrocarpus* (Fabaceae-Papilionoideae), and *Terminalia mucronata* (Combretaceae). The floristic affinities of many species in this habitat lie with the monsoon floras of India and Burma rather than with Indomalaysian floras.

While species of Dipterocarpaceae may be present in transitional communities to mixed deciduous forest, this family is generally absent from typical mixed deciduous forest. Unlike semi-evergreen forest, the understory of mixed deciduous forest is strongly deciduous and woody lianas are relatively uncommon.

Mixed deciduous forests are much more difficult to delineate and map in Cambodia in comparison to northern Laos and Thailand, where such forests are widespread and more typical in structure. In Cambodia, there is a murky transition between mixed deciduous forest and forms of semi-evergreen forest where deciduous species exhibit a strong co-dominance with evergreen species. Any separation of such types along this transition is unquestionably somewhat arbitrary. This separation is complicated by the fact that many taxa such as *Xylia, Pterocarpus, Lagerstroemia* and *Irvingia* have a wide range of ecological tolerance and occur from deciduous dipterocarp woodlands to mixed deciduous to semi-evergreen forest communities. It is noteworthy, therefore, that Blasco et al. (1997) do not use any map unit for an equivalent of mixed deciduous forest.

This absence of more typical mixed deciduous forest with teak from Cambodia undoubtedly relates to a climatic gradient with warmer temperatures, higher lowland rainfall levels, and less extreme seasonality in Cambodia. These conditions promote the development of semi-evergreen forest rather than mixed deciduous forest. If a strict definition of mixed deciduous forest were to follow the range of teak and the classic forest structure associated with *Tectona/Lagerstroemia* forest stands, then these mixed deciduous forests in Cambodia would be considered to be the most deciduous end of the spectrum of semi-evergreen forest.

Detailed descriptions of the composition of what has been termed mixed deciduous forest in Cambodia have been provided by Rollet (1952, 1962, 1972) for stands of what he termed *forêt denses décidues* near Seam Reap and near Buplok in northeastern Cambodia. For the Buplok area, he reported a density of 247 trees ha^{-1} with a diameter of 17.5 cm or above. Over a 48 ha area of this community, he found 112 tree species. The dominant species in this stand were:

Lagerstroemia spp. (Lythraceae)

Cratoxylum formosum (Guttiferae)
Grewia paniculata (Tiliaceae)
Irvingia malayana (Simaroubaceae)
Pterosperum greviaefolium (Sterculiaceae),
Sindora siamensis (Fabaceae-Caesalpinoideae),
Terminalia nigrovenulosa (Combretaceae)
Vitex peduncularis (Verbenaceae)
Xylia xylocarpa (Fabaceae-Mimosoideae)

In addition to these forests dominated by *Lagerstroemia*, it is also possible to find stands of what would be categorized broadly as mixed deciduous forest dominated by *Xylia*, *Sindora* and a mixed assemblage of other species, but with *Lagerstroemia* absent (Rollet 1972).

Because these mixed deciduous forests burn easily under dry season conditions, the understory is typically composed of species with a strong tolerance of fire. These include woody bamboos (e.g. *Oxytenanthera*) and shrubs and small trees such as:

Anneslea fragrans (Terstroemiaceae)
Buchanania sp. (Anacardiaceae)
Dalbergia lanceolaria (Fabaceae-Papilionoideae)
Elaeodendron glaucum (Celastraceae)
Emblica officinalis (Euphorbiaceae)
Glochidion velutimum (Euphorbiaceae)
Randia brandisii (Rubiaceae)
Terminalia chebula (Combretaceae)

Martin (1973) has described what she terms a dry deciduous forest on the lower slopes of hills on the northern margins of the Cardamom Mountains. This forest is characterized by an abundance of legumes, with an understory covered by a diversity of ferns and Zingiberaceae. The dominant trees included:

Erythrophleum teysmannii (Fabaceae-Caesalpinoideae)
Irvingia malayana (Simaroubaceae)
Lagerstroemia spp. (Lythraceae)

Associated canopy trees were:
Aquilaria crassna (Thymeleaceae)
Dalbergia nigrescens (Fabaceae-Papilionoideae)
Ficus sp. (Moraceae)
Garcinia ferrea (Guttiferae)
Sindora siamensis (Fabaceae-Caesalpinoideae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae)
Terminalia nigrovenulosa (Combretaceae)
Xylia xylocarpa (Fabaceae-Mimosoideae)

Degraded forest of what appear to be transitional areas between mixed deciduous and semi-evergreen forest are present in northeastern Thailand in Ratankiri Province ((Yem Sokhom et al. 1996).

6.1.5 Deciduous Dipterocarp Forests and Woodlands

6.1.5.1 Structure of Deciduous Dipterocarp Forests

Deciduous dipterocarp forests, often described as dry dipterocarp forests or *forêt claire* in the French literature (Rollet 1972, Legris and Blasco 1972), form a widespread cover of open forest or woodland over large areas of Cambodia on skeletal or arid soils up to about 600 m elevation. The name of this community comes from its deciduous character during the dry season and the dominance by a small number of species of Dipterocarpaceae. As described earlier, one or more of five species of dipterocarp are uniformly dominant or codominant in these habitats. These species are *Shorea siamensis, S. obtusa, Dipterocarpus tuberculatus, D. obtusifolius* and *D. intricatus*.

In structure, deciduous dipterocarp woodlands exhibit only a single low woody stratum of trees commonly 5-12 m in height, with scattered emergents to 15-20 m. These communities may be in the form of open forests with virtually closed canopy structure, particular in transitions to semi-evergreen forest or mixed deciduous forest, but more commonly take on the structure of open woodlands with 50-70% canopy cover in a mosaic of grass cover in the understory. Epiphytes are relatively few in number and low in diversity in these habitats, but increase in abundance with higher elevations and more humid conditions. Along gradients of increasing environmental stress, whether from natural drought or human intervention, deciduous dipterocarp communities become increasingly open in structure and lower in stature, grading eventually into savanna woodlands with decreasing woody cover.

Ground fires burning through the herbaceous understory are a regular aspect of the environment of deciduous dipterocarp forests, and thus this community has sometimes been termed a fire climax community. The question, therefore, is how much of this community has been formed by a history of human activities that have greatly increased the frequency of such fires. Most researchers agree that a portion of the modern coverage of this habitat represents a conversion of what was once semi-evergreen forest into deciduous dipterocarp forest under the influence of repeated burning (Legris and Blasco1972), but the degree to which such conversion has occurred remains unknown. At one extreme, Legris and Blasco (1972) hypothesize that excepting the most skeletal or arid sites, virtually all of the modern distribution of this habitat was once semi-evergreen forest in Cambodia. Other evidence for the recent origin of open woodland savannas and savanna woodlands lies with the absence of any specialized burrowing mammals (Wharton 1966). Nevertheless, many bird species are largely restricted to deciduous dioterocarp forests in Cambodia, and their ranges suggest that there have been extensive areas of this community for a very long time (Duckworth, personal communication). Large mammal grazers also seem well adapted to habitat mosaics of open deciduous forest woodlands and closed semi-evergreen forest.

Deciduous dipterocarp forests and woodlands are largely centered in Cambodia in lowland areas north of the floodplain of Tonle Sap and east of the Mekong River. Scattered areas of such woodlands also exist on the inland northern and eastern slopes of the Cardamom and Elephant Mountains. It is likely that the extent of these woodlands is due in part to the degradation of semi-evergreen forest by human impacts over centuries.

As previously described, there have been a number of forms of deciduous dipterocarp forest identified by researchers in Southeast Asia. For Cambodia, Legris and Blasco (1972) have identified four communities within this habitat that they separate on the basis of criteria of species dominance and community structure. A simpler scheme of classification would be to separate the more diverse communities of deciduous dipterocarp forest with multi-species dominance and more continuous canopy cover from open communities with single species dominance and lower diversity, stature and biomass. These are not discrete communities, however, and numerous intermediate forms of community structure and diversity are present in Cambodia.

6.1.5.2 Transitions to Semi-Evergreen Forest

On the most favorable end of environmental conditions for growth, deciduous dipterocarp communities grade into semi-evergreen forests in a community that has been termed *forêt dense séche décidue*. This community presents the greatest species richness and canopy coverage for dry dipterocarp forests, with a characteristic dominance by *Dipterocarpus intricatus* and a mixed composition of associated lower stature trees and shrubs. The majority of canopy trees are 8-12 m in height in this community but upper canopies of *D. intricatus* may reach 20 m. Soil conditions under this community commonly consist of sandy siliceous soil horizons over clay or laterite layers at 20-40 cm depth. Commonly associated trees and woody shrubs, a number of which may also occur in either mixed deciduous forest or semi-evergreen forest include:

Albizzia lebekkoides (Fabaceae-Mimosasoideae)
Azardirachta indica (Meliaceae)
Capparis cf. *thorelii* (Capparaceae)
Careya sphaerica (Lecythidaceae)
Cratoxylon species (Guttiferae)
Dalbergia nigrescens (Fabaceae-Papilionoideae)
Dalbergia oliveri (Fabaceae-Papilionoideae)
Dipterocarpus obtusifolius (Dipterocarpaceae)
Dipterocarpus tuberculatus (Dipterocarpaceae)
Eugenia cf. brachyata (Myrtaceae)
Irvingia malayana (Simaroubaceae)
Memecylon edule (Melastomataceae)
Memecylon laevigatum (Melastomataceae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae)
Parinari annamense (Chrysobalanaceae)
Randia tomentosa (Rubiaceae)
Shorea roxburghii (Dipterocarpaceae)
Sindora siamensis (Fabaceae-Caesalpinooideae)

Terminalia alata (Combretaceae)
Xylia xylocarpa (Fabaceae-Mimosoideae)

Depending on the relative closure of tree canopies in this community, the grassy understory may be continuous or instead patchy and discontinuous in distribution. The dominant grass cover may be formed by either a herbaceous bamboo, *Arundinaria falcata*, or by C_4 grasses such as *Themeda triangularis* and species of *Eulalia*. Mixed with these grasses are low perennial legumes such as species of *Desmodium, Crotalaria* and *Indigofera*, all of which are active nitrogen-fixers and thus of potential ecological significance. Also important in many arid sites are sedges in the genera *Fimbristylis*, *Cyperus* and *Cladium* (Wharton 1966). Often present also are small palms such as *Phoenix humilis* and *Corypha lecomtei* and species of the *Cycas* (Cycadaceae).

6.1.5.3 Dominance by *Dipterocarpus obtusifolius*

Two forms of deciduous dipterocarp forest are characterized by the strong dominance of a single species of dipterocarp. One such community is overwhelmingly dominated by the large-leaved *Dipterocarpus obtusifolius.* These open woodlands are simple in structure and species composition with little understory growth of woody species. Scattered individuals of *Corypha lecomtei* (Arecaceae) and *Memecylon edule* (Melastomataceae) and other low woody species may be present. *Dipterocarpus obtusifolius* is an ecological plastic species and stress tolerant species that adapts well to drought, poor drainage and cooler temperatures. It is the most cold tolerant of deciduous species of dipterocarp, occurring up to elevations of 700-1000 m. These *D. obtusifolius* communities are most characteristic of areas of Cambodia east of the Mekong on sites with thin sandy soils over laterites, often in sites with soils that are waterlogged during the wet season. The grass understory burns frequently in the dry season.

6.1.5.4 Dominance by *Shorea siamensis*

Also dominated by a single species are deciduous dipterocarp woodlands with major cover contributed by low-growing *Shorea siamensis* with a growth form of twisted trunks. This species is the most tolerant of dry habitat conditions among the deciduous species of dipterocarps, and thus attains its dominance on sites with eroded lithosols or skeletal soils such as occur over young basalt flows. There is rarely any well-developed understory in these stands, and even a herbaceous grass cover is discontinuous because of the poor soil development.

6.1.6 Lowland Pine Forests

Pine forests in Cambodia are restricted in distribution and limited to relatively low or middle elevations where they are often associated with deciduous dipterocarp woodlands or open semi-evergreen forest. The Cambodian pine flora includes only a single species, *Pinus merkusii*. This species may grow to 20 m in height on lowland plains in Cambodia, but on mountain slopes it is usually a smaller tree reaching no more than 12 m. The density of trees in stands where it occurs is highly variable, but canopy structure is

generally open with a continuous herbaceous ground cover. Pines may constitute as much as 50% of all trees present. These conditions promote frequent fires that have likely always been an environmental factor in these stands. Fire frequencies today, however, are much higher than under natural conditions because of human activities. Dy Phon (1970) suggests that seedlings of *Pinus merkusii* are threatened by fire until they reach an age of six years.

The primary distribution of *P. merkusii* in Cambodia lies to the south of Tonle Sap. The largest stand of pines here occurs on the plateau of Kirirom National Park in the southeastern corner of the Elephant Range. The pine forests at Kirirom occupied 9,000-10,000 ha over the plateau (Lay and Taylor-Hunt 1995), and are the only pine woodland in Cambodia that is sufficiently large to be mapped by Blasco et al. (1997). The pines range in elevation from about 400 m on the southern margin of the plateau to 1,000 to the north. Soils are red and yellow podzols with a moderate acidity of pH 5.0-5.5. Rainfall on the plateau is quite high, averaging about 2,000 annually (Dy Phon 1970).

The Kirirom pine forests are formed with three distinct strata - a tree stratum reaching 8-20 m or more in height, an understory woody stratum 2-8 m in height, and a low herbaceous ands semi-woody shrub stratum. *Pinus merkusii* strongly dominates the tree level, reaching well above 20 m in height and with diameters of up to 60 cm or more, and providing more than 50% of the canopy cover. Other associated hardwood tree species are also commonly present in a lower canopy layer. These include *Melanorrhoea laccifera* (Anacardiaceae), *Dipterocarpus obtusifolius, D. tuberculatus* and *D. intricatus* (Dipterocarpaceae), *Parinari anamensis* (Chrysobalanaceae), *Careya arborea* (Lecythidaceae), and *Vatica cinerea* (Dipterocarpaceae). The understory woody stratum contains a relatively diverse assemblage of species, the great majority of which are evergreen (Dy Phon 1970). These include

:

Aporosa ficifolia (Euphorbiaceae)
Aporosa sphaersperma (Euphorbiaceae)
Callicarpa rubella (Verbenaceae)
Crabiodendron stellatum (Ericaceae)
Decaspermum fruticosum (Myrtaceae)
Dillenia ovata (Dilleniaceae)
Dillenia pentagyna (Dilleniaceae)
Engelhardia spicata (Juglandaceae)
Fagaea ceilanica (Loganiaceae)
Gaertnera sralensis (Rubiaceae)
Grewia eriocarpa (Tiliaceae)
Lithocarpus cambodiensis (Fagaceae)
Lithocarpus eucalyptifolia (Fagaceae)
Lithocarpus harmandii (Fagaceae)
Mallotus cochinchinensis (Euphorbiaceae)
Melastoma sanguineum (Melastomataceae)
Memecylon acuminatum (Melastomataceae) - very common
Phyllanthus emblica (Euphorbiaceae) - very common
Pithecellobium lucidum (Fabaceae-Mimosoideae)
Ptenandra caerulescens (Melastomataceae)

Randia tomentosa (Rubiaceae)
Tristania burmanica (Myrtaceae) - very common
Vaccinium bracteatum var. *glabratum* (Ericaceae) - very common
Wendlandia cambodiana (Rubiaceae)
Wendlandia tonkiniana (Rubiaceae) - very common

Because of the relatively high rainfall on the Kirirom Plateau, epiphytes are quite common in the pine forests. Most notable among these epiphytes are a diverse assemblage of ferns including *Vittaria elongata* (Adiantaceae), *Asplenium nidus* (Aspleniaceae), *Davallia trichomanoides* and *Humata repens (*Davalliaceae), *Aglaonema coronans, Drynaria quercifolia, D. rigidula, Microsporium* sp., *Platycerium coronarium, Polypodium subauriculatus,* and *Pyrrhosia* sp. (Polypodiaceae), and *Schizaea digitata* (Schizaeaceae). Also present as epiphytes are *Dendrobium* and *Phreatia* spp. (Orchidaceae) and *Dischidia* and *Hoya* species (Asclepiadaceae).

The ground stratum of the Kirirom pine forests is made up largely by grasses. The dominants among these are *Andropogon intermedius, Selercasleriis* sp., *Amphilephis gleba,* and *Imperata cylindrica* (Lay and Taylor-Hunt 1995).

Pinus merkusii also occurs in southern Cambodia on scattered hills at 100-400 m elevation and at a variety of elevations in the Cardamom Mountains. Legris and Blasco (1972) and Martin (1973) mention a series of sites with pines on plateaus and hilltops on the north and northeast margins of the Cardamom Mountains and near Phnom Aural. *Tristania burmanica* (Myrtaceae) and *Dipterocarpus obtusifolius* (Dipterocarpaceae) were the most common associated species. Small pine stands are also present in the northern Cambodian lowlands at less than 100 m elevation across a series of small hills between Siem Reap and Kompong Thom to the north of Tonle Sap (Rollet 1972). There is also a small population near Siembeak in Stung Treng Province to the west of the Mekong (Legris and Blasco 1972).

There are no reported populations of *P. merkusii* in the Cambodian lowlands east of the Mekong, and only rare occurrences of this species at higher elevations on the slopes of the Annamite Range. One population has been reported growing with semi-evergreen forest near Mondulkiri at 800 m elevation on these slopes (Legris and Blasco 1972).

6.1.7 Savannas and Savanna Woodlands

6.1.7.1 Savanna Origin and Structure

Open savannas and savanna woodlands with a scattered distribution of low woody species cover extensive areas of the central Cambodian lowlands and areas of young basalt substrate to the east of the Mekong. These habitats are almost certainly of anthropogenic origin. Human activities of land clearance and burning have been occurring for centuries and have profoundly impacted this area by clearing woody vegetation and promoting the expansion of savanna grasses. The history of human occupation and use of fire in the Cambodian lowlands has been described in some detail by Wharton (1966).

The pantropical grass *Imperata cylindrica,* perhaps the most important savanna grass, has dramatically increased its range and abundance by rapidly and effectively colonizing

areas altered by human disturbance. Once established, this species is extremely tolerant of burning, grazing and even submergence by seasonal flooding.

Several distinctive forms of savanna grassland can be described within Cambodia. The most extensive areas are those dominated by dense cover of *I. cylindrica* reaching 0.8-1.5 m in height. These grasslands may support a virtual monoculture of *Imperata* or a mixed dominance with other grasses such as species of *Themeda* and *Cymbopogon*.

Area with shallow skeletal soils support a lower canopy of *Imperata* reaching only 0.5 m in height and a diverse mixture of invasive grasses such as *Themeda triandra* and *Heteropogon contortus*. All of these are grasses with C_4 metabolism. *Arundinella setosa* and *Aristida cumingiana* may be present in distinctive communities in openings between shrubs (Legris and Blasco 1972). A number of suffrutescent legumes, both widespread natives and non-natives, are also aggressive invaders of open areas in full sun. These include *Zornia gibbosa* (pantropical), *Desmodium pulchellum, D. gangeticum, Indigofera wightii* (tropical Asia) and *Crotalaria montana* (tropical Asia and Australia).

6.1.7.2 Savannas on Basaltic Soils

Areas of *terre rouge* soils in eastern Cambodia with basaltic parent materials at 400-600 m elevation often are covered by a secondary savanna of *Imperata* and the invasive *Chromalaena odorata* (Asteraceae), a native of the American tropics. This species is found today as a virtual monoculture over extensive areas.

A variety of small woody species, many of them spiny, become aggressive invaders of these savannas under regimes of frequent disturbance that open up the grass layer. These include bushy shrubs and small trees such as *Clerodendron serratum* (Verbenaceae), *Grewia* species (Tiliaceae), *Rhodomyrtus* (Myrtaceae), *Zizyphus* and *Rhamnus* (Rhamnaceae) and *Eriolaena* (Sterculiaceae).

6.2 Montane Forest Habitats

6.2.1 Montane Forest Structure and Environment

As in Laos, forests structure and composition undergo sharp changes from lowland forests to montane communities above about 800 m in Cambodia. These montane forests have commonly been generally been termed *hill evergreen forest* in Thailand (Rundel and Boonpragob 1995). These habitats have also been termed *forêt dense* and *forêt dense humide* in the French literature (Vidal 1956-60), and more recently *Northeast Indochina Montane Forest* (Wikramanayake et al. 1997). Rather than a single community type, these montane forests include a variety of forest associations under this general name of montane forest. Such montane forests are relatively limited in distribution in Laos because of the small area of topography sufficiently high to support montane habitats.

Above 600-800 m elevation, many of the lowland floristic elements begin to drop out as mean temperatures decline. These include the Dipterocarpaceae, Meliaceae, most palms, many Lythraceae, and many Fabaceae as well as characteristic species from semi-evergreen and rainforest communities. Replacing these is a montane flora with

representation of many temperate families such as the Fagaceae, Myrtaceae, Lauraceae, Magnoliaceae, Caprifoliaceae, and Theaceae.

Montane forests of Cambodia, as in other parts of Southeast Asia, are characterized by cool, humid conditions which support evergreen forests. Epiphytes are generally common in these habitats. There are two areas where elevations occur that are sufficiently high to support hill evergreen forest. These areas are the Cardamom and Elephant Mountains of southwestern Cambodia and the slopes of the Annamite Range and related uplands in northeastern Cambodia.

Relatively little ecological study has been made of forest structure, diversity, or dynamics in these montane habitats. Most of the existing published information on these habitats comes from relatively brief descriptions (Rollet 1972, Blasco and Legris 1972, Martin 1973).

6.2.2 Montane Forests of the Cardamom and Elephant Mountains

For the Cardamom and Elephant Mountains, the habitats of montane forest that are best known are those at about 1,000 m elevation in Bokor National Park, which were described by Dy Phon (1970) and Tixier (1979). Bokor is one of the wettest sites in all of mainland Indochina, receiving about 5,300 mm of rainfall annually (Tixier 1979). Two forms of hill evergreen forest are described for Bokor. The largest area is formed by dense evergreen forest, reaching up to 20 m in height, with a strong dominance of Fagaceae. Dy Phon (1969, 1970) described six common species – *Lithocarpus cambodiensis, L. guinieri, L. farinulenta, L. harmandii,* and *Castanopsis cambodiana*. Also important are species of Lauraceae (*Cinnamomum* and *Litsea*) and Myrtaceae (*Syzygium* and *Tristania*), while legumes are relative infrequent. There is a rich understory in these habitats with shrubs of Rubiaceae and Euphorbiaceae, palms (*Arenga pinnata* and *Pinanga cochinchinensis*), arborescent ferns (*Cibotium, Cyathea* and *Oleandra*), *Pandanus* and Araliaceae. Epiphytes, most notably orchids, may often be abundant, particularly in sites that receive frequent fogs or mists.

A second montane evergreen community within the Cardamom and Elephant Mountains is a dwarf forest of no more than 2-4 m height occurring typically on ridgelines or other areas habitually exposed to strong winds (Dy Phon 1970). This community is typically dominated by *Dacrydium elatum* with another conifer, *Podocarpus (Dacrycarpus) imbricatus* also commonly present. Other important associates in this dwarf forest are a diversity of Fagaceae and Myrtaceae, *Vaccinium viscifolium* (Ericaceae), and *Schima crenata* (Theaceae).

Open plateaus along the summit of the Cardamom and Elephant Mountains often support a wet grassland community dominated by bracken fern (*Pteridium aquilinum*), scattered shrubs of *Rhodomyrtus* (Myrtaceae) and *Melastoma* (Melastomataceae), herbaceous grasses, sedges, and Xyridaceae (Martin 1973, Tixier 1979). Carnivorous *Utricularia* (Scrophulariaceae), *Drosera* (Droseraceae), and the endemic *Nepenthes kampotiana* (Nepethaceae) are widely present with *Sphagnum* in wetter grasslands. Much of this area has shallow waterlogged soils occurring over an iron duripan layer. The wettest areas support a marshy cover of *Saccharum* and *Phragmites*.

6.2.3 Montane Forests of Northeastern Cambodia

Montane forests of the uplands to the east of the Mekong Forest structure here parallels that described above for the Cardamom and Elephant Mountains in the presence of both taller dense forest and dwarf forest. For the montane evergreen forest, species of Fagaceae, Myrtaceae and Lauraceae are again dominant (Legris and Blasco 1972). A curious pattern of distribution is present with *Hopea pierrei* (Dipterocarpaceae) extending to 1,000 m elevation to reach into elements of hill evergreen forest in this region. This same species does not apear to occur above 300 m in the Cardamom and Elephant Mountains (Dy Phon 1969). This condition likely occurs because of unusually high levels of rainfall at low elevations along the steep southern coast of Cambodia. Two other important species in the northeastern montane forests are *Cedrelia toona* (Meliaceae) which reaches to 1,600 m and *Canarium* (Burseraceae). The understory of these forests includes arborescent ferns, as in the Cardamom and Elephant Mountains, and numerous lianas of *Gnetum gnemon* (Gnetaceae).

Dwarf or thicket forests of the northeastern hill evergreen habitats differ somewhat in composition from those of the Cardamom and Elephant Mountains. *Schima crenata*, *Vaccinium bracteatum* (Ericaceae), *Castanopsis* species (Fagaceae) and Lauraceae are all more common, while conifers are less apparent. A rubiaceous shrub, *Wendlandia glabrata*, is often abundant in the understory (Legris and Blasco 1972).

6.3 Azonal Forest Formations

6.3.1 Swamp Forests and Shrublands

6.3.1.1 Seasonality of Inundation

Swamp forests typically occur in areas permanently inundated with shallow freshwater. The French literature has refereed to the swamp forest association in Cambodia as *forêt inondee* (Rollet 1972, Legris and Blasco 1972, Dy Phon 1970). Care must be given, however, in separating the seasonal swamp forests that characterize extensive areas of the Tonle Sap basin and lowlying floodplains of major Cambodian rivers from these classic swamp forests of Southeast Asia with permanent flooding. Conditions of permanent flooding compared to flooding for 6-8 months produce differential selective factors and thus a distinctive floristic assemblage for each of the two forms of swamp forest. Wikramanayake et al. (1997) separate two forms of swamp forest for Cambodia. These are the *Tonle Sap Freshwater Swamp Forests* that cover the seasonally inundated Tonle Sap Basin and floodplain areas along the lower Mekong, and the *Tonle Sap-Mekong Peat Swamp Forests* of more permanently inundated areas. It is not clear that such a separation can be clearly defined.

The area of seasonal swamp forest and marshland in Cambodia was once quite large but has been significantly reduced in size by human activities. Rollet (1972) gives an area of 6,340 km^2 for swamp forests and thickets, 2,520 km^2 for marshland, 273 km^2 for rivers, and 2,770 km^2 for Tonle Sap, for a total area of 11,900 km^2. Broad descriptions of signifcant wetlands in Cambodia were presented by Davis (1994).

6.3.1.2 Tonle Sap Wetlands

Seasonal conditions of inundation produce several notable characteristics of these floodplain habitats. Palms, often a characteristic component of typical swamp forests, are entirely absent from the Tonle Sap floodplain with the exception of the local occurrences of rattans in some gallery forests. Neither pneumatophores nor aerial roots are present among the swamp forest trees, and vascular epiphytes are lacking (Rollet 1972). The swamp shrublands and forest of the floodplain of Tonle Sap covers about 3,600 km^2 today, but is thought to have included more than three time this area before extensive cutting began in the 1930s (Woodsworth 1995). The Cambodian National Mekong Committee (1998) has published a preliminary checklist of vascular plant species present in the floodplain of Tonle Sap (about 200 species). This floristic list needs to be evaluated to determine its completeness.

Two broad forest associations have been described for the extensive floodplain area of Tonle Sap, a short-tree-shrubland covering the majority of the area, and a stunted swamp forest around the lake itself. Similar swamp forests are also present along floodplains of major rivers, although an evergreen gallery forest with tropical rainforest affinities in structure is also locally present along limited river areas (McDonald et al. 1997).

The strong seasonal cycle of flooding around the floodplain of Tonle Sap has made the great majority of woody species deciduous. Rather than lose their leaves in the dry season, however, these species lose their leaves when submerged as the lake deepens and the plants are submerged. There are several woody species, however, which remain evergreen despite submergence for 6-8 months each year. These include the common tree *Barringtonia acutangula* (Lecythidaceae) and the liana *Combretum trifoliatum* (Combretaceae). Nevertheless, these two species flush new leaves contemporaneously with the deciduous species once receding lake waters expose the trees and shrubs to the air again. With only a few exceptions [e.g. *Combretum trifoliatum*, *Crataeva nurvala* and *C. roxburghii* (Capparaceae), and *Gmelina asiatica* (Verbenaceae)], flowering and fruit production in the floodplain trees and shrubs is delayed for several months after the flush of new leaves. McDonald et al. (1997) report that the majority of woody species are laden with fruits and seeds at the time of submergence, suggesting the possibility that fish may serve as important dispersal agents.

Rollet (1972) presents a list of the dominant woody species for the Tonle Sap swamp forests. Large trees reaching up 20 m in height and 60 cm in diameter included:

Crudia crysantha (Fabaceae-Caesalpinoideae)
Cryptocarya oblongifolia (Lauraceae)
Cynometra cf. *dongnaiensis* (Fabaceae-Caesalpinoideae)
Cynometra cf. *inaequifolia* (Fabaceae-Caesalpinoideae)
Diospyros cf. *bejaudii* (Ebenaceae)
Diospyros sylvatica (Ebencaceae)
Diospyros sp. (Ebenaceae)
Garcinia cf. *loureiri* (Guttiferae)
Homalium brevidens (Flacourtiaceae)
Homalium griffithianum (Flacourtiaceae)

Lophopetalum fimbriatum (Celastraceae)
Minusops (?) (Sapotaceae)
Mitragyna cf. *diversifolia* (Rubiaceae)
Terminalia cambodiana (Combretaceae)
Xanthophyllum cf. glaucum (Xanthophyllaceae)

More common than these trees, however, was a group of small tree species:

Barringtonia acutangula (Lecythidaceae)
Barringtonia micrantha (Lecythidaceae)
Elaeocarpus griffithii (Elaeocarpaceae)
Elaeocarpus madropetalus (Elaeocarpaceae)
Hydnocarpus authelminthica (Flacourtiaceae)
Malotus anisopodum (Euphorbiaceae)

The low shrubby growth which dominates much of the Tonle Sap floodplain has led some authors to describe this area as a degraded forest resulting from logging and other human activities (e.g. ORSTOM 1993). The shrublands and swamp forests of the Tonle Sap floodplain have clearly been heavily impacted by centuries of human activities, and this impact has accelerated over the past decade. McDonald et al. (1997) described a perpetual state of disturbance and regeneration that characterizes the swamp forests and shrublands around the lake. Higher-lying zones of the floodplain commonly exhibit a dense web of oxcart roads that dissect the landscape as they cyclically open areas for firewood cutting, rice cultivation, and/or grazing. While much disturbance has clearly taken place, the structure and composition of woody vegetation on the floodplain appears to be as much a function of the microheterogeneity of soil moisture conditions and seasonal flood dynamics as human disturbance.

Large amounts of firewood are cut annually by villagers around the outer portions of the floodplain of Tonle Sap. It has been suggested that many areas of short trees and shrublands in the floodplain are cut to the ground on about a 5-10 year rotation (McDonald et al. 1997). Firewood collectors are relatively unselective in their cutting, but the preferred species are *Hymenocardia wallichii* (Euphorbiaceae), *Lumnitzera* aff. *racemosa* and *Terminalia cambodiana* (Combretaceae), and *Vitex holodenon* (Verbenaceae). The preferred tree species for construction material is *Diospyros cambodiana* (Ebencaeae)

6.3.1.3 Tonle Sap Short Tree-Shrublands

The short tree-shrubland association forms the dominant vegetation cover over approximately 80% of the Tonle Sap floodplain in those areas with nonsaturated soil during the dry season. In general, the dominant woody species form a semi-continuous canopy of deciduous species reaching no more than 2-4 m in height. The height reached by individual species appears to be related to soil moisture conditions, with the tallest individuals occurring closer to the permanent lake basin and smaller individuals present at the periphery of the floodplain area. Several characteristic species with shrubby growth forms in this community are capable of reaching tree size in swamp forest habitats. The

flora of these short tree-shrublands is dominated by species of Euphorbiaceae, Fabaceae and Combretaceae (McDonald et al. 1997). Several species (e.g. *Combretum trifoliatum*) which form woody lianas under more favorable condition form broad areas of shrub growth on upland floodplain areas under the seasonal cycles of flooding and disturbance. Herbaceous cover is largely lacking. Among the widespread and dominant woody species are:

Barringtonia acutangula (Lecythidaceae)
Bridelia cambodiana (Euphorbiaceae)
Brownlowia paludosa (Tiliaceae)
Capparis micrantha (Capparaceae)
Cissus hexangularis (Vitaceae) - liana
Croton mekongensis (Euphorbiaceae)
Croton krabas (Euphorbiaceae)
Dalbergia pinnata (Fabaceae-Papilionoideae)
Gardenia cambodiana (Rubiaceae)
Gmelina asiatica (Verbenaceae)
Phyllanthus taxodiifolius (Euphorbiaceae)
Popowia diospyrifolia (Annonaceae)
Quisqualis indica (Combretaceae)
Stenocaulon kleinii (Asclepiadaceae) – perennial vine
Terminalia cambodiana (Combretaceae)
Vitex holoadenon (Verbenaceae)

Several alien woody species have no invaded this habitat and are greatly expanding their cover and dominance. The giant mimosa, *Mimosa pigra* (Fabaceae-Mimosoideae), currently presents the most serious problems (Cambodian National Mekong Committee 1998). This aggressive species invades fallow fields and disturbed shrubland and swamp forest area after clearance or burning. Once established, giant mimosa forms dense impenetrable thickets of spiny growth that choke out other native species and produces little value as wildlife habitat. This species is already a serious pest in Indonesia and northern Australia. Two other alien *Mimosa* species, *M. invisa* and *M. pudica*, are also established around Tonle Sap but have been less aggressive (McDonald et al. 1997).

6.3.1.4 Tonle Sap Swamp Forest

A band of stunted swamp forest, 7-15 m in height, originally dominated the dry-season shoreline of Tonle Sap, covering about 10% of the floodplain, and forms the second forest association. A similar community once occurred as a gallery forest along the seasonal flood plains of many major rivers in southern Cambodia, following channels or other waterways and occasionally occurring in isolated depressions which hold surface water through the dry season. This community around Tonle Sap is generally flooded by 4-6 m of water for up to eight months each year, at which time the majority of species lose their leaves. Rather than forming a continuous forest, this community is broken into a mosaic of stands of large trees and open areas with floating aquatic herbs typical of the lake itself (see below). Two tree species, *Barringtonia acutangula* (Lecythidaceae) and

Diospyros cambodiana (Ebenaceae) are the primary dominates of this community, and generally occur with a woody lianas such as *Combretum trifoliatum* (Combretaceae), *Breynia rhamnoides* (Euphorbiaceae), *Tetracera sarmentosa* (Dilleniaceae) and *Acacia thailandica* (Fabaceae-Mimosoideae).

Other common tree species:

Crataeva nurvala (Capparaceae)
Crataeva roxburghii (Capparaceae)
Coccoceras anispodum (Euphorbiaceae)

Common shrub species:

Brownlowia paludosa (Tiliaceae)
Cudrania cambodiana (Moraceae)
Dalbergia entadoides (Fabaceae-Papilionoideae)
Gmelina asiatica (Verbenaceae)
Hymenocardia wallichii (Euphorbiaceae)
Ficus heterophylla (Moraceae)
Vitex holoadenon (Verbenaceae)

6.3.1.5 Tonle Sap Aquatic Flora

The shallow shoreline of Tonle Sap supports dense mats of herbaceous vegetation 1-3 m tall that may be emergent from shallow water but are more typically floating (McDonald et al. 1997). Large clonal mats of these species float freely over the lake, thereby colonizing large openings and gaps within the swamp forest. Notable among these species are extensive mats of the floating legume *Sesbania javanica* with huge mats of thickened rhizome bearing aerial stems reaching to 2 m above the lake surface. Given the heavy human impact around Tonle Sap for centuries, it seems likely that the structure and diversity of the aquatic flora is alter today from its original composition. The dominant floating herbs of these communities include:

Brachiaria mutica (Poaceae) – introduced species from Africa
Eichornia crassipes (Pontederiaceae) - water hyacinth*;* introduced species
Polygonum barbatum (Polygonaceae)

Other floating herbs that are distributed throughout the lake are:

Commelina salicifolia (Commelinaceae)
Ipomaea aquatica (Convolvulaceae)
Ipomaea chyseoides (Convolvulaceae) – twining herb
Ludwigia adscendens (Onagraceae)
Pistacia stratoites (Araceae) – introduced species
Salvinia cucullata (Salviniaceae)

A notable floristic character of the aquatic flora of Tonle Sap is the rarity of many families of rooted monocots and dicots that are typically important in similar Asian

habitats. These families include the Cyperaceae, Hydrocharitaceae, Marantaceae, Najadaceae, Nympaeaceae, Pontederiaceae and Potamogetonaceae (McDonald et al. 1997). The large seasonal change in water level of the lake and its strong turbidity are the likely cause of the absence of these groups. One rooted monocot, the grass *Phragmites karka,* is a local dominant at the mouth of Tonle Sap and at other river inlets and exits.

McDonald et al. (1997) have reported a distinctive community of aquatic species from isolated ponds in the upper reaches of the Tonle Sap floodplain. Here grasses and sedges were important, as well as a group of dicot emergents:

Echinochloa stagnina (Poaceae) – introduced species from Africa
Cyperus pilosus (Cyperaceae)
Rhynchspora sp. (Cyperaceae)
Scirpus grossus (Cyperaceae)
Aeschynomene indica (Fabaceae – Papilionoideae)
Impatiens sp. (Balsaminaceae)
Nelumbo nucifera (Nelumbonaceae)

A variety of exotic plant species have become established in the floodplain area of Tonle Sap (Cambodian National Mekong Committee 1998). The greatest problem among these lies with the introduced water hyacinth (*Eichornia crassipes*) which appears to be increasing greatly in abundance along the shore of Tonle Sap, as it has in many tropical river systems in Southeast Asia. Water hyacinth is most apparent along waterways with slow moving currents and in pools and ditches. While this species has some economic value as a pig fodder and in fish baits, its negative qualities greatly outweigh these. Water hyacinth has a remarkably high rate of growth, and quickly forms dense mats of vegetation that act to do-oxygenate waters. This action competes strongly with native aquatic species and impacts fish production through lowered water quality. Two grass species have also widely invaded wetland margins of Tonle Sap. *Brachiaria mutica* and *Echinochloa stagnina* were introduced at some time in the past from Africa as high quality species for grazing, and have become dominant species in many areas of the lake.

6.3.2 Hydromorphic Savannas

Areas of poor drainage around the margin of many forest communities and along rivers often support a hydromorphic savanna dominated by graminoids. This community is called a *veal* in Khmer and the French literature has adopted this term. These soils are commonly saturated for at least six months of the year. Characteristic species would include species of *Saccharum* and a diverse group of Cyperaceae (Legris and Blasco 1972).

An unusual habitat of freshwater marshland has been described around Prasat Tuyo (Bassac marshes) southeast of Phnom Penh between the Bassac and Mekong rivers. This marshland is inundated by up to 3 m of water from July to November, but forms a wetland surrounding a narrow body of open water during the dry season. The vegetation of this area consists of scattered individuals of *Barringtonia acutangula* in a wetland swamp matrix. The community structure of floating herbs appears to be very similar to

those found around Tonle Sap, with a zonation of species, and the presence of alien species. Shallow open waters have a dense submerged growth of *Ceratophyllum* (Ceratophyllaceae), *Hydrilla verticillata* (Hydrocharitaceae) and *Najas* (Najadaceae), species that are rare in the turbid waters of Tonle Sap. The extent of wetland habitat and abundance of waterbirds in the Bassac marshes has led to its nomination as a RAMSAR site.

6.3.3 Riverine Forests

Riverine or evergreen gallery forests occur in a scattered distribution along the channel of the Mekong and other major rivers. These flooded forests, often forming open and discontinous belts along river banks, are best known from scattered areas along the Mekong River in Stung Treng and Kratie Provinces. Riverine gallery forests may vary greatly in structure and diversity. At one extreme are relatively large and diverse gallery forests growing on alluvial soils subject to seasonal flooding which grade into semi-evergreen forests. Dominate tree species in such habitats are typically semi-evergreen forest dipterocarps such as *Dipterocarpus alatus, D. dyeri,* and *Hopea odorata*, but obligately riverine tree species may also be present. The floras of these riverine forests have distinctive affinities to wet evergreen forests of the Cardamom and Elephant Mountains, and thus may have sevred in the past as migration corridors between these ranges and the Annamite Range to the east. Thus, they have a major significance in protecting ecological processes of gene flow between "islands" of wet evergreen forest.

At the other extreme are low diversity woodlands inhabiting rocky and sandy islands in the midstream of major river courses. These forests are commonly dominated exclusively by a single species, *Anogeissus rivularis* (Combretaceae), which often exhibits a stunted growth form (Rollet 1972).

Other riverine forest communities have been described islands within the channel of the Mekong north of Steung Treng. These have been reported to include species of *Barringtonia* (Lecythidaceae), *Eugenia* (Myrtaceae), *Acacia* (Fabaceae-Mimosoideae), and *Ficus* (Moraceae) in the tree stratum, and *Morindopsis* (Rubiaceae) in a shrub layer. Legris and Blasco (1972) mention the restricted presence of *Anogeissus rivularis* (Combretaceae) on shore banks of islands in this same area. Many of the tree species have reduced narrow leaves and exhibit aerial root production up for one meter above their soil line. This habitat receives inundation and very strong river flow for part of the year, but the unconsolidated sandy soils suggest that drought may be present in the dry season. This community has been described as distinctive in floristic composition from surrounding dry upland areas, although few details are known of its species composition. The highly diverse populations of fish and presence of several rare birds and the Irrawaddy dolphin have led to the recommendation that this habitat area be declared a RAMSAR site (McDonald et al. 1997).

Another evergreen riverine forest habitat identified by a tall and species-rich gallery forest has been described for the Steung Sangke northwest of Tonle Sap (McDonald et al. 1997). Although the typical swamp forest tree species of Tonle Sap and other floodplain areas are present (*Barringtonia acutangula, Coccoceras anispodum, Crataeva nurvala, Crataeva roxburghii and Terminalia cambodiana*), dominating along the banks of the river, a distictive element of tall, evergreen forest trees occupy more elevated terrain.

This community shows no dominance by a single species, and includes trees with trunks reaching 1-3 m in diameter and 15 m in height. Important species include:

Crudia chrysantha (Fabaceae–Caesalpinoideae)
Hydnocarpus anthelminthica (Flacourtiaceae)
Eleocarpus griffithii (Elaeocarpoaceae)
Ficus spp. (Moraceae)
Garcinia loureiri (Guttiferae)
Samandura harmandii (Simaroubaceae)

Also present in the stratified canopy of this forest were large lianas of the rattan *Calamus palustris*, as well as a diverse assemblage of typical swamp forest lianas including *Acacia thailandica* (Fabaceae-Mimosoideae), *Breynia rhamnoides* (Euphorbiaceae), *Cissus hexangularis* (Vitaceae), and *Combretum trifoliatum* (Combretaceae). A mixture of shrubs typical of the short tree-shrubland association dominated the shrub understory of this community, together with other species found nowhere else in these wetlands. Likewise, the abundant understory herb *Schummanianthus dichotomus* (Marantaceae) was only encountered in this habitat (McDonald et al. 1997).

6.3.4 Mangroves

Mangroves once formed extensive stands along several areas of the short coastal areas of Cambodia (Dy Phon 1970, Rollet 1972). These formations were once extensively developed around Veal Renh and Kompong Som Bays and near Kas Klong closer to the border with Thailand. The absence of more extensive mangrove stands along the Gulf of Thailand is strongly related to the rocky Cambodian coastline and relative lack of major estuaries or river deltas. Virtually all mangrove stands have been heavily impacted by human activities (Mangrove Working Group 1995).

The most diverse mangrove communities occur in areas which are inundated at high tide, but which are otherwise influenced by freshwater flows. *Rhizophora apiculata* (Rhizophoraceae) and stands of the palm *Nypa fruticans* (Arecaceae) commonly front small islands in protected bays and streams flowing into estuaries, while *Avicennia* alba (Verbenaceae) may occur as the most exposed trees on accreting mudflats. Behind a narrow fringe of these mangroves there is typically a diverse mix of other mangrove and coastal species. At Kompong Som Bay these that may include (Dy Phon 1970):

Species 2-7 m in height:
Afzelia xylocarpa (Fagaceae-Caesalpinoideae)
Brugieria gymnorhiza (Rhizophoraceae)
Brugieria sexangula (Rhizophoraceae)
Ceriops decandra (Rhizophoraceae)
Cerios tagal (Rhizophoraceae)
Clerodendron inerme (Verbenaceae)
Exocoecaria agallocha (Euphorbiaceae)
Hibiscus tiliaceus (Malvaceae)

Licuala spinosa (Arecaceae)
Lumnitzera littorea (Combretaceae)
Phoenix paludosa (Arecaceae)
Rhizophora mucronata (Rhizophoraceae)
Salacia viminea (Celastraceae)
Samandura harmandii (Simaroubaceae)
Scyphiphora hydrophyllacea (Rubiaceae)
Sonneratia alba (Sonnerateaceae)
Sonneratia caseolaris (Sonnerateaceae)
Sonneratia ovata (Sonnerateaceae)
Xylocarpus granatum (Meliaceae)

Species less than 2 m in height:

Acanthus ebracteatus (Acanthaceae)
Acanthus ilicifolius (Acanthaceae)
Acrostichum aureum (Adiantaceae)
Aegiceras corniculata (Myrsinaceae)
Glochidion littorale (Euphorbiaceae)
Lumitzera racemosa (Combretaceae)
Nephrolepis sp. (Davalliaceae)
Pluchea indica (Asteraceae)

Mangrove trees typically reach to heights of 5-10 m, but *Rhizophora conjugata* and *Lumnitzera littorea* may reach 10-15 m.

Only scattered remnants of these mangroves exist today.

6.3.5 "Rear Mangrove" Paperbark Swamps

Brakish wetlands behind mangrove areas in southern Cambodia are typically dominated by dense stands of shrubby *Meleuca leucadendron* (Myrtaceae) termed the rear mangrove community (Dy Phon 1970, Rollet 1972, Legris and Blasco 1972). These individuals are commonly only a few meters in height, with trunks 20-30 cm in diameter. The evergreen *M. leucadendron*, widespread throughout Southeast Asia and south to Australia, has excellent powers of vegetative regeneration following damage by either cutting or fire. Although many virtual monocultures of this species exist, these are probably a secondary result of disturbance. While paperbark swamps are typical of coastal areas, they may occur as much as 40 km inland as near Phuni Chhuk north of Kampot where clay pans allow soil waterlogging.

Seasonal to semi-permanent waterlogging is a characteristic of these paperbark swamps. Hozumi et al. (1969) describe a community growing in pure white silica sand with a water table at about 1 m depth in the dry season but flooded in the wet season. In the Malay Peninsula, paperbark swamps behind mangrove areas are often permanently saturated with soil moisture.

An unusual pattern of natural regeneration for paperbark swamps has been described by Rollet (1972). In the dry season, the leaves and humus of paperbark gives off volatile oils which are highly flammable. Any ignition of these oils initiatives a fire which opens the stand to prolific regeneration, while the papery bark of adult trees protects them from fire.

A variety of other species are characteristic of this community, including both mangroves and less salt tolerant species, and climbers including rattans are common. Characteristic associated species include:

Amoora cucullata (Meliaceae)
Barringtonia angusta (Lecythidaceae)
Barringtonia pauciflora (Lecythidaceae)
Bruguiera gymnorhiza (Rhizophoraceae)
Bruguiera sexangula (Rhizophoraceae)
Caryota urens (Arecaceae)
Excoecaria agallocha (Euphorbiaceae)
Heritiera littoralis (Sterculiaceae)
Hibiscus tiliaceus (Malvaceae)
Ilex walichii (Aquifoliaceae)
Licuala spinosa (Arecaceae)
Ochna integerrima (Ochnaceae)
Oncospermum tigillaria (Arecaceae)
Pandanus tectorius (Pandanaceae)
Phoenix paludosa (Arecaceae)
Rapanea capitellata (Myrsinaceae)
Samandura harmandii (Simaroubaceae)
Sindora maritima (Fabaceae-Caesalpinoideae)
Syzgium polyanthum (Myrtaceae)
Syzgium zeylanicum (Myrtaceae)

The ground layer of paperbark wetlands is commonly dominated by:

Acanthus ilicifolius (Acanthaceae)
Acrostichum aureum (Adiantaceae)
Calophyllum retusum var. *cambodgense* (Guttiferae)
Cyperus spp. (Cyperaceae)
Glochidion rubrum (Euphorbiaceae)
Melastoma sanguineum (Melastomataceae)
Pluchea indica (Asteraceae)
Scirpus spp. (Cyperaceae)
Wedelia biflora (Asteraceae)

An interesting associated sedge-like species from these paperbark wetlands is *Leptocarpus disjunctus*, one of the few members of the Restionaceae to reach the Northern Hemisphere. Sunny understory areas are often covered by a nearly pure monoculture of this species (Hozumi et al. 1969).

Unlike the swamp forests around Tonle Sap, the paperbark wetlands support a moderate diversity of epiphytes. Most common among these epiphytes are species of orchids and the birds-nest fern, *Asplenium nitidum*. Other ferns present include *Humata repens* ((Davalliaceae), *Drynaria quercifolia* (Polypodiaceae), and *Polypodium* sp. (Polypodiaceae).

Stand structure and biomass characteristics of paperbark swamps in Cambodia have been reported by Hozumi et al. (1969). They reported a density of 150 trees ha^{-1} with diameters of 10 cm or more. They found a basal area of 3.5 m^2 ha^{-1}, a leaf area index of 0.4 m^2 m^{-2}, and a dry weight woody biomass of 14.7 (12.1 tons ha^{-1} above-ground) with an additional herb layer of 2.6 tons ha^{-1}.

6.3.6 Coastal Strand Vegetation

The coast of Cambodia includes alternating areas of sandy beach, silty mud flats, and rocky shore. An open cover of woody vegetation or thicket growth is often present along a coastal belt between the beach and the first dunes. Present in this community are both taller trees reaching 8-15 m and shrubs 2-8 m in height (Dy Phon 1970). All of the dominant species in this community are evergreen, with deciduous trees and shrubs playing a relatively minor role forming less than 20% of the species.

Characteristic trees:

Casuarina equisetifolia (Casuarinaceae)
Heritiera javanica (Sterculiaceae)
Heritiera littoralis (Sterculiaceae)
Manilkara hexandra (Sapotaceae)
Podocarpus fleuryi (Podocarpaceae))

Shrubs:

Barringtonia acutangula (Lecythidaceae)
Barringtonia angusta (Lecythidaceae)
Calophyllum inophyllum (Guttiferae)
Cerbera odollam (Apocynaceae)
Cycas rumphii (Cycadaceae)
Hibiscus tileaceus (Malvaceae)
Hypobatrum frutescens (Rubiaceae)
Pandanus tectorius (Pandanaceae)

On rocky coastal sites, *Terminalia catappa* (Combretaceae), *Rhizophora mucronata* (Rhizophoraceae), and *Pemphis acidula* (Lythraceae) become more common (Department of Nature Conservation and Protection 1996).

Epiphytes are present in these coastal evergreen thickets, but generally with species different than those present in the paperbark swamps (Dy Phon 1970). Common epiphytes include *Microsorium* and *Pyrrhosia* (Polypodiaceae), *Bulbophyllum* and *Dendrobium* (Orchidaceae), and *Dischidia nummularia* and *D. rafflesiana* (Asclepiadaceae).

Transitional areas to mangroves often show a dominance by *Hibiscus tileaceus* (Malvaceae) and *Excoecaria agallocha* (Euphorbiaceae).

Table 5.1. Land use and cover classification systems for Cambodia.

Blasco et al. (1997) - Vegetation Map of Cambodia

Vegetation units mapped at scale of 1:1,000,000 are largely structural rather than floristic units and arrayed in the following hierarchy on the basis of rainfall regime, elevation and forest structure. Categories mapped are as follows:

A. Very humid types of the Gulf of Thailand (>2,000 mm rainfall)
    Low elevations (<600-700 m)
        Dense evergreen forest
        Low dense evergreen forest
        Dense thicket
        Discontinuous thicket
        Savanna
    Medium elevation (>700 m)
        Dense evergreen forest
        Low dense evergreen forest
        Dense thicket
B. Humid types (1,500-2,000 mm rainfall)
    Low elevation
        Dense semi-deciduous forest
        Mosaic of dense forest and secondary vegetation with dense forest predominant
        Mosaic of dense forest and secondary vegetation with secondary vegetation predominant
        Dense thicket
        Discontinuous thicket
        Savanna
    Medium elevation
        Dense semi-deciduous forest
        Dense thicket
        Discontinuous thicket
        Herbaceous savanna

C. Sub-humid types (<1,500 mm rainfall)
- Woodland with Dipterocarpaceae
- Degraded woodland; with crops
- Dense thicket
- Discontinouous thicket

D. Forest types with *Pinus merkusii*

E. Edaphic types
- Swampy degraded plant communities
- Discontinuous forest
- Herbaceous hydromorphic types
- Mangrove
- Back-mangrove

F. Cultivated vegetation
- Plantations
- Crops

Kunneke (1997) - Cambodian Land Use and Cover Classification System (CLUCCS)

Selected areas of Cambodia mapped at 1:50,000 using aerial panchromatic phtography from 1992-97 at 1:25,000 scale. Categories mapped are as follows:

- Urban and built-up land
- Agricultural Land
- Upland Forest
  - Evergreen broadleaf
  - Evergreen conifer
  - Deciduous
  - Mixed evergreen/deciduous
  - Bamboo
  - Secondary Forest
  - Scrub forest
  - Plantation forest
  - Savanna
- Rangeland
  - Grassland
  - Shrub/scrub
  - Mixed rangeland
- Wetlands
  - Palustrine (with subdivisions)
  - Riverine (with subdivisions)
  - Lacustrine (with subdivisions)
  - Estuarine (including mangrove and paperbark units)
  - Marine
- Transportation, Communication and other utilities
- Barren land
- Other (human influenced)

FAO (1996) - Tonle Sap land use / land cover and inundated habitat mapping

Map of Tonle Sap region at 1:50,000 scale made using aerial panchromatic photography from 1992-93 at 1:25,000 scale. Categories mapped are as follows:

- Forest (>10 m height)

- Flooded forest with high density (>90% closed)
- Flooded forest with medium density (50-90% closed)
- Broadleaf evergreen forest
- Broadleaf deciduous with closed canopy (>90% closed)
- Broadleaf deciduous with open canopy (<90% closed)
- Mixed evergreen/deciduous forest
- Secondary forest

Woodland (6-10 m height)
- Woodland with high density (>90% closed)
- Woodland with medium density (50-90% closed)

Bushland (2-6 m height)
- Bushland with low density trees (10-50% trees)
- Bushland with scattered trees (<10% trees)

Shrubland (0-2 m height)
- Shrubland with low density trees (10-50% trees)
- Shrubland with scattered trees (<10% trees)
- Shrubland

Grassland (dominance by herbaceous cover)
- Shrubland with low density trees (10-50% trees)
- Grassland and scattered trees (<10% trees)
- Grassland

Mekong Secretariat (1994) - Land/Use Cover Mapping of Cambodia; 1973-76

Mapped on a scale of 1:250,000 using Landsat imagery of 1973-76. Categories mapped are as follows:

Forests, woodlands, and shrublands
- Evergreen forest
- Coniferous forest
- Deciduous forest
- Mixed forest
- Secondary forest
- Mangrove forest
- Flooded forest
- Flooded secondary forest
- Woodland and scrub

Grasslands

Other surfaces without vegetation
- Water surface
- Barren land
- Urban/city

Agricultural land
- Rice field/paddy field
- Upland crop
- Swidden agriculture
- Orchards and plantation
- Field crop

Mekong Secretariat (1993) - Land/Use Cover Mapping of Cambodia; 1992-93

Mapped at scale of 1:500,000 using Landsat data at 1:250,000 scale from 1992-93 and aerial panchromatic photography at 1:25,000 scale from 1992-93. Categories mapped are as follows:

- Forests and woodlands
  - Evergreen forest
  - Coniferous forest
  - Deciduous forest
  - Mixed forest
  - Secondary forest
  - Mangrove forest
  - Flooded forest
  - Flooded secondary forest
  - Woodlands
- Shrublands
  - Natural shrublands
  - Abandoned shrublands
- Herbaceous cover
  - Swamps
  - Grasslands
  - Grass savanna
  - Flooded grasslands
  - Abandoned grasslands
  - Marshes
- Other surfaces without vegetation
  - Water surfaces
  - Barren lands
  - Urban/cities
- Agricultural lands
  - Paddy fields
  - Receding rice fields
  - Upland crops
  - Swidden agriculture
  - Orchards
  - Plantation
  - Field crops

Mekong Secretariat (1991) - Reconnaissance land use map of Cambodia

Mapping based on 1988-89 Landsat imagery at 1:250,000 scale. Categories mapped are as follows:

- Natural areas
  - Evergreen forests
    - Broad-leaved forests
      - Dense broad-leaved forest
      - Flooded evergreen forest\
      - Mangrove forest
      - Mosaic of forest and secondary vegetation
      - Mosaic of flooded forest and swampy fallow land
      - Secondary forest
    - Pine forest
  - Deciduous forest

- Other vegetation
  - Thickets
  - Scrubs, brushwoods
  - Grass savanna
  - Grassland susceptible to flooding
  - Swampy vegetation
- Cultivated areas (with subdivisions)
- Disused areas
- Others
  - Open water
  - Rivers
  - Urban areas and infrastructure (many subdivisions)

VIETNAM

1. Physical Geography

Vietnam has an area of 325,360 km^2, making it just slightly larger than the Philippine Islands and slightly smaller than Germany, but less than two-thirds the area of Thailand. It extends from the upper Red River drainage near the Tropic of Cancer at 23°23' N lat. to 8°30' N lat. at Ca Mau Point in the south, a linear distance of about 1,600 km. Yunnan and Guangxi Provinces of China border it to the north, and Lao and Cambodia to the west. The inland border of Vietnam with these three countries extends for 4,639 km, while the coastline along the Gulf of Tonkin, South China Sea, and Gulf of Thailand is about 3,440 km in length. At its narrowest point in central Vietnam near Hue, the country is only 35 km wide.

1.1 Mountain Regions

The overall landscape of Vietnam is strongly mountainous, with over three fourths of the land area covered in hills and mountains. The mountain areas fall superficially into three broad regions - the mountains of northeastern Vietnam north of the Red River, the Hoang Lien Son of northern Vietnam west of the Red River which represents a southern extension of the Himalayas, and the long Annamite Range which forms the backbone of Southeast Asia between Vietnam and Lao and Cambodia. With a closer examination of the geologic structure and history of this country, however, the geomorphic provinces are more complex.

1.1.1 Northeastern Vietnam

Vietnam northeast of the Red River forms a part of the old structural block of south-central China, and is structurally distinct from the remainder of Southeast Asia. This block has been referred to as the South China Platform, and comprises western Kuangsi, southern Kweichow, and eastern Yunnan Provinces of China along with northeastern Vietnam. This area has experienced repeated uplift and subsidence but relatively little deformation through the Phanerozoic. The sediments here consist of a combination of exposed ancient metamorphic basement rock and marine sediments deposited in the late Paleozoic and early Triassic. Many of these sediments are limestones that have been uplifted and weathered to form an extensive karst topography with steep topography. Tectonic activity in the late Triassic led to the intrusion of an extensive area of granitic-granidiorite in the Viet Bac massif near the Chinese border. The highest peak here is Tsi Con Ling at 2,531 m, but most of the area is only of moderate relief. Only a few areas along the Chinese border reach above 1,600 m. There is a prominent depression extending from Cao Bang to the coast.

The northwest-southeast trending valley of the Red River separates this northeastern region of Vietnam from the southern Himalayan regin, as described below. The delta area of the Red River and other major rivers of theis region are commonly bounded by

wide limestone terraces, extensive alluvial plains, and low hills. The northeast coast is dotted with hundreds of small limestone islands.

1.1.2 Southern Himalayan Region

The southern extension of the Himalayan Range (Henduan Mountains) of Yunnan Province, China, extends into northern Vietnam as high mountains known as the Hoang Lien Song. The Fan Si Pan massif near the Chinese border, formed by a granitic intrusion in the late Mesozoic, reaches the highest point in mainland Southeast Asia at 3,143 m. Ta Giang Phinh is only slightly lower at 3,096 m. This region of northern Vietnam has a relatively large area of uplands extending above 2,000 m, and a number of peaks reaching 2,500-3,000 m. These include Phoung Chang (2,825 m) and Lang Cung (2,817 m).

Southwest of this massif lies an area of complex folded parent material termed the Song Da and Dien Bien Phu synclinoria and the Song Ma anticlinorium. To the south of the Song Da (Black) River, the Ta P'ing, Son La and Moc Hau plateaus which reach to as much as 1,800 m elevation are separated by deep valleys. The highest peaks to the south of the Song Da River are Sam Sao (1,896 m) and Pha Luong (1,884 m).

To the south of these structures is a zone of Permian limestones which cross the northern and central Annamite Range and has weathered into a spectacular area of karst topography.

1.1.3 Greater Annamite Range

The Annamite Range, in its broad sense including the southern plateau areas, extends for nearly 1,200 km in a north-south direction along the border between Vietnam and Lao and Cambodia to the west. The Annamite Range represents a complex geomorphic structure with a long history of multiple folding of both marine sediments and metamophic rock, uplifted basement rock, and later volcanic activity with extensive basalt flows. This long history of uplift and deformation along the mountain axis has led to a variety of parent materials and soil structures, with resulting strong influence on forest communities. The primary uplift of the Annamite Range occurred with the Indosinian orogenies of the late Paleozoic and early Mesozoic. This range was subsequently subjected to Tertiary folding under the influences of compressional movements of the Indian subcontinent to the west and tensional forces from sea floor spreading in the western pacific to the east.

The major portion of the Annamite Range is composed of deformed Paleozoic marine sedimentary rock and late Paleozoic granitic intrusives termed variscides because they date from the period of Indosinian orogenies. The highest peak in the central Annamites of Vietnam is Phu Lai Lang which reaches 2,711 m near the Lao border. Over much of the Annamite Range in central Vietnam, however, the highest peaks are to the west in Lao. As central Vietnam narrows south of Vinh, the Annamite Range falling within Vietnam is relatively low with the highest peaks reaching only rarely above 1,300 m. Within this region is a belt of thick continental sandstones of late Triassic age, rich in early plant fossils, that extends from Lao across central Vietnam around Hoi An to the south of Danang.

The variscide zone is interrupted to the north of Da Nang by the large Kontum Massif of exposed metamorphic basement rock. This region of basement parent rock extends over an area for approximately 250 km to south and inland for 200 km. Ngoc Linh (Ngoc Pan) at the northwestern margin of the Kontum Massif is the highest point of the Annamite Range in central Vietnam at 2,598 m. It lies 100 km inland from the coast to the south of Da Nang.

The Paleozoic variscides continue again to the south of the Kontum Massif, but here they form a complex mosiac of exposed rock with late Paleozoic granitic intrusives and Triassic volcanics. Chu Yang Sinh located in this region 80 km inland from Nha Trang forms the highest peak in the southern Annamite Range at 2,410 m. At the southern margin of the Annamite Range in southwestern Vietnam the variscide formations give way to terrestrial sedimentary formations of Tertiary age. Subsequent to the formation and uplift of the southern Annamite Range, extensive lava flows in the late Tertiary and Quaternary formed large plateaus of resistant basalt. These are the Dac Lac (Darlac), Pleiku, Haute Cochinchine and Djirling plateaus of southern Vietnam which reach maximum elevations as high as 1,400-2,200 m. The geomorphology of this region of Vietnam is reviewed in detail by Schmid (1974).

The Dac Lac (Darlac) and Pleiku plateaus, sometimes referred to collectively as the Taynguyen Plateau, rise to a maximum of only 400-800 m, with lower elevations of 100-200 m to the west and south. This means that local drainage patterns run largely to the west toward Cambodia, isolating river valleys from the more impacted eastern slopes in Vietnam. Pleiku is bounded on the north by the granitic Kontum Massif, and to the east of these plateaus are the large Song Ba Valley and Cho Reo depression with extensive alluvial plains at an elevation of about 150 m. The basaltic soils of Dac Lac (Darlac) are the most weathered and deepest to the south and shallower to the north, while the soils of western margin of the Pleiku plateau are also deep and rich.

Haut Chhlong and Haut Cochinchine form plateaus at the southwestern end of the folded mass of the southern Annamite Range and the alluvial plains of the Mekong delta. Haut Chhlong is a basaltic dome reaching 950 m elevation at its center, and dropping to 400 m along its western margin. The exposure of this plateau to moisture-laden winds from the southwest produces unusually heavy rainfall in this region and thus deep weathering of the older basalts. Haut Cochinchine, located to the south, is a peneplain of older schists and sandstone largely overlain by basalts of varying ages. The older basalts lie to the north and younger basalts to the south. Scattered areas of granite outcrops and small volcanic cones are also present. It reaches a maximum height of 734 m. Lying in a partial rain shadow of the Cardamom and Elephant Mountains, the Haut Cochinchine area is much drier and more markedly seasonal than that of Haut Chhlong. The small plateau area of Djiring to the east of Haut Cochinchine also has a primary cover of basalts that are well weathered by heavy rainfall.

The heavily eroded Dalat Plateau of southern Vietnam comprises a more complex geology. Present are schists and quartzites, as well as extensive areas of granites and volcanic rhyolites, andesites and dactites. The eastern and northern portions of the Dalat highlands are dominated by dactites, including the peak of Lang Bian which reaches 2,163 m. Extensive rolling hills to the south and west with elevations of 1,300-1,600 m are largely formed of weathered granites.

The southern margin of the greater Annamite Range is marked by a terrace region that gives way to the Mekong delta. Alluvial plains along the Saigon and Dong Nai rivers comprise portions of these terraces. The delta region of the Mekong, extending over 40,500 km^2, cover much of the lowlands of southern Vietnam.

A narrow and irregular coastal plain connects the fertile river valleys of northern and southern Vietnam. This coastal plain is at its broadest in southern Vietnam between Ho Chi Minh City and Nha Trang, where it may extend inland for 20-30 km. It appears again in a narrower belt along the coast of central Vietnam between Da Nang and Vinh. Much of this coastal plain is formed of Quaternary alluvium deposited from the Annamite range to the west. Small deltaic alluvial plains are also present along the south-central coast. A distinctive area of stabilized red sands occurs around Cam Ranh Bay to the south of Nha Trang and supports unique coastal forests.

2. River Basins and Hydrology

Two broad river basins and deltas form distinct geomorphic regions of Vietnam. These are the Red River basin in northern Vietnam and the Mekong delta region in southern Vietnam. Rich alluvial soils in each of the regions have led these areas to evolve as major population centers based on their agricultural productivity.

The Red River rises in the mountains of Yunnan Province in China, and flows southeast for more than 1,127 km, finally emptying into the Gulf of Tonkin through a broad delta area. Its course flows along a deep and relatively wide valley that follows the major Cenezoic rift zone separating the South China and Southeast Asian plates. In its flow through southern China, the Red River is called the Yuan Jiang, and in northern Vietnam is known as the Song Hong, (formerly called the Song Coi). The chief tributaries of the Red River are the Song Da (Black) and Song Chay (Clear) rivers. Associated with the lower Red River basin are the Au Chan and Tu Le basins of sediments that formed from the deposition of terrestrial material into an area of shallow inland sea during the Indosinian period. The delta region of the Red River extends approximately 240 km inland and is 120 km wide at the coast.

The southwestern region of Vietnam below Ho Chi Minh City is formed by the extensive triangle of the Mekong delta. This low-lying terrain is largely composed of Quaternary sediments deposited by the river, which here branches into a series of channels to form its broad delta. Although major tributaries join the Mekong within Vietnam, extensive areas of the eastern slopes of the southern Annamite region of Vietnam drain westward into Cambodia where they eventually join the Mekong. This separation of drainage basins has had a significant historical association with the levels of human impact in the southern Annamite Region.

3. Climatic patterns

Three basic climate types are found in Vietnam. In the north, especially in the interior, the temperatures are subtropical. Shifting seasonal wind patterns result in short dry winters in the lowlands of northern Vietnam, with a drought period of 3-4 months

extending from December to February or March. Summers are wet, with peak rainfall in July and August. Hanoi has a mean annual rainfall of 1,809 mm, but rainfall increases moving northeast up the coast of northern Vietnam. Mon Cai near the Chinese border has 2,853 mm of annual rainfall, with only two months with less than 50 mm rainfall (and with no totally dry months). Temperature regimes in the north have a strong seasonality. Winter conditions with cool temperatures in Hanoi extend from November to April, reaching lows of 5°C, and persistent drizzling rains are typical from early February until the end of March. Summers are hot and humid, with extreme tempeatures in Hanoi reaching to 43°C. The mean annual temperature at Hanoi is 23.9°C (Gaussen et al. 1967).

The mountains of northeastern Vietnam experience cooler temperatures and higher levels of mean annual rainfall with increasing elevation. At lower elevations, however, topographic position with respect to the monsoon winds is far more important than elevation in influencing annual rainfall. Lang Son at 259 m elevation experiences a small degree of rainshadow and has only 1,440 mm of annual rainfall, while Lao Cay at 93 m along the Red River valley has an average of 1,780 and Ha Giang at 187 m elevation has 2,450 mm. Chapa at 1,640 m elevation has 2,850 mm rainfall (Gaussen et al. 1967).

The high mountain areas of the Fan Si Pan massif in northwestern Vietnam have a cool, humid climate more characteristic of temperate Chinese areas than subtropical Southeast Asia. Temperatures frequently drop below freezing in December and January on the higher mountain slopes, and snow falls on 1-3 days each year. The mean annual temperatures are in the range of 15-17°C. The range of temperature reported is from alow of -3°C to a high of 29°C. Annual rainfall typically falls in the range of 2,770-3,550 mm, with the heaviest rains concentrated in the summer months of July and August (Nguyen Nghai Thin and Nguyen Thi Thoi 1998).

The central and southeastern areas of Vietnam typify the tropical monsoon climate, with high temperatures and abundant precipitation, but the nature of monsoon seasonality varies significantly between central and southern coastal Vietnam. Vinh at 18°40' lat on the north-central coast has a mean annual rainfall similar to Hanoi, with 1,790 mm. The peak of rainfall, however, is shifted back in the year to September and October, and every month receives at least 50 mm of rainfall. Peak rainfall is pushed back even further at Quang Tri (16°44' lat) along the central coast where peak rainfall comes in October and November, and mean annual total is 2,543 mm. The pronounced wet season here extends from September through January, and no month of the year has less than 60 mm of rainfall. Total rainfall continues to increase moving southward down the coast with 3,040 mm at Hue (16°24'), but then drops to 2,075 at Da Nang (16°02') and 2,260 mm at Quang Ngai (15°08'). These coastal stations retain the late rainfall peaks from September through November. There is a semi-dry season of 3-4 months from February to April or May, but significant rains of 20-50 mm fall in all of these months (Gaussen et al. 1967).

In the southwest, distinct wet and dry periods are evident, but temperatures are higher than in the north. At Yok Don Nature Reserve along the Cambodian border (about 13°N lat., 107°30' E long.) the mean annual rainfall is 1,540 mm with a well-defined dry season from October to April. The mean annual temperature is 24-26°C.

Patterns of climatic variation and rainfall in southern Vietnam (but not including the Mekong delta region) have been described in detail by Schmid (1974) who recognized five climatic regions. The most arid of these is his semi-arid climate which characterizes the coastal zone from Nha Trang southward and the Song Ba Valley and Cho Reo

depression southwest of Pleiku. These regions, lying in a rain shadow of the southern Annamite Range, have a mean annual rainfall of less than 1,500 mm, and a dry season of six months (months with less than 50 mm rainfall). The driest point in Vietnam occurs at Cape Padaran south of Phan Rang where Schmid (1974) reports only 757 mm of annual rainfall. This station expiences a second summer drought period in July and August when flows from the monsoon rains are blocked. Rainfall in the coastal belt is highly variable between years, and monthly totals are less than 100 mm for 6-9 months each year. The peak months for rainfall are typically October and November under the influence of northeastern monsoon winds. Mean annual temperatures are 25-26^{o}C. Coastal stations in this zone include Qui Nhon, Nha Trang, and Phan Thiet.

The second climatic region is the hot, semi-humid zone, which is characterized by moderate levels of rainfall of 1,500 to 2,000 mm or more and a strong predominance of summer precipitation. Typically, there are four months each year with less than 50 mm rainfall. Dew is frequent in the dry season, but fog is rare. Mean annual temperatures are 22-25^{o}C. The hot, semi-humid zone dominates more than half of southern Vietnam, covering the majority of lowland and middle elevation areas below 800 m. Stations which exhibit this climatic zone are Pleiku, Kontum, Ban Me Thuot and Gia Ray (Schmid 1974).

The higher Kontum Massif and Dalat Plateaus of central and southern Vietnam, and to a lesser degree the plateaus of Pleiku, Haut Chhlong, Djiring, and Haut Cochinchine, all rise to elevations or have exposures sufficient to give them more humid climatic zones. The semi-humid submontane zone at elevations of about 800-1,000 m has moderate levels of rainfall with 1,500-2,200 mm annually. The peak of this rainfall occurs in September or October under the influence of the southward return of the monsoon with northeastern winds. Mean annual temperatures are about 20-21^{o}C. Winter diurnal temperature variation can be quite large in this zone, with an average range from high to low of 20-25^{o}C. Typical climatic stations within this climatic zone are Djiring, Lang Hanh, and Liang Khang (Schmid 1974).

The humid submontane climate zone comprises upland areas at middle elevations below about 1,100 m that are exposed to humid winds. Although mean annual temperatures are similar to those in the previous zone, mean annual rainfall is generally above 2,500 mm and quite regular, with brief dry seasons lasting three months or less. Peak months for rainfall are typically August through October. Dew is abundant in the brief dry season and foggy mists are common. The climatic zone covers much of the Kontum Massif, Haut Chhlong and Haut Cochinchine, and small areas east of the Dac Lac (Darlac) Plateau. Le Rolland and Blao are stations which represent this climatic zone (Schmid 1974).

The final climatic zone of southern Vietnam is the montane climate which occurs at elevations above 1,100-1,200 m. This zone is present in the Kontum Massif and around the Dalat Plateau. At Dalat (1,500 m elevation), the mean annual rainfall is about 1,820 mm, and there are 3-4 dry months of less than 50 mm rainfall. Dalat has a mean annual temperature of only 18.5^{o}C. On the eastern margin of the Dalat Plateau at Hon Ba (1,480 m elevation), very heavy rains of 3,851 mm occur with no dry month (Schmid 1974). These rains peak very late in November under the influence of the northeastern monsoon winds. Morning dew is common throughout this zone, as well as foggy mists.

4. Flora

The intensity of botanical activity and collecting in Vietnam has been far greater than that in either Lao or Cambodia, and relatively large herbaria collections exist. Schmid (1989) reported that Vietnamese institutions held about 400,000 collections, and another 150,000 Southeast Asian collections (largely from Vietnam) were housed in Paris. Smaller but significant collections of Vietnamese plants also exist at a number of other institutions in England (Kew), the United States (Arnold Arboretum, Universty of California, Berkeley, and the New York Botanical Garden), Japan (University of Tokyo), and Russia (Komorov Botanical Institute in Leningrad).

There have been a number of estimates made in the literature on he size of the flora of Vietnam. Schmid stated that approximately 10,000 species of vascular plants are known to occur within the broad Indochina region of Lao, Cambodia and Vietnam, and that the total number of native vascular plant species over this region is likely to be 12,000-15,000. Based on a subsample of groups treated in the ongoing flora of Indochina project, approximately 80% of these, or 9,600-12,000 species, would be expected to occur within Vietnam. Both Quy (1995) and Cuc (1995) offer figures of 7,000 known species of vascular plants in Vietnam, but an estimated 5,000 additional species not yet listed for a total vascular plant flora of about 12,000 species. This is a remarkably diverse flora for a small country.

The most complete analysis of the flora of Vietnam has been made by Nguyen Nghia Thin (1998). As shown in Table 1 below, he estimated a vascular plant flora of 10,605 species, divided into 2,342 genera and 318 families. These species included 739 species of ferns and fern relatives, 63 species of gymnosperms, and 9,812 species of angiosperms. In addition, there were 793 species of bryophytes, divided into 182 genera and 60 families. Five vascular plant families had 400 or more species in Vietnam. These were the Orchidaceae (about 800 species), Fabaceae (about 470 species), Euphorbiaceae (about 425 species), and Poaceae and Rubiaceae (about 400 species each). The largest 30 families in the flora of Vietnam, each with more than 100 species, are shown in Table 2.

The flora of Vietnam is not only large, but also rich in endemic species, adding to its significance. Vo Quy (1995) suggests that 10% of species and 3% of genera in this flora are endemic to Vietnam. The endemism of the Indochina region is discussed later in this report. Future field studies in Lao, however, will almost certainly discover many taxa previously known only from Vietnam but many Vietnamese endemics no doubt also remain to be discovered. Thus it is difficult to calculate an accurate level of national endemism for vascular plants.

The high species diversity of vascular plants in Vietnam can be well illustrated from a detailed study of the flora of Cuc Phong National Park in northern Vietnam. This park covers 22,220 ha and is situated in low limestone hills 120 km southwest of Hanoi. The topography is rather limited with a maximum elevation of 650 m. There are 1,799 species of vascular plants, divided into 920 genera and 198 families (Nguyen Nghia Thin 1997).

Table 1. Estimated size of the flora of Vietnam (Nguyen Nghia Thin 1997).

Division	Species	Genera	Families
Psilopsida	2	1	1
Lycopodiophyta	57	5	3
Equisetophyta	2	1	1
Polypodiophyta	669	137	25
Gymnospermae	63	23	8
Angiospermae	9,812	2,524	378
Total Vascular Plants		10,605	
Bryophyta	793	182	60

Table 2. Estimated species richness of the 30 largest vascular plant families in Vietnam (adapted from Nguyen Nghia Thin 1997).

1. Orchidaceae	800	16. Scrophulariaceae	128
2. Fabaceae	470	17. Arecaeae	125
3. Euphorbiaceae	425	18. Melastomataceae	124
4. Poaceae	400	19. Caesalpiniaceae	118
5. Rubiaceae	400	20. Moraceae	118
6. Asteraceae	336	21. Asclepiadaceae	113
7. Cyperaceae	303	22. Polypodiaceae	113
8. Lauraceae	246	23. Fagaceae	111
9. Aanthaceae	217	24. Araliaceae	110
10. Annonaceae	173	25. Zingiberaceae	109
11. Apocynaceae	170	26. Rutaceae	108
12. Lamiaceae	145	27. Myrtaceae	107
13. Myrsinaceae	139	28. Theaceae	101
14. Araceae	134	29. Rosaceae	100
15. Verbenaceae	131	30. Urticaceae	100

Schmid (1974) tabulated the total number of species that he had observed within four primary climatic zones of southern Vietnam (Table 3). In each of these zones he variously categorized species by a combination of growth form and community type. His hot, semi-arid zone corresponds to the coastal forests described below. The hot, semi-humid zone is formed of semi-evergreen forest and deciduous dipterocarp forest communities. The humid and semi-humid submontane zones are largely dominated by wet evergreen forest, but with lowland pine woodlands on shallow soils. The montane climatic zone supports a range of montane coniferous and broad-leaved forest communities. Each of these zones has azonal wetland communities as well. Overall, Schmid's observations cover 3,480 different species.

Table 3. Distribution of species among life-forms within each of four major climatic zones in southern Vietnam (adapted from Schmid 1974).

	Semi-arid hot zone	Subhumid hot zone	Lower montane zones	Montane zone
Zonal Communities				
Woody species	323	539	668	414
Herbaceous species	139	325	344	366
Azonal Wetlands				
Woody species	20	62	75	42
Herbaceous species	68	232	179	145
Lianas and hemi-epiphytes	143	139	183	73
Epiphytes	30	49	139	216
Parasites	14	10	20	20
Vascular cryptogams - terrestrial	11	85	185	220
Total species *	737	1073	1380	1154

Total species observed = 3480

* Totals are less than the sum of the columns because of species occurring in more than a single vegetation unit within each climatic zone

Although the total flora of the southern Annamite Range and adjacent coastal areas studied by Schmid is undoubtedly much larger than the total species count of 3,480 that he observed, these numbers provide a relative perspective on pattern of species diversity. The highest overall species richness occurred in the wet evergreen forest habitats of the

lower montane zone at 600-1,200 m, a habitat holding 40% of total observed species. This area had the highest diversity of woody species in both zonal and wetland forest habitats, and the highest number of liana species. The second highest zone of species richness was the montane zone, an area relatively limited in geographical extent but which included 33% of the observed species. The montane habitats had the highest richness of herbaceous forest species, epiphytes, and vascular cryptogams (ferns and fern relatives) of any zone, but a relatively low diversity of lianas. Only slightly less diverse were the communities of the hot, semi-humid zone with 31% of total observed species. This zone was second only to the lower montane zone in the diversity of woody species, rich in wetland herb species, but low in diversity of epiphytes. Finally, the semi-arid coastal zone had the lowest species richness (21% of total observed species), with epiphytes and vascular cryptogams being particularly low in diversity.

For the 3,400 species considered by Schmid (1974) in his analysis of the flora of the southern Annamite Range and adjacent coastal areas, ten families formed 39% of the flora. The ten largest families were the following:

Orchidaceae (243 species)
Fabaceae (226 species)
Poaceae (219 species)
Euphorbiaceae (146 species)
Rubiaceae (114 species)
Cyperaceae (105 species)
Fagaceae (90 species)
Asteraceae (85 species)
Annonaceae (62 species)
Moraceae (58 species)

Among specialized growth forms, both lianas and epiphytes have notably high species richness in Vietnam. The most important families of lianas are the Arecaceae, Ampelidaceae, Annonaceae, Asclepiadaceae, Convolvulaceae, Fabaceae (subfamilies Caesalpinoideae and Papilionoideae), Moraceae, Piperaceae, and Rutaceae. Many other families, however, contribute smaller numbers of important lianas. These include the Acanthaceae (*Thunbergia*), Araceae, Araliaceae, Poaceae (Bambusoideae), Celastraceae (*Celastrus*), Combretaceae (*Calycopteris*), Connaraceae, Gnetaceae, Hippocrateaceae (*Salacia*, *Reissantia*), Loganiaceae (*Strychnos*), Melastomataceae (*Amplectrum*), Pandanaceae (*Freycinetia*), Rosaceae, Rubiaceae (*Mussaenda*, *Paederia*, et al.), Urticaceae (*Conocephalus*), and Verbenaceae (*Sphenodesma*, *Congea*).

Epiphyte diversity is overwhelmingly dominated by the Orchidaceae, with an estimated 700 species occurring within Vietnam (Seidenfaden 1992). The ferns collectively provide a second large group of epiphytes, particularly in more humid forest habitats. The interesting epiphytic species of *Agapetes* (Ericaceae) are largely restricted to upper montane zones. Humid open forests on acid soils contain *Myrmecodia* and *Hydnophytum*, two unusual genera of Rubiaceae with obligate mutualisms with ant species that live within inflated stem tissue of the host plant. Ant mutualisms also occur within the epiphytic *Dischidia rafflesiana* (Asclepiadaceae). Hemi-epiphyic stranglers

include about fifty species of *Ficus* (Moraceae), one of Rubiaceae (*Hymenopogon*), and one of Rosaceae (*Pirus*).

The diversity of parasitic and hemiparasitic species is relatively low in Vietnam. The flora of the southern Ammanite Range includes about 40 such species (Schmid 1974). The majority of these, about 25 species, are hemiparasites in the Loranthaceae and are most abundant in montane forests. Other hemiparasites include *Henslowia* (Santalaceae) and *Alectra* (Scrophulariaceae). Among the true parasites, there are several species of Balanophoraceae (*Balanophora*), two Orobanchaceae (*Aegynetia*), one Lauraceae (*Cassytha*), and one Rafflesiaceae (*Sapria*).

Schmid (1974) cites a number of groups with interesting or unusual patterns of endemism within the southern Annamite region. These include the Orchidaceae (Dalat region), the Fagaceae (Dalat and Blao regions), Rubiaceae (Blao region), the Euphorbiaceae (eastern areas), Celastraceae (eastern areas). The montane forests and uplands provide a home for a number of unusual endemics in the Theaceae, Symplocaceae, Rosaceae, Malpighiaceae, Ericaceae, Cycadaceae, and Pinaceae.

5. Vegetation Mapping

There have been several attempts made to prepare vegetation maps of all or portions of Vietnam. Early maps largely focused on divisions based on structural rather than floristic characteristics, however, and thus have limited value in defining ecoregions and natural floristic units.

A vegetation and land use map of the Vietnam south of 17^{o}N lat. at a scale of 1:1,000,000 was published 30 years ago (Institut Géographique, Republic of Vietnam 1969). This map separated 19 forms of plant cover or agricultural land use, but these only very crudely separate forest types:

- Dense forest
- Dense forest/secondary forest closely mixed
- Secondary forest
- Open forest
- Bamboo
- Pine forest
- Swamp vegetation
- Vegetation of swamp areas in Dong Thap Muroi
- Vegetation of swamp areas in the Mekong Delta
- Mountainous grasslands
- Vegetation of sand dunes and seashore
- Brushwood (i.e. thickets)
- Mangroves
- *Tram* forest
- Plantations – industrial plants and orchards
- Plantations – rubber
- Plantations – coffee
- Plantations – tea

- Rice fields, dry crops and fruit trees

Schmid (1974) presented a vegetation map of the southern Annamite Range and adjacent coastal areas of southern Vietnam. In this small map he separated eight plant formations:

- Semi-arid formations (= coastal forests)
- Prairie-steppe
- Savannas and scrubland
- Thickets and bamboo thickets
- Open forests and pine forests (= deciduous dipterocarp forests and pine forests)
- Dense semi-deciduous or deciduous forests (= semi-evergreen forests)
- Dense evergreen forest (= wet evergreen forest)
- Montane forests (= montane forests)

Unpublished vegetation maps of Vietnam at a scale of 1: 2 million and 1: 1 million by the Forest Inventory and Planning Institute (FIPI) in Hanoi were mentioned by Schmid (1989), but these have not been available for study.

A more recent division of ecoregions of Vietnam was made by Wikramanayake et al. (1997) who separated 16 ecoregions within the country. Their categories can only broadly be compared to the forest habitats described in this text and do not correspond well with natural floristic or vegation boundaries. The closest approximation of their categories with those used here is as follows. In their map, mountainous areas of northern Vietnam were classified as *northern Indochina subtropical forest* (= subtropical broad-leaf forest). The Annamite Range was divided into a series of ecoregions beginning in the north with the *northeast Indochina montane forest*, followed by the *Annamite Range moist forest* and *Bolovens-Kon Tum montane forest* in central Vietnam, and the *Eastern Indochina moist forest* and *Da Lat-Phnom Lyr montane forest* in southern Vietnam. A small area around Da Lat and adjacent plateaus is mapped as *eastern Indochina pine forests*. All of these types are included within montane forests here, but the areas mapped by Wikramanayake et al. (1997) includes lowland areas as well. The *Cardamom Mountains moist forests* of southern Cambodia extends very slightly into Vietnam on Dao Phu Quoc island. Coastal areas are described in the north as *northern Vietnam coastal moist forest* and in the south as *southern Vietnam coastal forest.* An area of *central Indochina dry forest* (= deciduous dipterocarp forest) extends into the western foothills of the Annamite Range in south-central Vietnam. Five ecoregions of azonal wetland forests are also mapped. In northern Vetnam, these are *Red River swamp forests* and *Gulf of Tonkin mangroves* of the Red River basin. In southern Vietnam, there is a much larger area of wetland forests with the *Tonle Sap-Mekong peat swamp forests*, the *Tonle Sap freshwater swamp forests*, and the *Gulf of Thailand mangroves*.

6. Forest Habitats

Despite the relatively extensive floristic studies that have been carried out in Vietnam, qualitative and quantitative descriptions of forest structure and diversity are

much less available for many areas Vietnam than those that exist for Lao and Cambodia. Schmid (1974) has described the southern Annamite region of Vietnam thoroughly in the only detailed study of Vietnamese floristics and vegetation over a broad region, but no similar survey has been made of vegetation structure in central or northern Vietnam. A brief sketch of the floristic structure of Vietnamese forest habitats was outlined in an unpublished thesis proposal by Nhung (1982).

Detailed discussions of forest structure and floristics in Vietnam are only available for the southern Annamite Range and adjacent coastal areas in a very thorough study by Schmid (1974). There is not an equivalent study of forest structure and composition for any part of central or northern Vietnam. Because of this, much of the discussion below is limited to areas of southern Vietnam.

6.1 Lowland Forest Habitats

The annual rainfall and the seasonality of this rainfall are the primary factors in determining the distribution of forest habitats in Vietnam. These lowland habitats are those occurring below about 1,000 m in southern Vietnam and below about 800 m in northern Vietnam. The rainfall regime of these lowland areas ranges from levels above 3,000 mm to others with less than 1,500 mm. The former may have only 1-3 months of functional drought compared to six months at the latter.

Edaphic conditions may also have a profound effect on the structure and floristics of lowland forest habitats in southern Vietnam (Schmid 1974). In the foothills of the southern Annamite region in areas with a hot, semi-humid climatic regime, characteristics of soil parent material, soil age and weathering, and soil hydrology all are important factors in influencing vegetation structure. Deep, rich basaltic soils (*terres rouges*) typically support a rich semi-evergreen forest, while younger basalts with thin soil cover or eroded soil surfaces (*terres brunes*) support a more deciduous forest community. A deciduous dipterocarp forest characterizes hydromorphic soils that are saturated for part of the year, while soils saturated for the majority of the year have a cover of swamp forest or grassland.

The largest tree species in southern Vietnam are largely found in lowland evergreen forests. Dicotelydonous tree genera with species reaching heights of 35-40 m or more and diameters above 1 m (Schmid 1974) include the following list, arranged by family:

Anacardiaceae (*Dracontomelum, Swintonia*)
Apocynaceae (*Alstonia*)
Bignoniaceae (*Stereospermum*)
Burseraceae (*Dacryodes*)
Combretaceae (*Anogeissus, Terminalia*)
Datiscaceae (*Tetrameles*)
Dipterocarpaceae (*Dipterocarpus, Hopea*)
Fabaceae (*Pterocarpus, Sindora, Parkia*)
Fagaceae (*Quercus*)
Guttiferae (*Calophyllum*)
Lauraceae (many genera)
Lythraceae (*Lagerstroemia*)

Magnoliaceae (*Michelia*)
Meliaceae (*Amoora*)
Moraceae (*Ficus, Artocarpus*)
Sapindaceae (*Pometia*)
Sterculiaceae (*Pterospermum, Scaphium, Sterculia*)

Lowland forest habitats in Vietnam are divided here into five broad groups: wet evergreen forests, semi-evergreen forests, deciduous dipterocarp forests, lowland pine woodlands, and coastal forests.

6.1.1 Wet Evergreen Forest

Wet evergreen forest in Vietnam has been termed *forêt dense humide sepervirente* (Aubreville 1956), *forêt hygrophile* (Maurand 1954), *forêt humide sempervirente* (Schmid 1962), and *forêt dense sempervirente* (Schmid 1974). Nhung (1982) interprets wet evergreen forest broadly to include areas that extend from coastal forest northeast of Hanoi in Quang Ninh Province, south to Lam Dong Province in the southern Annamite Range. This habitat would include areas with mean annual rainfall of 1,200-2,500 mm and 1-3 dry months. He characterizes the community on the basis of the presence of an assemblage of large Dipterocarpaceae. These include *Hopea pierrei, H. odorata, Parashorea stellata, Dipterocarpus retusus, D. alatus, Vatica odorata,* and *Anisoptera robusta*. In the northern Annamite Range, however, the species richness of Dipterocarpacerae is low despite a strong ecological importance of tree species in this family. These wet evergreen forests grade into semi-evergreen forest, with no absolute criteria for delineating a clear line of distinction.

6.1.1.1 Wet Evergreen Forests in the Northern Annamite Range

Floristic studies of wet evergreen forest have been carried out in the northern Annamite Range in the proposed Pu Mat Nature and Bu Huong Reserves in Nghe An Province (Kemp et al. 1995). This is an area of northwest to southeast trending ranges near the border with Lao with enclosed small valleys and ridges. Most of the area of the reserves lie below 700 m elevation, but a number of peaks exceed 1,000 m elevation. The highest peak in this area is Pu Mat at 1,841 m. In the proposed Bu Huong Reserve the highest peak is Phu Lon at 1,580 m elevation. Mean annual rainfall at Con Cuong, the nearest station, is 1,791 mm, but the totals for Pu Mat is likely significantly higher. Rainfall largely occurs from May to October, but scattered rains are present throughout the winter season from November to March.

The flora of the Pu Mat Reserve has been estimated to include at least 1,000 species, with a high level of endemism to Indochina (Kemp et al. 1995). Overall, the flora shows a stronger affinity to that of northern Vietnam and southern China than to that of southern Vietnam. Although the Dipterocarpaceae is an ecologically significant element of the lower elevation wet evergreen forest of Pu Mat, only three species were present. Floristic elements more typical of northern Vietnam are diverse and important at Pu Mat, notably in the Fagaceae, Lauraceae, and Rosaceae.

Primary wet evergreen forest at Pu Mat consists of a dense, three-tiered canopy reaching 25-35 m, and occasionally 45 m height in undisturbed sites, with large emergent trees extending above this level to give a rough upper surface to the canopy. The upper canopy is dominated by a species of *Hopea* (Dipterocarpaceae), *Castanopsis hystrix* (Fagaceae), and *Madhuca pasquieri* (Sapotaceae). The fan palm *Livistona saribus* is a common subcanopy species, common in small gaps, which reaches to 20 m height and forms about 10% of the stand basal area. The total forest community has a basal area of 29.3 $m^2 ha^{-1}$. Also important in the subcanopy at 10-25 m height are *Syzgium cumini* and *S. hancei* (Myrtaceae) and *Gironniera subequalis* (Ulmaceae). The understory at 5-10 m height is largely composed of saplings of the canopy trees, but *Canthium dicoccum* (Rubiaceae) is common. Wet evergreen forest stands disturbed by logging show a characteristic presence of *Knema erratica* (Myristicaceae), a fast-growing colonizer, and an increased dominance of *Livistona saribus* in the upper canopy which reaches only about 20 m height.

Primary wet evergreen forest in the Bu Huong Reserve undisturbed by human activities supports very large forest trees which reach to 3 m in diameter and 50 m in height. As many as five canopy strata have been identified for this forest, with emergent trees at 30-50 m height and a more continuous upper canopy at 23-30 m height. The most frequent canopy trees are *Hopea mollissima* (Dipterocarpaceae), *Ormosia balansae* and *O. merrilliana* (Fabaceae-Papilionoideae), and *Phoebe angustifolia* (Lauraceae). Epiphytes, lianas, and palms (including rattans) are all common in this forest community.

6.1.1.2 Wet Evergreen Forests in the Southern Annamite range

The southwest-facing slopes of the southern Annamite Range provide topographic conditions which produce local areas of very high rainfall. Distinctive vegetation zones are present in this region with a lower forest zone below 600 m elevation and a more humid submontane zone at 600-1,000 (1,200) m elevation. This transition may be relatively sharp, or more gradual as in the regions of Haut Cochinchine and Haut Chhlong. The topography in this region is generally one with steep slopes with poor soil cover and narrow valleys. The valley bottoms have largely been cleared of forest cover, but some evergreen forest remains in area too steep or too eroded for the cultivation of crops.

Although montane elements in the form of species of Fagaceae and Podocarpaceae may enter these habitats, the dense forest canopy is dominated by a distinctly Malaysian element of trees in the Dipterocarpaceae, Magnoliaceae, Annonaceae and Lauraceae. The Rubiaceae and Myrtaceae are notably diverse in this habitat, while woody legumes (particularly Fabaceae subfamily Papilionoideae) are relatively uncommon. Despite the designation of this habitat as wet evergreen forest, a significant number of briefly deciduous tree species are present.

Wet evergreen forests on the basalt plateaus of the region of Haut Chhlong and Blao at about 700-1,100 m elevation occur on relatively deep and well-drained soils. These soils may be 0.5-3.0 m in depth. In comparison to lowland soils in the semi-humid climatic zone, these soils are poorer in nutrient availability but richer in organic matter.

The canopy height of this wet evergreen forest commonly exceeds 30 m and is generally discontinuous, with mixed distribution of canopies in middle and lower strata.

Generally, relatively few tree species exhibit large buttresses. A lower strata of shrubs and tree saplings is relatively continuous in the understory, but there is little development of a distinctive herb strata on the forest floor. Lianas are relatively abundant, particularly around forest openings and along stream valleys where more light penentrates. Epiphytes are common at all levels in the canopy, but epiphytic ferns are proportionally less abundant than in lower elevation forests.

Schmid (1974) presented data on forest tree density from figures provided by the *Service Forestier* for a 6 ha stand dominated by *Hopea*. In this stand there were 162 trees ha^{-1} equal or greater than 20 cm in diameter, and 5.5 trees ha^{-1} greater than 100 cm diameter.

The great majority of tree species are evergreen in leaf phenology. These trees have leaves that have been described as mesophyllous, semi-coriaceous and glabrous (Schmid 1974). Species with pubescent leaves are, nevertheless, widespread (e.g. *Lasianthus, Melodorum, Actnodaphne*). Deciduous tree species of several types are present. *Schima crenata* (Theaceae) and *Swintonia griffithii* (Anacardiaceae) lose there leaves for a brief period at the time of flowering in February, while other tree species such as *Choerospondias axillaris* (Anacardiaceae) and *Bombax insigne* (Bombacaceae) are leafless for as significant period. These latter two species characteristically require open areas for establshment and do not become established as seedlings beneath a dense forest canopy.

The flowering of trees in these wet evergreen forests occurs in the period from January to April. Fruits of most species ripen before summer. Seed dispersal of most groups (e.g. Lauraceae, Fagaceae, Myrtaceae, Elaeocarpaceae, Guttiferae) is by animals, but a significant group of species are wind dispersed. These latter include both trees (*Swintonia, Hopea, Engelhardia, Acer*) and lianas (*Anodendron, Neurolepis, Illigera*).

The upper canopy structure of these evergreen rainforests is floristically dominated by species of Fagaceae, Myrtaceae, and Lauraceae. For the Fagaceae, as many as 20 species of *Lithocarpus*, five species of *Castanopsis* and three species of *Quercus* may be present in this formation. Very large emergent trees are also present among the Anacardiaceae, Burseraceae, Dipterocarpaceae, and *Schima crenata* (Theaceae). *Hopea* cf. *pierrei* (Dipterocarpaceae) may be the most abundant of the large trees, forming up to 90% of all trunks 100 cm or more in diameter and 60% of stems above 50 cm diameter (Schmid 1974). The largest individuals attain trunk diameters above 1.5 m. Another dipterocarp, *Dipterocarpus* cf. *costatus* reaches 35-40 m in height with diameters up to 1.3 m. *Swintonia griffithii* make up some of the largest individual trees in the forests, with canopies commonly reaching above 45 m. This species favors sites along streams at 200-900 mm elevation, and is characterized by large buttresses. Another tall canopy tree is *Dacryodes rostrata* (Burseraceae) which reaches above 40 m height in its range at 600-900 m elevation.

Schmid (1974) reported the following as the most important canopy trees:

Acer decandrum (Aceraceae)
Aglaia (?) sp. (Meliaceae)
Alstonia sp. (Apocynaceae)
Anisophyllea penninervata (Rhizophoraceae)
Artocarpus spp. (Moraceae)

Bombax insigne (Bombacaceae)
Calophyllum sp. (Guttiferae)
Canarium littorale (Burseraceae)
Celtis cf. *sinensis* (Ulmaceae)
Cinnamomum mairei (Lauraceae) - very common
Dacryodes rostrata (Burseraceae)
Dipterocarpus sp. (Dipterocarpaceae)
Elaeocarpus floribundus (Elaeocarpaceae)
Eugenia cf. *grandis* (Myrtaceae)
Eugenia cf. *zeylandica* (Myrtaceae)
Ficus spp. (Moraceae)
Hopea sp. (Dipterocarpaceae)
Ixonanthes cochinchinensis (Ixonanthaceae)
Lithocarpus leiostachya (Fagaceae)
Lithocarpus pachycarpa (Fagaceae)
Litsea sp. (Lauraceae)
Notaphoebe sp. (Lauraceae)
Phoebe sp. (Lauraceae)
Quercus austro-cochinchinensis (Fagaceae)
Quercus cf. *langbianensis* (Fagaceae)
Rhodoleya championi (Hamamelidaceae) - secondary formations
Sandoricum indicum (Meliaceae)
Sapindus mukorossi (Sapindaceae)
Sapium baccatum (Euphorbiaceae)
Scaphium affine (Sterculiaceae)
Schima crenata (Theaceae) - secondary formations
Swintonia griffithii (Anacardiaceae)
Xerospermum glabrum (Sapindaceae)

Species observed by Schmid (1974) in the middle canopy layer included:

Adina polycephala (Rubiaceae) - secondary formations
Apodytes cambodiana (Icacinaceae)
Baccaurea sapida (Euphorbiaceae)
Calophyllum sp. (Guttiferae)
Catanopsis hystrix (Fagaceae)
Castanopsis tesselata (Fagaceae) - secondary formations
Chaetocarpus castanocarpus (Euphorbiaceae)
Chisocheton paniculatus (Meliaceae)
Cratoxylon cf. *polyanthum* (Guttiferae)
Cryptocarya annamensis (Lauraceae)
Elaeocarpus parviflorus (Elaeocarpaceae)
Elaeocarpus petiolatus (Elaeocarpaceae)
Eugenia spp. (Myrtaceae)
Engelhardtia roxburghiana (Juglandaceae)
Garcinia merguenis (Guttiferae)

Horsfieldia amygdalina (Myristicaceae)
Ilex rotunda (Aquifoliaceae)
Lindera annamensis (Lauraceae)
Lithocarpus blaoensis (Fagaceae)
Lithocarpus cf. *honbaensis* (Fagaceae)
Lithocarpus microsperma (Fagaceae) - very common
Litsea elongata var. *cuneifolia* (Lauraceae)
Machilus cochinchinensis (Lauraceae)
Manglietia spp. (Magnoliaceae)
Meliosma donnaiensis (Sabiaceae)
Mischocarpus pentapetalus (Sapindaceae)
Mischocarpus sundaicus (Sapindaceae)
Neolitsea poilanei (Lauraceae)
Pygeum parreauanum (Rosaceae)
Pygeum spp. (Rosaceae)
Pyrenaria jonquieriana (Theaceae)
Sapium discolor (Euphorbiaceae) - secondary formations
Symplocos glauca (Symplocaceae)
Vernonia arborea (Asteraceae) - secondary formations
Xanthophyllum annamense (Xanthophyllaceae)

The lower shrub canopy of this forest formation is rich and diverse, with a notably large number of Rubiaceae present. Also important are the Lauraceae (*Litsea*), Flacourtiaceae (*Casearia*), and Symplocaceae (*Symplocos*). The ecologically dominant understory group, however, are species of *Strobilanthes* (Acanthaceae) which often form a continuous cover 1.2-1.5 m in height.

Lianas form an important component of this forest community. Schmid (1974) observed a large number of species representing at least 17 families. These included a number of rattans and two species of *Gnetum* (Gnetaceae). Epiphyes were likewise abundant and diverse, with ferns and the Orchidaceae forming the major portion of epiphyte biomass.

Schmid (1974) briefly mentions the presence of tall forests of dominated by the deciduous *Toona* cf. *febrifuga* (Meliaceae) on local areas basaltic soils of thin depth but relatively unaltered by erosion.

6.1.1.2 Forests on Slopes with Granitic or Other Metamorphic Substrates

In contrast to the basalt plateaus, soil development on slopes with granite, dactite or schist substrates is almost always poor. Soils are characteristically shallow and rocky, and on granites quite acidic. However, because of their steeper inclination compared to the plateaus, these slopes receive a strong influence from humid winds and moisture-laden mists and fog are common. Rains and frequent cloud cover produce mild temperature conditions that allow wet evergreen forests to reach to as high as 1,200 m elevations where they are gradually replaced by montane forest communities.

Schmid has broadly described the floristic composition of dominant forest species on both granites and dactites, and on schists, in the region of Blao. These communities are

highly variable in structure owing to heterogeneous patterns of soil development. There are characteristically mosaics of well-developed forest communities on better soils separated by patches of open forests or shrublands where soils are shallow or parent rock is exposed. Floristically, these slope communities present a transition between the lowland forest communities and the montane forests of the plateaus and higher elevations. Floristic differences from the forest communities described above for the basalt plateaus are the presence of Podocarpaceae, and the richness of diversity of palms, *Quercus*, Magnoliaceae, and ferns. A notable occurrence is the abundance of lianas of *Freycinetia* (Pandanaceae) and *Pseudostachyum polymorphum* (Poaceae), both taxa associated with wet Malaysian forests. Lauraceae are relatively poor in both species richness and abundance.

The dominant canopy tree, as in the plateau forests, is commonly *Hopea* cf. *pierrei*. This large tree may grow in relatively pure populations at about 1,000-1,200 m elevation, or more commonly in mixed stands with species of *Quercus* (Fagaceae) and *Podocarpus* (Podocarpaceae). Three species of Podocarpaceae may be present - *Podocarpus neriifolius, P*. (*Dacrycarpus*) *imbricatus* and *Dacrydium elatum*. Schmid (1974) mentions that almost pure populations of huge *P. imbricatus* occurred at about 1,200 m elevation on the southeast-facing slopes of Nam Nung in Haut Chhlong. The Magnoliaceae are represented by a variety of species of *Michelia*, and the Fagaceae by at least three large species of *Quercus*. Another conifer, *Cephalotaxus mannii* (Cephalotaxaceae) is present in this community in the area around Yang Kar.

The understory shrub strata of these humid forests is dominated by a diverse assemblage of Rubiaceae (*Psychotria, Gaertnera, Urophyllum, Maschalocorymbus, Ixora, Chasalia*), as well as Meliaceae (*Disoxyum, Agaia*), Dichapetalaceae (*Dichapetalum*), Symplocaceae (*Symplocos*) and Myrsinaceae (*Ardisia*). Also notable is a diversity of understory palm species including *Pinanga annamensis, Areca laoensis, Licuala* cf. *bracteata, Licuala paludosa*).

In addition to *Freycinetia* (Pandanaceae) and *Pseudostachyum polymorphum* (Poaceae) which were mentioned above, lianas include species of *Bauhinia* (Fabaceae-Caesalpinoideae), *Ancistrocladus* (Ancistrocladaceae), and a diverse number of rattans (*Calamus tetradactylus, C. pseudoscutellaris, C. bousigonii*).

Rocky substrates on these humid slopes exhibit a development of an interesting community rich in terrestrial orchids. This community has not been well described nor its composition examined in any detail.

Schmid (1974) provides a very brief description of slope forests on schist parent material in the region of Blao, a forest community which he stated had been heavily impacted by human activities. The dominant trees in the upper forest canopy were *Swintonia griffithii* (Anacardiaceae), *Podocarpus imbricatus*, and a species of *Michelia*.

6.1.2 Semi-Evergreen Forests

Semi-evergreen forests in Vietnam are an extension of a similar community that extends across large areas of Thailand, Cambodia and Lao. As in these areas, this is a forest type that includes a variety of different community types that share the characteristic of a semi-evergreen forest cover with multiple strata and a well-developed presence of lianas. The canopy composition can vary from being primarily evergreen to

one in which deciduous species dominate. The basis for separation of semi-evergreen forests with decidous tree dominants from mixed deciduous forests was described earlier in the introduction to forest habitats in mainland Southeast Asia. These habitats are less mesic than those of the wet evergreen forest, with moderate annual rainfall regimes of 1,200-2,000 (2,500) mm and 3-6 months of drought. Forests with this structure and related floristics occur from Quang Ninh Province in northern Vietnam to Tay Ninh Province in the south.

Semi-evergreen forests in Vietnam have had a variety of names in the French literature. When evergreen species predominate in the canopy, these forest have been called *forêt dense semi-décidue* (Aubreville 1956), *forêt semi-humide mixte* (Maurant 1954), *forêt dense hemiombrophile* (Vidal 1956-60), *forêt dense humide cauducifolié* (Schmid 1962), and *forêt dense humide tropicale semi-décidue* (Nhung 1982). Forest stands where deciduous species are predominant in the canopy often share much of the same floristic composition but have been designated differently. These have been termed *forêt dense sèche décidue* (Aubreville 1956), *forêt dense tropophile sèche* (Maurant 1954), *forêt mixte cauducifolié* (Vidal 1958), *forêt sèche cauducifolié* (Schmid 1962), and *forêt dense humide décidue tropicale* (Nhung 1982). Wikramanayake et al. (1997) include this forest habitat within their concept of *eastern Indochina moist forest.*

6.1.2.1 Semi-Evergreen Forests on Basalt

The distribution of semi-evergreen forest is largely determined by climatic factors related to soil moisture availability, and may form over a variety of substrates in southern Vietnam. In the hot semi-humid climatic region, much of this habitat occurs over basalt parent materials. Deep *terre rouges* soils formed from basaltic parent materials in the southern Annamite Range support a rich semi-evergreen forest with an upper canopy reaching to 40 m. Emergent trees such as *Tetrameles nudiflora* (Datiscaceae) and *Lagerstroemia angustifolia* (Lythraceae) growing along forest edges may reach 40-50 m in height. The greatest density of foliage, however, occurs somewhat lower at 15-30 m height. The largest trees with a diameter of more than 80 cm typically number about 20 per hectare, with the majority of trunks of canopy trees in the size range of 50-80 cm diameter (Schmid 1974). A species of *Phoebe* (?) (Lauraceae) reached to more than 2 m in diameter. Large buttresses are characteristic in many species: *Tetrameles*, *Dracontomelum duperreanum* (Anacardiaceae), *Pometia pinnata* (Sapindaceae), and *Terminalia bellirica* (Combretaceae). Lianas are abundant, particularly species of Ampelidaceae and Annonaceae. Epiphytes are present, particularly in the upper forest canopy where light levels are higher, but nowhere abundant or diverse in number of species. Strangler figs, however, are common. The forest understory cover of smaller trees is relatively dense, but the low light levels penetrating to the forest floor limits the density of ferns and herbaceous species on the forest floor. The diversity of understory shrubs, herbs and lianas is described by Schmid (1974).

Many of the large trees are deciduous in this community, with leaf fall reaching its peak in February. New leaf production occurs at the end of the dry season when temperatures are high. Other important tree species remain evergreen throughout the year, with members of the Lauraceae typical of this group. Despite the mixed dominance of evergreen and deciduous trees in the forest canopy, understory trees are largely

evergreen. The canopy trees exhibit a peak of flowering in the late dry season, and have mature fruit in December and January. Understory trees tend to flower earlier in the dry season, at a time associated with the reduction of overstory foliage cover as many canopy trees lose their leaves. Schmid (1974) remarks that many of the canopy trees have heavy fruits that are animal dispersed. He suggests that the clumps of seeds are often found in the neighborhood of parent trees of *Dracontomelum duperreanum*, *Pometia pinnata*, and *Amoora* cf. *gigantea* (Meliaceae), while wind-dispersed species such as *Lagerstroemia angustifolia* (Lythraceae) and *Holoptelea integrifolia* (Ulmaceae) are more widely distributed and are particularly common along forest edges.

The dominant canopy tree species reported by Schmid (1974) for this community were:

Aglaia sp. (Meliaceae)
Amoora gigantea (?) (Meliaceae)
Artocarpus spp. (Moraceae)
Cassia siamea (Fabaceae-Casalpinoideae)
Celtis sinensis (Ulmaceae)
Dracontomelum duperreanum (Anacardiaceae)
Dysoxylum sp. (?) (Meliaceae)
Eugenia sp. (Myrtaceae)
Ficus spp. (Moraceae)
Holoptelea integrifolia (Ulmaceae)
Hopea odorata (Dipterocarpaceae)
Lagerstroemia angustifolia (Lythraceae)
Palaquium obovatum (Sapotaceae)
Phoebe sp. (?) (Lauraceae)
Pometia pinnata (Sapindaceae)
Pterospermum cf. *diversifolium* (Sterculiaceae)
Pterospermum cf. *megalocarpum* (Sterculiaceae)
Sandoricum indicum (Meliaceae)
Sapindus mukorossi (Sapindaceae)
Stereospermum sp. (Bignoniaceae)
Terminalia bellirica (Combretaceae)
Tetrameles nudiflora (Datiscaceae)

The subcanopy of smaller trees has a flora distinctive from that of the canopy trees, with many different families represented. The Annonaceae and Araliaceae are particularly important in this stratum. Common subcanopy trees include:

Baccaurea oxycarpa (Euphorbiaceae)
Diospyros nitida (Ebenaceae)
Eugenia sp. (Myrtaceae)
Excoecaria oppositifolia (Euphorbiaceae)
Gironniera subaequalis (Ulmaceae)
Gomphandra sp. (Icacinaceae)
Harpullia arborea (Sapindaceae)
Knema cf. *linifolia* (Myristicaceae)

Laportea sp. (Urticaceae)
Macropanax cf. *concinnum* (Araliaceae)
Miliusa velutina (Annonaceae)
Paracleisthus sp. (?) (Euphorbiaceae)
Polyalthia evecta (Annonaceae)
Polyalthia cf. *jucunda* (Annonaceae)
Symplocos cf. *longifolia* (Symplocaceae)

Schmid (1974) described a particular dense form of semi-evergreen forest growing on deep colluvial soils formed from schist and granite parent material near Chu Ui on the eastern margin of the Dac Lac (Darlac) plateau. Here *Hopea odorata* and *Dipterocarpus turbinatus* (?) were the dominant species, and a diverse understory with notable dominance of Euphorbiaceae and Arecaceae (*Licuala*).

6.1.2.2 Semi-Deciduous Forest on Skeletal Soils

Dense to semi-dense deciduous forests with a floristic structure related to semi-evergreen forest occur on skeletal basaltic soils (*terres brunes*) in the southern Annamite Range. These soils are present on younger basalts of the Dac Lac (Darlac) and Haut Cochinchine plateaus. The strata of canopy trees in this habitat may reach to 35-45 m, but with a distinctive lower strata of smaller tree canopies at 15-20 m height. The largest trees, for example *Lagerstroemia angustifolia* (Lythraceae) and *Afzelia xylocarpa* (Fabaceae-Caesalpinoideae) may reach more than 2 m in trunk diameter. This latter species, along with a variety of Fabaceae and Combretaceae, forms the most dominant group. Lianas are abundant and epiphytes are relatively common.

Although this community shares many species with the semi-evergreen forests on *terres rouges* soils, the upper canopy here is largely dominated by deciduous species. Evergreen trees such as *Hopea odorata* (Dipterocarpaceae) may be present, however, in wetter sites. The understory trees and shrubs are a mix of evergreen and deciduous species.

The canopy species observed by Schmid (1974) in this habitat were:

Adina cordifolia (Rubiaceae)
Afzelia xylocarpa (Fabaceae-Caesalpinoideae)
Anogeissus acuminata (Combretaceae) - young soils
Dipterocarpus intricatus (Dipterocarpaceae)
Dipterocarpus turbinatus (Dipterocarpaceae)
Dracontomelum duperreanum (Anacardiaceae)
Ficus spp. (Moraceae)
Holoptelea integrifolia (Ulmaceae)
Hopea odorata (Dipterocarpaceae)
Irvingia oliverei (Simaroubaceae)
Lagerstroemia angustifolia (Lythraceae)
Lagerstroemia cf. *petiolaris* (Lythraceae) - hydromorphic soils
Miliusa cf. *baillonii* (Annonaceae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae) - young soils

Pterospermum diversifolium (Sterculiaceae) - young soils
Pterospermum cf. *megalocarpum* (Sterculiaceae)
Sterculia hypochra (Sterculiaceae) - young soils
Stereospermum sp. (Bignoniaceae)
Terminalia calamansanai (Combretaceae)
Terminalia chebula (Combretaceae) - hydromorphic soils
Terminalia nigrovenulosa (Combretaceae) - hydromorphic soils
Tetrameles nudiflora (Datiscaceae)
Toona ferifuga (Meliaceae)
Vitex pubescens (Verbenaceae)

In the understory tree strata, the Euphorbiaceae are notably common. Other species reported by Schmid (1974) included:

Baccaurea sp. (Euphorbiaceae)
Brownlowia spp. (Tiliaceae)
Cleistanthus sp. (Euphorbiaceae) - evergreen
Coelodiscus sp. (Euphorbiaceae)
Exocoecaria oppositifolia (Euphorbiaceae)
Gelonium multiflorum (Euphorbiaceae) - deciduous
Harpullia arborea (Sapindaceae)
Lagerstroemia flos-reginae (Lythraceae) - hydromorphic soils
Macaranga cf. *henricorum* (Euphorbiaceae) - evergreen
Mischocarpus sp. (Sapindaceae)
Polyalthia sp. (Annonaceae) - deciduous
Xerospermum laoticum (Sapindaceae)

Schmid (1974) reports a series of distinctive forest communities associated with special habitats within the semi-deciduous forest habitat. One such habitat occurs along small seasonal streams that drain *terres brunes* areas. Such humid ravines include species such as *Ocna harmandia* (Ochnaceae), *Pandanus* sp. (Pandanaceae), and many large-leaved understory herbs in the Araceae and Marantaceae.

Young lava flows with weakly weathered basaltic soils support a deciduous thicket community dominated by Euphorbiaceae (e.g. *Bridelia, Antidesma,* and *Euphorbia antiquorum*), with associates that may include Lagerstroemia (Lythraceae), shrubby legumes and grasses. More diverse thickets dominate shallow hydromorphic soils. The dominant families represented in this habitat are shrubby Euphorbiaceae (*Antidesma, Aporosa, Glochidion*), Rubiaceae (*Gardenia, Randia*), Verbenaceae (*Premna latifolia, Clerodendron lecomtei, Gmelina hystrix*), Sapindaceae (*Allophyllus*), Guttiferae (*Cratoxylon, Garcinia*), Loganiaceae (*Strychnos*), Flacourtiaceae (*Flacourtia*), and Olacaeae (*Schoepfia acuminata*).

On wetter sites where the basalt layer over schists is relatively thin, the forest canopy is enriched by a variety of species more characteristic of deciduous dipterocarp forest. These include Dipterocarpaceae (*Dipterocarpus intricatus, Shorea siamensis, Shorea obtusa*), Fabaceae (*Xylia xylocarpa, Sindora siamensis*), *Irvingia oliveri* (Simaroubaceae) and *Parinari annamense* (Chrysobalanaceae).

6.1.2.3 Semi-Evergreen Forest on Granitic and Metamorphic Parent Material

Semi-evergreen forests occur at elevations below 600 m on a series of parallel granitic ridges and metamorphic slopes that characterize the landscape of parts of Haut Cochinchine. The higher portions of these ridges support good forest growth, while the steep slopes have thickets of bamboo. Schmid (1974) described forest communities 4-50 m in height dominated by gregarious assemblages of *Dipterocarpus turbinatus* (Dipterocarpaceae) and *Swintonia griffithii* (Anacardiaceae). This community contained a diverse assemblage of Dipterocarpaceae (*Dipterocarpus, Hopea, Shorea*) and Fabaceae in the upper strata.

6.1.2.4 Podzolized Alluvial Soils

Schmid (1974) briefly describes an open forest community growing on highly leached ancient alluvium with a sandy gray podzolic soil cover in the Cho Reo basin. This forest is dominated by Dipterocarpaceae, *Terminalia corticosa* (Combretaceae), *Cassia fistula* (Fabaceae-Caesalpinoideae), *Buchanania reticulata* (Anacardiaceae), *Hiptage corymbifera* (Malpighiaceae), and low-growing *Cycas siamensis* (Cycadaceae). *Corypha lecomptei*, a large monocarpic palm, also grows in this area.

6.1.2.5 Alluvial Basins

The vegetation of the semi-arid alluvial plains of the Cho Reo region was described by Schmid (1974). This area has been highly modified by human activities, but seems to have once supported a semi-deciduous community related to semi-evergreen forests. This basin with deep, fine-textured alluvium is largely dominated by thickets of such small trees as *Combretum* (Combretaceae), *Albizia* (Fabaceae-Mimosoideae), *Bridelia* (Euphorbiaceae), and *Capparis* (Capparidaceae), and by open grassy savannas of *Heteropogon contortus* (Poaceae) and scattered small woody Fabaceae and Rubiaceae. Also present were clusters of a variety of large deciduous trees, suggesting that these once formed the dominant cover. Among these trees were:

Adina cordifolia (Rubiaceae)
Anogeissus acuminata (Combretaceae)
Dipterocarpus alatus (Dipterocarpaceae)
Cordia sp. (Boraginaceae)
Irvingia malayanum (Simaroubaceae)
Lagerstroemia angustifolia (Lythraceae)
Pterocarpus macrocarpus. (Fabaceae-Papilionoideae)
Schleichera trijuga (Sapindaceae)
Sindora siamensis (Fabaceae-Caesalpinoideae)
Vitex spp. (Verbenaceae)
Xylia xylocarpa (Fabaceae-Mimosoideae)

6.1.2.6 Riverine Forests

Tall gallery forests originally lined many rivers in Vietnam, with a community structure distinctive from that of forest habitats away from the influence of stream water. These riverine forest communities are treated here as semi-evergreen forests because of the floristic relationship of the component species, but these might otherwise be classified as an azonal forest community since they occur independently of the regional rainfall regime. Evergreen tree species predominate where rivers supply water to these gallery forest throughout the year, but more commonly there is a major component of large deciduous tree species.

Such gallery forest community occur along tributary streams flowing into the Srepok River in the Yok Don Nature Reserve. Typical gallery forests here reach about 30 m in height and exhibit a large basal area of about 35 m^2 ha^{-1}. The dominant canopy trees are largely deciduous species, although large Ficus species are common. The most notable of the deciduous trees are:

Afzelia xylocarpa (Fabaceae-Caesalpinoideae)
Lagerstroemia calyculata (Lythraceae)
L. angustifolia (Lythraceae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae)
Sindora siamensis (Fabaceae-Caesalpinoideae)
Tetrameles nudiflora (Datiscaceae)

Tall, dense clumps of bamboo often form a virtually impenetrable barrier along these streams. *Bambusa arundinacea* and *B. beecheyi* are the most important bamboos.

6.1.2.7 Anthropogenic Habitats of Thickets, Shrublands, Grasslands and Savannas

Distinctive secondary communities of thickets, shrublands, and grasslands have developed under the long history of human impact on semi-evergreen forests that once covered much of the lowland plateau region of southern Vietnam. The resulting anthropogenic habitats have a highly variable composition depending on the nature of the past disturbance regime. In the thickets, Schmid (1974) reports a range of 2,000 to 4,000 stems with a diameter of 5-20 cm per hectare, plus an additional density of 300-800 stems ha^{-1} with a diameter greater than 20 cm. This indicates one woody stem every 2-4 m^2. The thickets form from a mixture of small trees, shrubs and woody lianas. These communities are a mixture of both evergreen and deciduous species, with the evergreen species increasing with greater availability of soil moisture. Schmid describes that evergreen species are more common in thickets in Haut Cochinchine than in the Dac Lac (Darlac) region. There is a long list of small and larger tree species that may be present in these thickets, as reported by Schmid (1974):

Acronychia pedunculata (Rutaceae)
Albizia lebekkoides (Fabaceae-Mimosoideae)
Albizia lucida (Fabaceae-Mimosoideae)
Albizia stipulata (Fabaceae-Mimosoideae)
Albizia vialeana (Fabaceae-Mimosoideae)

Aporosa microcalyx (Euphorbiaceae)
Bridelia tomentosa (Euphorbiaceae)
Broussonetia payrifera (Moraceae)
Carallia lucida (Rhizophoraceae)
Cassia javanica (Fabaceae-Caesalpinoideae)
Cratoxylon formosum (Guttiferae) - very common
Crypteronia paniculata (Crypteroniaceae)
Dalbergia lanceolaria (Fabaceae-Papilionoideae)
Dalbergia stipulacea (Fabaceae-Papilionoideae)
Engelhardia spicata (Juglandaceae)
Eugenia chanlos (Myrtaceae)
Eugenia jambolana (Myrtaceae)
Garcinia hamburyi (Guttiferae)
Glochidion fagifolium (Euphorbiaceae)
Grewia paniculata (Tiliaceae)
Holarrhena antidysenterica (Apocynaceae)
Ilex godajam (Aquifoliaceae)
Lagerstroemia angustifolia (Lythraceae)
Lagerstroemia ovalifolia (Lythraceae)
Linociera macrophylla (Oleaceae)
Lithocarpus spicata (Fagaceae)
Litsea polyantha (Lauraceae)
Litsea sebifera (Lauraceae)
Maesa subdentata (Myrsinaceae)
Mallotus cochinchinensis (Euphorbiaceae)
Microdesmis casearaefolia (Euphorbiaceae)
Mischocarpus sundaicus (Sapindaceae)
Nephelium sp. (Sapindaceae)
Oroxylum indicum (Bignoniaceae)
Phoebe cuneata (Lauraceae)
Premna latifolia (Verbenaceae)
Polyalthia cerasoides (Annonaceae)
Schoepfia acuminata (Olacaceae)
Styrax benzoin (Styracaceae)
Symplocos sp. (Symplocaceae)
Trema velutina (Ulmaceae)
Vitex ajugaefolia (Verbenaceae)
Vitex canescens (Verbenaceae)
Vitex peduncularis (Verbenaceae)
Wendlandia galbrata (Rubiaceae)
Wrightia tomentosa (Apocynaceae)
Zanthoxylum cf. *retsoides* (Rutaceae)

Those noted as being very common among these were *Aporosa*, *Cratoxylon*, *Grewia*, and *Phoebe*. Lianas are also common in these thickets. Most abundant among these were *Acacia pennata* (Fabaceae-Mimosoideae), *Caesalpinia furfuracea* (Fabaceae-

Caesalpinoideae), *Milletia peduliformis* (Fabaceae-Papilionoideae), and *Thunbergia grandiflora* (Acanthaceae).

Large areas in the Dac Lac (Darlac) region that once supported semi-evergreen forest have been converted to open grassy savannas. The structure of these savannas varies considerably with the relative fertility of the soil and the nature of the disturbance. On more fertile soils, extensive grass savannas are present, typically with *Sorghum affine* or *Imperata cylindrica* as dominant species. Extensive areas may also be covered by the tall invasive herb *Chromalaena odorata* (Asteraceae). Where soils are more impoverished, the grass *Themeda arundinacea* assumes dominance.

Open savanna communities retain a characteristic group of small tree species, with these including a subset of that present in dry deciduous dipoterocarp forests and in secondary thickets (Schmid 1974). This situation complicates an understanding of the original distributions of semi-evergreen and deciduous dipterocarp forest habitats before the influence of human populations. Characteristic trees species in such savanna habitats include:

Albizia procera (Fabaceae-Mimosaceae) - very common
Antidesma ghaesembilla (Euphorbiaceae)
Azadirachta integrifolia (Meliaceae)
Bauhinia malabarica (Fabaceae-Caesalpinoideae)
Buchanania reticulata (Anacardiaceae) - very common
Canarium subulatum (Burseraceae)
Careya sphaerica (Lecythidaceae)
Casearia graveolens (Flacourtiaceae)
Crypteronia paniculata (Crypteroniaceae)
Derris polyphylla (Fabaceae-Papilionoideae)
Dillenia ovata (Dilleniaceae)
Eugenia jambolana (Myrtaceae)
Glochidion fagifolium (Euphorbiaceae)
Grewia asiatica (Tiliaceae)
Holarrhena antidysenterica (Apocynaceae)
Hymenodictyon excelsum (Rubiaceae)
Lannea wodier (Anacardiaceae) - very common
Pavetta indica (Rubiaceae) - very common
Phyllanthus emblica (Euphorbiaceae)
Premna cambodiana (Verbenaceae)
Semecarpus sp. (Anacardiaceae)
Spondias pinnata (Anacardiaceae)
Styrax benzoin (Styracaceae)
Symplocos racemosa (Symplocaceae)
Zizyphus rugosa (Rhamnaceae) - very common

6.1.3 Deciduous Dipterocarp Forests and Woodlands

Deciduous dipterocarp forests and woodlands in Vietnam represent the eastern extension of this forest type that extends across all of mainland Southeast Asia in habitats

with less than 1,800 mm annual rainfall and 5-7 months of drought. Additionally, this community may be edaphically determined by skeletal soils in areas where semi-evergreen forest exists nearby on deeper soils with greater water-holding capacity. For Vietnam, deciduous dipterocarp forest is present as far north as Nghe An Province and extends southward to Dong Nai Province.

In the French literature for Vietnam, this community has been called *forêt claire* (Aubreville 1956), *forêt claire à Dipterocarpaceae* (Vidal 1956-60), *forêt claire sans pin* (Schmid 1962), and *forêt claire sèche tropophile à feuilles larges* (Nhung 1982). This community is roughly equivalent to the *central Indochina dry forest* of Wikramanayake et al. (1997).

Deciduous dipterocarp communities are distributed within both the hot, semi-arid and and hot semi-humid climate zones of southern Vietnam. These woodlands form over a variety of substrates, but are most widespread on young basalts. They may also be present on shallow granitic soils near the coast between Dalat and Phan Rang. Many of these open woodlands have been highly impacted by many years of human activities, but no careful assessment has been made of the detailed distribution, forest structure and conservationj status of deciduous dipterocarp forest in Vietnam.

The dominant species of decidous dipterocarp forest are generally widespread throughout mainland Southeast Asia where these forest communities are present. Notable local endemism is present in southern Vietnam, however, among epiphytic orchids in these woodlands on the lower eastern slopes of the southern Annamite Range (Schmid 1974).

Dry dipterocarp deciduous forests and woodlands on basaltic areas of the Dac Lac (Darlac) region occupy thin soils low in nutrients and hydromorphic soils of moderate depth. These soils have been termed *terres grises* where poor drainage leads to anaerobic soil conditions. Compact clay concretions (laterites) are common in the soil and impede root penetration. While most of this community in Vietnam occurs over basalts, deciduous dipterocarp forest is not restricted to this substrate and extends in a continuous manner into Cambodia on granitic soils.

The general structure of this community is similar in appearance to elsewhere in Southeast Asia. The canopy structure is open with scattered trees and shrubs in a matrix of grassy understory. Canopy height is highly irregular, varying from no more than 10 m in areas where *Shorea obtusa* dominates to as much as 25 m for individual trees of *Dipterocarpus tuberculatus* on deeper soils. Schmid (1974) presents figures that the average density of woody stems reaching 5 cm diameter or more is about 800 ha^{-1}, with a range of about 500-1,000 ha^{-1} depending on site conditions. He reported an average of about 70-80 stems ha^{-1} with diameters more than 35 cm.

Lianas are neither diverse nor abundant in dry deciduous diopterocarp forest. Often there is a lack of a distinct understory stratum of woody species, although low thickets of woody species may be present. Epiphyte diversity and abundance is also low. The groups present are largely ferns (*Drynaria, Platycerium, Polypodium*), Asclepiadaceae (*Dischidia, Hoya*), and Orchidaceae (*Dendrobium. Oberonia, Otochilus*). The diversity of herbaceous perennials is relatively large, with Poaceae, Fabaceae, and Asteraceae particularly high in species. The grass understory frequently reaches as much as 1-1.5 m in height. Notably important among the grasses is *Arundinella*, an herbaceous bamboo, on rocky sites with thin soils, and *Pseudopogonantherum* on wetter prairie soils. Other

grasses that may be important in the understory of these deciduous dipterocarp forests are *Imperata cylindrica*, *Heteropogon contortus*, *Themeda triandra*, and *Alloteropsis semialata.*

Virtually the entire tree canopy of the deciduous dipterocarp forest is deciduous. Leaf fall is clearly brought on more by drought stress than by photoperiod, with the time of abscission varying between species and between sites. *Shorea obtusa*, for example, loses its leaves relatively late into the dry season, while *S. roxbughii* loses its leaves in December in the early dry season and begins to form new leaves in January. *Dipterocarpus obtusifolius* loses is leaves very gradually as the dry season progresses, and rarely becomes completely leafless. Seedlings of this species remain evergreen, while those of *Shorea* species are typically leafless in the dry season.

Flowering typically reaches its peak in the middle of the dry season, just before or at the moment of new leaf formation. *Dipterocarpus obtusifolius* is one of the earliest species to flower in November, while *Shorea roxbughii* flowers in January and *S. siamensis* even later in February. Fruit dispersal is centered in the late dry season. While the Dipterocarpaceae demonstrate specialized winged seeds for wind dispersal, the majority of tree species in other families have fleshy fruits adapted for animal dispersal.

Thick, corky bark is a characteristic of many woody species in the deciduous dipterocarp forest, and this trait helps protects stem from damage from frequent ground fires that burn through these forests in the dry season. Also present in many species, most notably *Shorea siamensis*, is a root crown from which even seedlings can resprout quickly following fire. Only a few species are spiny, e.g. *Gardenia* and *Randia* (Rubiaceae).

Although the overall diversity of species may be moderately high in deciduous dipterocarp forests and woodlands, a relatively small number of species are strongly dominant in southern Vietnam, as they are throughout the range of this forest habitat. These represent just four families - the Dipterocarpaceae, Fabaceae, Combretaceae and Fagaceae:

Dipterocarpus obtusifolius (Dipterocarpaceae)
Dipterocarpus tuberculatus (Dipterocarpaceae)
Lithocarpus lindleyana (Fagaceae)
Pterocarpus macrocarpus (Fabaceae-Papilionoideae)
Quercus kerrii (Fagaceae)
Shorea obtusa (Dipterocarpaceae)
Shorea siamensis (Dipterocarpaceae)
Terminalia alata (Combretaceae)
Terminalia chebula (Combretaceae)
Terminalia corticosa (Combretaceae)

There are large numbers of other woody species that may be present, as described by Schmid (1974):

Adina cordifolia (Rubiaceae) - transitional habitats to semi-evergreen forest
Adina sessilifolia (Rubiaceae) - edge of swamp habitats

Albizia procera (Fabaceae-Mimosoideae)
Aporosa sphaerosperma (Euphorbiaceae) - thickets
Bambusa arundinaceae (Poaceae) - rocky soils along streams
Bauhinia variegata - open areas of savanna
Bombax anceps (Bombacaeae)
Buchanania reticulata (Anacardiaceae) - open areas of savanna
Canarium subulatum (Burseraceae) - open areas of savanna
Careya sphaerica (Lecythidaceae)
Cratoxylon formosum (Guttiferae) - thickets
Cycas siamensis (Cycadaceae)
Dalbergia nigrescens (Fabaceae-Papilionoideae) - rocky areas
Dalbergia spp. (Fabaceae-Papilionoideae) - thickets
Dillenia pentagyna (Dilleniaceae)
Diospyros ehretioides (Ebenaceae) - transitional habitats to semi-evergreen forest
Erioglossum rubiginosum (Sapindaceae)
Eriolaena candollei (Sterculiaceae)
Eugenia jambolana (Myrtaceae)
Gardenia erythroclada (Rubiaceae)
Gardenia obtusifolia (Rubiaceae)
Gardenia philastrei (Rubiaceae) - thickets
Glochidion fagifolium (Euphorbiaceae) - savannas and thickets
Glochidion obliquum (Euphorbiaceae) - rocky streamsides
Gmelina hystrix (Verbenaceae)
Grewia asiatica (Tiliaceae)
Grewia paniculata (Tiliaceae) - thickets
Hymenodictyon excelsum (Rubiaceae) - transitions to savanna
Ixora cuneifolia (Rubiaceae) - transitional habitats to semi-evergreen forest
Lagerstroemia spp. (Lythraceae) - transitional habitats to semi-evergreen forest
Lannea wodier (Anacardiaceae) - open areas of savanna
Mangifera sp. (Anacardiaceae) - old termite mounds
Morinda citrifolia (Rubiaceae)
Paradina hirsuta (Rubiaceae)
Phyllanthus emblica (Euphorbiaceae) - open areas of savanna
Premna cambodiana (Verbenaceae)
Randia tomentosa (Rubiaceae)
Randia uliginosa (Rubiaceae)
Schrebera swietenoides (Oleaceae) - transitional habitats to semi-evergreen forest
Semecarpus reticulata (Anacardiaceae) - transitional habitats to semi-evergreen forest
Shorea roxburghii (Dipterocarpaceae) - transitional habitats to semi-evergreen forest
Solenospermum wallichii (Celastraceae)

Stereospermum chelonoides (Bignoniaceae)
Strychnos nux-blanda (Loganeaceae)
Symplocos spp. (Symplocaceae)
Tristania burmanica (Myrtaceae)
Vitex spp. (Verbenaceae) - transitional habitats to semi-evergreen forest
Viburnum punctatum (Caprifoliaceae) - rocky areas
Wendlandia cf. *glabrata* (Rubiaceae) - open thickets
Zizyphus rugosa (Rhamnaceae) - open areas of savanna

Deciduous dipterocarp forest may also occur on deeper soils away from the basalt substrates. These include relatively deep silty soils derived from schists and on granites. These soils often support taller tree growth, with *Dipterocarpus intricatus* reaching to 30 m in height. On the deep silty soils, woody legumes typically are less common and the grass understory less diverse that on the basaltic soils. *Arundinaria pusilla* is the dominant grass while *Pogonatherum crinitum*, absent from the basaltic soils, is common. Granitic soils of the Ea Hlieo basin between Dac Lac (Darlac) and Pleiku and areas to the east of the dalat Plateau support a deciduous dipterocarp forest dominated by *Dipterocarpus tuberculatus,* with scattered small stands of *Pinus merkusii* (see pine forests below).

6.1.4 Lowland Pine Woodlands

Lowland pine forests are common on thin, but well-drained basaltic soils under semi-humid rainfall regime, as well as under wetter conditions on both basalt and schist parent material in southern Vietnam. These open forests are dominated by *Pinus merkusii* (Pinaceae), with scattered shrubby associates and a grassy understory. This pine is a sun-loving species growing in open woodlands. In many respects, these pine forests represent an extension of deciduous dipterocarp forest, with the addition of *P. merkusii* as a dominant or co-dominant species. *Pinus merkusii* is a widespread species over a broad area of southeastern Asia. In Vietnam, it occurs from the northern Than Hoa Province south to at least Lam Dong Province (Santisuk 1997).

In the French literature, this community has been lumped with deciduous dipterocarp forest as *forêt claire* (Aubreville 1956), or separated and termed *pinede à Pinus merkusii* (Maurand 1954), *forêt claire de gymnospermes* (Vidal 1956-60), *pinede et forêt claire à Pinus merkusii* (Schmid 1962), and *forêt claire sèche tropophile de conifères* (Nhung 1982).

Dipterocarpus obtusifolius is the most frequent associate of *P. merkusii*, particularly in areas with a shallow impermeable hardpan. Other species of variable presence in the canopy of these woodlands in southern Vietnam include *Lithocarpus harmandii* (Fagaceae), *Michelia baillonii* (Magnoliaceae), *Mangifera* sp. (Anacardiaceae), and *Xantolis cambodiana* (Sapotaceae). Other smaller trees observed by Schmid (1974) in this community included *Lithocarpus dealbata* and *Quercus helferiana* (Fagaceae), *Crypteronia paniculata* (Crypteroniaceae), *Mitragyna hirsuta* (Rubiaceae), *Terminalia chebula* (Combretaceae), *Vaccinium chevalieri* (Ericaceae), and *Schima crenata* (Theaceae).

Maurand (1943) presented data on the population structure of a 15 ha area of *Pinus merkusii* woodland at Lang Hanh. The density of trees greater than 10 cm diameter was 95 ha^{-1}, with 45% of these being pines, 32% *Dipterocarpus obtusifolius*, and 16% Fagaceae. Two-thirds of these pines were 50 cm or greater in diameter, with the largest individuals exceeding 90 cm diameter.

Although *Pinus merkusii* is a lower elevation species and *P. kesiya* is a typically montane species, the elevational ranges of the two frequently overlap in southern Vietnam. *Pinus kesiya*, the more invasive of the two species, prefers more mesic conditions and deeper soils, while *P. merkusii* is less demanding of soil moisture availability, depth and nutrient availability. Thus, the two species often separate in their range of overlap more on the basis of edaphic conditions than on elevation alone.

A moderate richness of woody and semi-woody species is present in this community. Lianas and epiphytes also occur here but not in great numbers. They are associated primarily with with more closed canopy structure on deeper soils. The epiphytes include *Dischidia* (Asclepiadaceae), *Aeschynanthus* (Gesneriaceae), orchids and ferns.

The dominant grasses in the understory of this community in more humid environments include *Imperata cylindrica, Exotheca abyssinica, Polytoca heteroclita,* and *Hyparrhenia schmidiana*. Schmid (1974) lists *Kerriochloa siamensis* as the dominant grass in drier subhumid areas with this community.

6.1.5 Coastal Vegetation

The semi-arid coastal areas of southern Vietnam have been heavily impacted by human activities and greatly altered from their natural condition. These areas are the most arid in Vietnam because of the rainshadow effects of the plateaus of the southern Annamite region which restrict the flow of humid air in the early monsoon season. Mean annual rainfall is less than 1,500 mm in the coastal belt south of Nha Trang, and reaches below 800 m at Cape Padaran south of Phan Rang. Similar but less intense rain shadows impact interior valleys between the plateaus, as in the Song Ba valley and Cho Reo depression.

The coastal region around Nha Trang, Cam Ranh Bay and Phan Rang in southern Vietnam is formed as a succession of small alluvial plains to the east of the Annamite Range and separated by low hills of rhyolite or granite (Saurin 1935). These isolated coastal hills reach significant elevations as at Nui Cau Hin (973 m) south of Nha Trang, Nui Ong (1,040 m) between Phan Rang and Ba Ngoi, and Padaran below Cana (Schmid 1974). This area has been mapped as a portion of *southern Vietnam coastal forests* by Wikramanayake et al. (1997), but is heterogeneous in vegetation structure.

6.1.2.5 Coastal Scrub Communities

The first woody community encountered away from the beach in southern Vietnam is generally a thicket dominated by such species as *Scaevola koenigii* (Goodeniaceae), the poisonous *Cerbera manghas* (Apocynaceae), *Pandanus tectorius* (Pandanaceae), and *Cycas rumphii* (Cycadaceae). Bordering this thicket is an herbaceous band with a dominance of *Spinifex littoreus* (Poaceae), *Lepturus repens* (Poaceae), *Ipomaea biloba* (Convolvulaceae), and *Pentatrophis tectorius* (Asclepiadaceae).

A little further inland these species are replaced by a community with a distinctive assemblage of shrubby trees including (Schmid 1974):

Caesalpinia godefroyana (Fabaceae-Caesalpinoideae)
Clerodendron inerme (Verbenaceae)
Litchi longana (Sapotaceae)
Hiptage corymbifera (Malpighiaceae)
Markhamia stipulata var. *pierrei* (Bignoniaceae)
Pleiospermium littorale (Rutaceae)
Sindora siamensis var. *maritima* (Fabaceae-Caesalpinoideae)
Vitex trifolia (Verbenaceae)
Wedelia siamensis (Asteraceae)

Also abundant in this community are a variety of lianas, most notably:

Abrus precatorius (Fabaceae-Papilionoideae)
Canavallia obtusifolia (Fabaceae-Papilionoideae)
Capparis beneolens (Capparidaceae)
Dalbergia cf. *thorelii* (Fabaceae-Papilionoideae)

Areas with extensive coverage of unstabilized dunes support a distinctive community of shrubby trees with extensive root systems. On low dunes these species have a shrubby growth form. However, where a significant phreatophytic zone of freshwater develops at the base of these dunes, a true forest may develop with trees reaching up to 12 m in height. The dominant woody species in these stands are (Schmid 1974):

Albizia corniculata (Fabaceae-Mimosoideae)
Breynia baudouini (Euphorbiaceae)
Breynia coriacea (Euphorbiaceae)
Calopohyllum ceriferum (Guttiferae)
Canthium cochinchinensis (Rubiaceae)
Carissa cochinchinensis (Apocynaceae)
Connarus longipetalus (Connaraceae)
Decaspermum paniculatum (Myrtaceae)
Diospyros bangoensis (Ebenaceae)
Eugenia tinctoria (Myratceae)
Leucopogon sp. (Epacridaceae)
Manilkara hexandra (Sapotaceae)
Ochna pruinosa (Ochnaceae)
Ouratea striata (Ochnaceae)
Rhodamnia trinervia (Myrtaceae)
Vaccinium cf. *bracteatum* (Ericaceae)
Vatica mangachapoi ssp. *obtusifolia* (Dipterocarpaceae)
Xantolis maritima (Sapotaceae)

Moist depressions within these dunes are occupied by *Baeckia frutescens* (Myrtaceae), *Melaleuca leucadendron* (Myrtaceae), *Leptocarpus disjonctus* (Restionaceae) and by herbaceous wetlands dominated by grasses (*Panicum repens, Eremochloa ciliaris*), sedges (*Fuirena glomerata, Schoenus coelostachyus, Scleria tonkinensis*), and Xyridaceae (*Xyris complanata*).

6.1.5.2 Coastal Dune Forests

Extensive areas of coastal dunes formed of stabilized red sands form a characteristic component of this coastal region.around Cam Ranh Bay on granitic parent material. Two endemic species of Dipterocarpaceae, *Hopea cordata* and *Shorea falcata*, are known only from dune forests on these sands. These are two of only five endemic Dipterocarpaceae for all of Indochina, suggesting that many other endemic species may present in this habitat were it more carefully studied. These coastal forests have been described by Barry et al. (1960, 1961a,b) and Le Cong Kiet (1962). Behind these dunes, small brackish lakes frequently form and these may have mangrove species present (see below under mangrove forests). Behind these lakes and locally extending considerable distances inland are low plains of granite alluvium with skeletal soils. These habitats support low thickets of spiny shrub species or occasional open woodlands. Evergreen and semi-evergreen forest cover may be present on the coastal hills that reach higher elevations.

Another distinctive community forms on sandy terraces where the sand has been more or less stabilized and the phreatophytic fringe is not so deep. Such areas occur between Cam Ranh Bay and Nha Trang support a growth of shrubland or low forest cover. The dominant groups of woody species present are Annoncaceae (*Miliusa*), Moraceae (*Taxotrophis*), Euphorbiaceae (*Phyllanthus, Breynia, Sauropus, Fluggea*), Tiliaceae (*Grewia*), Fabaceae (*Derris, Dalbergia* lianas), Capparidaceae, Malpighiaceae (*Hiptage*), Rhamnaceae (*Zizyphus*), Ebenaceae (*Diospyros*), Oleaceae (*Jasminum*), Bignoniaceae (*Stereospermum annamense*), Anacardiaceae (*Lannea woodier*), and Chrysobalanaceae (*Parinari annamense*).

6.1.5.3 Coastal Slope Forests

A unique low forest or thicket community occurring on semi-arid slopes along the coast of southern Vietnam is notably rich in endemic species. Schmid (1974) described that this community was very degraded in the area of Phan Rang but better conserved in the sectors of Ba Ngoi and Nha Trang. The families of woody species of interest noted by Schmid were:

Annonaceae (*Rauwenhoffia, Popowia, Dasymaschalon, Cyathocalyx, Mitrephor*a)
Bixaceae (*Scolopia*)
Capparidaceae (*Capparis*)
Celastraceae (*Salacia, Siphonodon*)
Euphoprbiaceae (*Phyllanthus, Drypetes, Gelonium, Actephila, Nephrostylus, Dimorphocalyx, Poilaniella*)
Moraceae (*Taxotrophis, Phyllochlamys*)

Rutaceae (*Pleiospermum, Murraya, Atalantia*)

Schmid (1974) found an interesting group of species adapted to this arid habitat and growing over rocky terrain in this area. These species included *Cycas* cf. *pectinata* (Cycadaceae), *Dracaena cambodiana* (Agavaceae), succulent Crassulaceae (*Kalanchoe*), and xerophytic pteridophytes (*Cheilanthes, Notholaena, Selaginella*).

A brief structural description of coastal forests without species identifications along the Annamese lowlands of central Vietnam was published as a component of a study of pheasant conservation (Eames et al. 1994). Detailed descriptions and floristic data, however, only exist in the published literature for the southern coastal forests.

Forest structure further south in the Binh Chau - Phouc Buu Nature Reserve, southwest of Phan Thiet, has been described by Tam (1997). The low rolling hills of this reserve exhibit a diversity of dry forest communities in an area of 11,293 ha. Studies by FIPI in 1995 identified 661 species of vascular plants. Included are notable tree endemics including *Lithocarpus dinhensis* (Fagaceae) *Dalbergia bariensis* (Fabaceae-Papilionoideae), and the recently discovered *Dipterocarpus caudatus* (Dipterocarpaceae). The forest types identified by Tam (1997) were dominated by varying combinations of *Dipterocarpus caudatus, D. intricatus, Shorea siamensis* and *S. roxburghii*. Stand basal areas ranged from about 7-20 m^2 ha^{-1}.

6.2 Montane Forest Habitats

The humid and cool climatic conditions of mountain areas in Vietnam produce a relatively sharp change in vegetation structure from lowland forest communities to montane forest communities at an elevation of about 1,100-1,200 m in the south and 700-900 m in the north. This change is marked, as in Lao, by the rapid decline in the presence of tropical families such as the Dipterocarpaceae, Anacardiaceae, and Euphorbiaceae, and the increase in dominance of temperate families with relationships to the montane flora of southern China. These include, for example, a diverse assemblage of conifers, Fagaceae, Theaceae, and Magnoliaceae. Many Dipterocarpaceae drop out at elevations of 600-900 m, while the upper limit of this family occurs with *Dipterocarpus obtusifolius* which is common to elevations 1,100 m and rarely reaches to 1,300 m, *D. turbinatus* which extends up to 1,150 m, and *Hopea pierrei* which reaches 1,250 m. Similarly, the lower elevational limits of many characteristic montane tree species are at 900-1,200 m. Montane forests are generally lower in stature than lowland forest communities, and are characterized by a dense evergreen upper canopy. Lianas are much less abundant and diverse than in lowland evergreen forests, while epiphytes are particularly notable in their abundance and diversity.

Montane habitats in central and southern Vietnam typically have annual rainfall totals of 2,500 to more than 3,000 mm, and relatively short dry seasons. To the north, mean annual rainfall in montane habitats is lower at 1,500-2,500 mm and more seasonal because of lower moisture input from the northeast monsoon winds. The largest area of montane regions above 1,200 m elevation in southern Vietnam occurs on the Kontum Massif and Dalat Plateau, with a number of smaller areas scattered around the region of Blao. In central Vietnam there are few areas that reach above 1,000 m and thus montane habitats are much more restricted in distribution. In the north, however, there are

extensive areas of montane habitat. These areas occur in Nghe An, Son La, and Lai Chau Provinces along the Lao border, and in the latter, Lao Cai, Yen Bai, Ha Giang and Cao Bang Provinces across northern Vietnam.

Montane habitats in Vietnam include a range of intergrading communities dominated by evergreen broad-leaved trees, conifers and mixed conifer/broad-leaved forest. Local area of montane graslands and shrublands are also present. Factors which lead to dominance of montane forests by either broad-leaved trees or conifers have not been investigated. The high elevations present in northern Vietnam and the connection of this area with mountains in southern China bring a temperate floristic element into these montane forests that does not exist elsewhere in Southeast Asia. The phytogeography of Fagacaeae in Vietnam, and Lao illustrate these patterns of floristic relationship (see discussion of floristic patterns for Indochina).

The high diversity of conifers in Vietnam is a floristic feature distinct from other parts of mainland Southeast Asia. Less humid montane habitats up to 2,000 m or more often support open forests of *Keteleeria evelyiana* and *Pinus kesiya,* two montane conifers widespread throughout Vietnam. *Calocedrus macrolepis* is less common in these habitats. The montane Dalat Plateau of southern Vietnam, as described below, is the locality for two local endemic species of pine, *P. krempfii* and *P. dalatensis*. Two relatively rare Chinese pines, *P. kwangtungensis* and *P. wangii,* have have been found growing at a few scattered sites in nothern Vietnam and the central Annamite Range. None of the seven species of Taxaceae and Cephalotaxaceae that are known to occur in montane habitats of Vietnam have been reported for Lao and Cambodia, but more extensive field studies in eastern Lao may find some of these to be present. The majority of the Taxaceae and Cephalotaxaceae in Vietnam are Chinese species at their southern limit of distribution, although one species is endemic to central Vietnam.

Humid montane forests at about 1200-1,800 m throughout Vietnam may support a rich forest dominated by *Fokienia hodginsii*, *Podocarpus imbricatus* and *Cunninghamia lanceolata*. *Fokienia* can reach massive sizes of 40-50 m in height and 1.5 m in diameter in this community. These forests may also have *Calocedrus macrolepis* as an important species at elevations up to 1,500 m.

A conifer community of distinctly temperate affinites enters northern Vietnam at higher elevations of 2,400-2,900 m on the Fan Si Pan massif, with a dominance of *Tsuga dumosa* and *Abies delavayi* var. *nukiangensis*. No quantitative descriptions of these higher elevation conifer forests in Vietnam have been published, but floristic studies have shown that the high montane area the Fan Si Pan massif is significant because of a large number of endemic species (Nguyen Nghai Thin and Harder 1996, Nguyen Nghai Thin and Nguyen Thi Thoi 1998), as described below.

6.2.1 Montane Pine Forests

Pinus kesiya extends over a fairly broad range of montane areas of the Dalat Plateau and other uplands in southern Vietnam at elevations up to 1,800 m (Champsoloix 1958, Eames and Cu 1994). These are less mesic habitats than those of the high elevation humid montane forests where more diverse conifer forests are present. *Pinus kesiya* has broad environmental tolerances and thus the influence of macroclimate on its pattern of distribution is not entirely clear. It reaches elevations as low as 800 m at the margin of

the semi-arid zone, but only rarely occurs together with *P. merkusii*. Human impacts on montane landscapes have almost certainly promoted the expansion of the range of *P. kesiya* at the expense of what were once montane evergreen forests.

The open canopy of montane pine forests is strongly dominated by *Pinus kesiya*. *Keteleeria evelyniana* may be present in denser gallery forests along the margins of the pine stands, but seldom as an associate of the pure pine formations. Typical stands have been reported to have no more than 100 pine individuals per hectare, with mature trees reaching 20-30 m in height and 70-100 cm in diameter. A lower open stratum of small trees and shrubs is present, with relatively low diversity. Virtually all of these species are evergreen, and many are from groups such as the Ericaceae and Proteaceae which are known to be commonly adapted to low nutrient conditions.

Fire is a common factor in these forests. Seedlings less than five years in age are usually killed by fire, while saplings up to 12 years in age are damaged but survive fire. Mature pines appear to benefit from fires that eliminate competing species and reduce the impact of certain parasites.

The subcanopy woody stratum includes the following as common species (Schmid 1974):

Albizia attopeuensis (Fabaceae-Mimosoideae)
Archidendron clypearia (Fabaceae-Mimosoideae) - shrub thickets
Archidendron lucidum (Fabaceae-Mimosoideae)
Adinandra sp. (Theaceae)
Agapetes sp. (Ericaceae)
Anneslea sp. (Theaceae)
Craibiodendron stellatum (Ericaceae)
Eurya sp. (Theaceae)
Gardenia sootepensis (Rubiaceae)
Helicia nilagirica (Proteaceae)
Hibiscus squamosus (Malvaceae)
Leucomeris decora (Asteraceae) - shrub thickets
Lithocarpus dealbata (Fagaceae)
Lithocarpus pycnostachys (Fagaceae)
Myrica sapida var. *chevalieri* (Myricaceae)
Phyllanthus emblica (Euphorbiaceae)
Quercus helferiana (Fagaceae)
Quercus lanata (Fagaceae)
Rhamnus crenatus (Rhamnaceae)
Styrax benzoin (Styracaceae)
Ternstroemia sp. (Theaceae)
Tristania burmannica (Myrtaceae)

Epiphytes are abundant and diverse in these montane pine forests. Schmid (1974) mentions that abou 50 species of orchids are present with the genera best represented being *Dendrobium, Bulbophyllum, Eria,* and *Coelogyne*). Common epiphytic ferns represent genera such as *Humata, Lepisorus, Hymenolepis, Loxogramma, Phymatodes, Aglaomorpha, Drynaria* and *Polypodium*.

6.2.2 Humid Montane Forest in the Northern Annamite Range

Humid lower montane forests in the Pu Mat and Bu Huong Reserves in the northern Annamite Range have exhibit high levels of forest cover and basal area. The montane forest at Pu Mat consists of a two-tiered forest canopy reaching to about 15-25 m in height. This forest community occurs in the reserve at elevations of 800-1,200 m. The dominant floristic elements in this forest are the Myrtaceae with 19% of the basal area, the Fagaceae with 18% of the basal area and dominance in the upper canopy, the Elaeocarpaceae with 11% of the basal area, and the Lauraceae with 7% of the basal area. Also notable in this forest community is the presence of species of Podocarpaceae. The stand basal area was measured as 30.0 m^2 ha^{-1}. The most important tree species are:

Castanopsis hystrix (Fagaceae) - upper canopy dominant
Cinnamomum balansae (Lauraceae)
Cinnamomum zeylandium (Lauraceae)
Cryptocarya impressa (Lauraceae)
Elaeocarpus apiculatus (Elaeocarpaceae)
Elaeocarpus dubius (Elaeocarpaceae)
Elaeocarpus griffithii (Elaeocarpaceae)
Elaeocarpus hainanensis (Elaeocarpaceae)
Elaeocarpus harmandii (Elaeocarpaceae)
Elaeocarpus sylvestris (Elaeocarpaceae)
Lithocarpus pseudosundaicus (Fagaceae) - upper canopy dominant
Madhuca pasquieri (Sapotaceae)
Quercus bambusifolia (Fagaceae)
Quercus sp. (Fagaceae) - upper canopy dominant
Syzygium cuminii (Myrtaceae)
Syzygium hancei (Myrtaceae)
Syzygium latilimbum (Myrtaceae)
Syzygium sp. (Myrtaceae)

Conifers play an increasing role in the canopy of humid montane forests on the higher peaks of the Pu Mat Reserve above 1,200 m elevation. These include two species of *Podocarpus* (*P. imbricatus* and an unidentified species) and *Fokienia hodgensii* (Cupressaceae). Much of the *Fokienia*, however, has been felled for its valuable wood. At this elevation, lowland floristic elements such as *Hopea* (Dipterocarpaceae) and *Madhuca pasquieri* (Sapotaceae) are no longer present.

The humid montane forest community at Bu Huong is reported to be taller than at Pu Mat, reaching to 25-35 m height over an elevational range of 950-1,580 m. Species of the Fagaceae, Juglandaceae and Lauraceae provided much of the canopy cover. The dominant canopy species for this community include:

Castanopsis hystrix (Fagaceae)
Castanopsis indica (Fagaceae)
Cinnamomum obtusifolium (Lauraceae)
Cryptocarya impressa (Lauraceae)

Cryptocarya lenticellata (Lauraceae)
Cylindrokelupha balansae (Fabaceae-Papilionoideae)
Engelhardtia chrysolepis (Juglandaceae)
Fokienia hodginsii (Cupressaceae) - higher elevations
Gironniera subequalis (Ulmaceae)
Lindera sp. (Lauraceae)
Lithocarpus cornea (Fagaceae)
Litsea baviensis (Lauraceae)
Machilus thunbergii (Lauraceae)
Michelia balansae (Magnoliaceae)
Michelia cavaleriei (Magnoliaceae)
Podocarpus imbricatus (Podocarpaceae) - higher elevations
Podocarpus neriifolius (Podocarpaceae) - higher elevations
Quercus platycalyx (Fagaceae)

The dense canopy structure of undisturbed humid montane forest allows little light to penentrate to ground level, and thus understory vegetation is relatively sparse. However, understory in relatively open areas of forest often support thick stands of woody bamboo (*Chimonobambusa* and *Dendrocalamus*). It has been suggested that typhoons which regularly reach this area provide a natural disturbance regime that continually opens the canopy and promotes bamboo growth.

6.2.3 Montane Forests on Rhyolite Substrates in the Southern Annamite Range

Montane forests on volcanic rhyolite substrates in the southern Annamites form dense evergreen forests with an upper canopy reaching to about 30 m in height. Tree growth forms are less monopodial (more branched) compared to lowland forests, and few trunks reach anywhere near the large diameters present in lowland areas. Canopy heights decline with increasing elevation and with decreasing soil depth.

The family best represented in the upper canopy of these habitats is the Fagaceae, with important contributions as well from the Magnoliaceae, Aceraceae, Podocarpaceae, Lauraceae, and Theaceae. Among the Fagaceae, dominance of individual species seems to vary greatly between montane areas. The diversity of conifer species which may occur in humid montane forests, including five genera (*Podocarpus* sensu latu., *Calocedrus, Fokienia, Cephalotaxus* and *Taxus*) is far greater than is present in montane forests of northern Thailand. The primary canopy tree species observed by Schmid (1974) in this montane habitat were:

Acer labellatum (Aceraceae)
Acer oblongum (Aceraceae)
Calocedrus macrolepis (Cupressaceae)
Calophyllum thorelii (Guttiferae)
Canarium sp. (Burseraceae) - 1,300-1,500 m
Castanopsis chevalieri (Fagaceae)
Castanopsis dongchoensis (Fagaceae)
Castanopsis ferox var. *longispinna* (Fagaceae)

Castanopsis indica (Fagaceae)
Cephalotaxus mannii (Cephalotaxaceae)
Cinnamomum burmannii (Lauraceae)
Dipterocarpus hasseltii (Dipterocarpaceae) - up to about 1500 m
Elaeocarpus spp. (Elaeocarpaceae)
Engelhardtia sp. (Juglandaceae)
Eurya sp. (Theaceae)
Ficus spp. (Moraceae) - up to about 1500 m
Fokienia hodginsii (Cupressaceae)
Garcinia spp. (Guttiferae)
Gordonia sp. (Theaceae)
Illicium griffithii (Magnoliaceae)
Lepisanthes langbianensis (Sapindaceae)
Lithocarpus bacgiangensis (Fagaceae)
Lithocarpus megastachya (Fagaceae)
Lithocarpus spicata var. *poilaniana* (Fagaceae)
Lithocarpus sylvicolarum (Fagaceae)
Lithocarpus cf. *tenuinervis* (Fagaceae)
Lithocarpus trachycarpa (Fagaceae)
Lithocarpus truncata (Fagaceae)
Macropanax concinnum (Araliaceae)
Michelia constricta (Magnoliaceae)
Neolitsea poilanei (Lauraceae)
Pirus doumeri (Rosaceae)
Podocarpus (Dacrycarpus) imbricatus (Podocarpaceae)
Podocarpus neriifolius (Podocarpaceae)
Podocarpus wallichianus (Podocarpaceae)
Pygeum spp. (Rosaceae)
Pyrenaria sp. (Theaceae)
Quercus braianensis (Fagaceae)
Quercus cf. *chapensis* (Fagaceae)
Quercus erioclada (Fagaceae)
Quercus cf. *langbianensis* (Fagaceae)
Quercus cf. *quangtriensis* (Fagaceae)
Quercus cf. *schottkyana* (Fagaceae)
Rhodoleia sp. (Hamamelidaceae)
Schima crenata (Theaceae)
Talauma hodgsonii (Magnoliaceae)
Taxus wallichiana (Taxaceae)
Thea sp. (Theaceae)
Xerospermum donnaiensis (Sapindaceae)

The understory stratum of woody and semi-woody species is dominated by Acanthaceae, Rubiaceae, and Urticaceae, with tree ferns (*Cyathea* spp. and *Ctenitopsis austro-sinensis*) also important. Individuals of *Cyathea* may reach as much as 10 m in height. Dense stands of Acanthaceae, particularly *Strobilanthes saltiensis*, may form an

almost continuous understory cover at 1.2-1.5 m height. *Medinilla coerulescens* (Melastomataceae) is very common as well in the understory.

Epiphytes form a notable part of the biodiversity of these montane forests. Particularly diverse are the orchids in the upper canopy and ferns in the middle and lower canopy. In addition to these more characteristic groups, epiphytic species occur in other families that are more typically terrestrial. These include the Ericaceae (*Agapetes* spp.), Rubiaceae (the strangler *Neohymenopogon parasiticus*), Rosaceae (the strangler *Pirus granulosa*), and Zingiberaceae (*Hedychium villosum*). Another interesting life-form in these montane forests is the presence of a number of uncommon achlorophyllous root parasites. The most widespread of these are *Balanophora pierrei* (Balanophoraceae) and *Sapria himalayana* (Rafflesiaceae). The latter is largely restricted to growing on roots of lianas in the Ampelidaceae.

6.2.3 Montane Forests on Granitic Substrates in the Southern Annamite Range

Montane forests growing on granitic substrates in the mountains of southern Vietnam do not differ dramatically in structure from those described above for the areas with volcanic rhyolite substrates. The differences are in the less dense and continuous canopy cover and more open understory on the granitic areas. Commonly the Fagaceae plays a less dominant role in the canopy on the granites, while the conifers take on a stronger role.

Montane evergreen forests of the Dalat Plateau are dominated by Fagaceae and Lauraceae above the less mesic forests of *Pinus kesiya*. These are moderately low forests with semi-closed canopies reaching about 20 m in height. Observations of this forest community on Chu Yang Sin from elevation of 1,000 m to the upper summit at 2,442 m documented the strong dominance and richness of Fagaceae and Lauraceae (Eames and Cu 1994). Including the upper dipterocarp zone of evergreen forest below 1,000 m, they reported a diverse flora of 694 species of vascular plants along the northern slopes of Chu Yang Sin. The montane zone included three genera and 13 species of Fagaceae:

Castanopsis chevaliei
Castanopsis echinocarpa
Castanopsis indica
Castanopsis wilsoni
Lithocarpus agaregalum
Lithocarpus annamicorum
Lithocarpus auriculata
Lithocarpus echinophorus
Lithocarpus harmandii
Lithocarpus xylocarpus
Quercus angustinii
Quercus dongnaiensis
Quercus langbianensis

There were additionally seven genera and 18 species of Lauraceae:

Actinodaphne pilosa
Cinnamonum burmanii
Cinnamonum cassia
Cinnamonum iners
Cinnamonum litseafolium
Cinnamonum obtusifolium
Cinnamonum validinerve
Cinnamonum zeylandicum
Lindera chenii
Litsea balansae
Litsea cubeba
Litsea glutinosa
Litsea polyantha
Litsea thorelii
Machilus chinensis
Machilus odoratissimus
Phoebe cuneata
Neolitsea zeylandica

A number of species of Lauraceae (*Cinnamomum* spp., *Actinodaphne cochinchinensis, Notaphoebe* sp., *Neolitsea zeylanica*) and Magnoliaceae (*Magnolia* sp., *Illicium griffithii*) are generally more abundant on the granites than on the rhyolites. The more open structure of these montane forests on the granites leads to the presence of a greater diversity of light-demanding species in the understory compared to the shadier montane forests on rhyolites. Among the epiphytes, the orchids remain diverse and abundant but the ferns are less important on the granites.

Mixed with these hardwoods were a diverse assemblage of conifers, including four large Podocarpaceae (*Dacrydium elatum, Podocarpus imbricatus, Podocarpus neriifolius,* and *Podcarpus wallichianus*) and understory *Cephalotaxus mannii* (Cephalotaxaceae) and *Taxus wallichiana* (Taxaceae).

Another group of conifers may reach very large size in humid areas with shorter dry seasons and rich soil development, as with *Fokienia hodginsii* which grows to 45 m in height and 1.5 m in diameter. Associated with *Fokienia* in the Dalat region are two local endemic species of pines, *Pinus dalatensis* and *P. krempfii* (Dinh and Chinh n.d.) The latter species was once placed into a monotypic genus *Ducampopinus* on the basis of its unique flattened needles. Virtually nothing is known about the ecology of these species. *Pinus dalatensis* is a five-needled pine reaching 40 m in height and nearly 1 m in diameter. It grows with other conifers in montane forests at 1500-2400 m elevation in four provinces of central and southern Vietnam, and has recently been found in Lao. *Pinus krempfii* is a two-needled pine reaching 15-30 m in height and 2 m in diameter, and grows in humid montane forests at 1,200-2,000 m elevation in Khanh Hoa and Lam Dong Provinces in southern Vietnam. These three large conifers are generally emergents above a matrix of forest dominated by Fagaceae, Lauraceae, and Magnoliaceae.

6.2.4 Mountain Valleys in the Southern Annamite Range

The narrow valleys of the montane region of southern Vietnam provide shady habitats with good water availability and relatively deep soils from erosional deposition. Conifers form the dominant element of forest communities in these valleys, with the Fagaceae, Magnoliaceae and Lauraceae as important co-dominants. In the region of Dalat, *Podocarpus (Dacrycarpus) imbricatus* is the dominant conifer species, with a series of associates including *P. (Nageia) wallichianus* (deep soils), *Calocedrus macrolepis*, and *Keteleeria evelyniana* (shallow soils with good light availability). *Fokienia* and some of the Lauraceae may reach heights of 40 m in this habitat. A number of temperate genera are typical of the middle tree canopy of these forests. Common subcanopy genera reported by Schmid (1974) include *Taxus* (Taxaceae), *Acer* (Aceraceae), *Carpinus* (Ulmaceae), *Pirus* and *Pygeum* (Rosaceae), *Sloanea* (Elaeocarpaceae), *Ardisia* (Myrsinaceae), *Fraxinus* (Oleaceae), *Ostodes* (Euphorbiaceae), and *Macropanax* (Araliaceae).

Marshy soils along streams, which coulkd be considered an azonal habitat but are considered here, are characterized by another group of woody species. Among these are *Salix thorelii* and *S. tetrasperma* (Salicaceae), *Reevesia gagnepainiana* (Sterculiaceae), *Nyssa javanica* (Nyssaceae), *Eugenia* spp. (Myrtaceae), *Elaeocarpus* spp. (Elaeocarpaceae), *Pandanus* cf. *capusii* (Pandanaceae) and tree ferns (*Cyathea* spp.). Still another assemblage of woody species forms a riparian gallery forest on better-drained soils. These species include *Cinnamomum* sp. (Lauraceae), *Castanopsis guinieri* (Fagaceae), *Thea* sp. (Theaceae), *Ficus pyrifolia* (Moraceae), *Lasianthus* spp. (Rubiaceae), and *Caryota sympetala* and *Pinanga banaensis* (Arecaceae). Large understory herbs are also typical of these humid riparian habitats - ferns and tree ferns (*Cyathea, Marattia, Angipteris, Cibotium, Rumohra, Polystichum, Cyclosorus*), *Chloranthus* (Chloranthaceae), *Begonia* (Begoniaceae), *Impatiens* (Balsamiaceae), *Musa* (Musaceae), and *Curculigo* (Liliaceae). Soils kept constantly wet by mists along streams often support diverse assemblages of terrestrial orchids and ferns, along with *Impatiens* and Araliaceae. *Acorus gramineus* (Araceae) and the fern *Osmunda vachelii* (Osmundaceae) are common in the streams themselves.

6.2.5 Montane Cloud Forests in the Southern Annamite Range

The highest elevations and those slopes most exposed to humid winds in the montane zone are frequently bathed in moist clouds. The abundant dew and fog in these areas compensate for the lack of rainfall in the short dry season, producing lush conditions of mossy forest. Soils here are shallow, but rich in organic matter and highly acid. Much of this zone lies at 1,400-1,800 m elevation. The dominant elements of the relatively low forest cover are conifers (*Fokienia hodginsii, Podocarpus* spp.), Fagaceae (*Quercus* spp., *Lithocarpus* spp.), and Theaceae (*Gordonia, Pyrenaria, Ternstroemia*) which give way to increasing dominance by Ericaceae. On upper montane areas of Chu Yang Sin on the Dalat Plateau, the ericaceous forest zone averages about 10 m in height with a mean canopy cover of just above 75% (Eames and Cu 1994). The domonant species of Ericaceae here are:

Lyonia annamense
Lyonia ovalifolia
Rhododendron fleuryi

Rhododendron langbianense
Vaccinium chevalieri
Vaccinium greenwayae
Vaccinium harmandianum

The epiphyte diversity and biomass here is dominated by mosses and lichens, but with dwarf orchids and ferns also diverse and numerous. The latter include a diversity of Hymenophyllaceae, *Vittaria, Calymnodon* and *Ctenopteris*. Many of the tree trunks and branches support a continuous cover of epiphytes.

The skeletal soils that occur along ridges and near mountain summits at higher elevations support distinctive communites of low woody growth 3-5 m in height. Among many temperate floristic elements that occur in these habitats, the Ericaceae are particularly notable. Representatives of this family include *Rhododendron excelsum, R. chevalieri. R. fleuryi, R. triumphans, Vaccinium dunalianum, V. viscifolium, V. yersinii*, and *Agapetes* spp.

6.2.6 Broadleaf Evergreen Forest in Northern Vietnam

Broadleaf evergreen forest once covered much of the area of northern Vietnam. The lower elevation broadleaf forests up to 600-800 m elevation appear to represent a transition from wet evergreen lowland forest to montane forests. This transition zone contails clear elements of wet evergreen forests to the south, but also subtropical Chinese elements from the north. Above this zone at elevations of 800-2,000 m, a clear montane evergreen forest takes over with low temperature conditions eliminating most of the tropical lowland forest elements. Little area of these broad leaf evergreen forests remain intact today.

Qualitative descriptions forest have been made for small stands of relatively undisturbed lowland forest growing on limestones in the Na Hang Nature Reserve in Tuyen Quang Province north of Hanoi. The forest canopies here occasionally rose to 30-35 m height, but more commonly reached only 15-20 m. There were few emergent trees in most stands, although exceptions to this pattern suggest past cutting of larger trees. More generally, there was a relatively continuous upper canopy of variable composition. The important canopy tree species recorded in a series of sample plots at 500-695 m elevation included:

Aglaia gigantea (Meliaceae)
Aglaia aff. *per-viridis* (Meliaceae)
Burretiodenderon hsienmu (Tiliaceae)
Caryodaphnopsis tonkinensis (Lauraceae)
Castanopsis indica (Fagaceae)
Chisocheton globulus (Meliaceae)
Choerospondias axillaris (Anacardiaceae)
Diospyros mun (Ebenaceae)
Diospyros pilosella (Ebenaceae)
Garcinia fragraeoides (Guttiferae)
Lithocarpus bacgiangensis (Fagaceae)

Lithocarpus licentii (Fagaceae)
Madhuca pasqueri (Sapotaceae)
Paralbizzia lucida (Fabaceae-Mimosoideae)
Phoebe cuneata (Lauraceae)
Phoebe poilanei (Lauraceae)
Pterospermum diversifolium (Sterculiaceae)
Reheodendron macrocarpum (Styracaceae)
Streblus tonkinensis (Moraceae) - up to 80% of canopy trees in one stand
Symingtonia tonkinensis (Hamamelidaceae)

The density of trees in these plots ranged from 644-1,300 trees over 4.5 m in height ha^{-1}, and the basal area ranged from 26.8-75.0 m^2 ha^{-1}.

The floristic structure of the Na Hang Reserve is rich with more than 900 species recorded. Many species show strong affinities with the flora of southern China. The large canopy tree *Burretiodenderon hsienmu* (Tiliaceae), endemic to northern Vietnam and southern China, illustrates this biogeographic relationship.

Nguyen Nghai Thin and Nguyen Thi Thin (1998) described that primary stands of montane broadleaf evergreen forest can only be found in scattered isolated and inaccessible valleys and on steep slopes of the area of Fan Si Pan in northeastern Vietnam. They mention that characteristic families for the dominant forest trees are the Betulaceae, Fagaceae, Hamamelidaceae, Lauraceae, Magnoliaceae, Sapotaceae, Elaeocarpaceae, and Theaceae. These are all familes characteristic of montane evergreen forests to the south, as well as to the north into China. In some areas of the Fan Si Pan massif, large canopy trees of 1-2 m diameter have been allowed to remain as shade trees for ginger cultivation (Nguyen Nghia and Nguyen Thi Thoi 1998). These include *Eberhardtia aurita* (Sapotaceae), *Vitex peduncularis* (Verbenaceae), *Lithocarpus* (Fagaceae), *Cryptocarya* (Lauraceae), and *Mangleitia* (Magnoliaceae).

The montane broadleaf evergreen forests of northern Vietnam show a number of floristic elements indicating that this is a relictual Tertiary flora. The floristic relationships of the flora of this habitat on the Fan Si Pan massif have been described in considerable detail by Nguyen Nghia and Nguyen Thi Thoi (1998). The subtropical elements of this flora are notable in the following families and genera:

Cornaceae - *Cornus*
Hamamelidaceae - *Exbucklandia, Rhodoleia*
Hydrangeaceae -*Hydrangea*
Loganiaceae - *Fagraea*
Magnoliaceae - *Liriodendron, Magnolia, Manglietia*
Melastomataceae - *Allomorpha, Anerincleistus, Bredia, Fordiophyton, Oxyspora, Plagiopetalum, Sarcopyramis*
Myrsinaceae - *Embelia*
Polygonaceae - *Polygonum*
Ranunculaceae - *Anemone*
Rosaceae - *Potentilla, Sorbus*
Schisandraceae - *Kadsura, Schisandra*
Styracaceae - *Huodendron, Rehderodendron*

Theaceae - *Adinandra, Anneslea, Gordonia, Pyrenaria*
Violaceae - *Viola*

Much of the former area of broadleaf evergreen forest in northern Vietnam has been converted to grasslands and/or savannas under the widespread heavy impact of human over-exploitation and swidden agriculture. The structure of these secondary communities has been described in some detail for the Fan Si Pan massif by Nguyen Nghia and Nguyen Thi Thoi (1998). They characterize these as submontane subtropical savanna with non-gaminoid growth forms and submontane subtropical savanna with graminoid growth forms. The former type, with a good representation of shrub cover, is considered to be relatively easy to restore to forest habitat if it is well protected.

6.2.7 Temperate High Montane Forest in Northern Vietnam

Elevations above about 2,000 m in the Fan Si Pan massif of northern Vietnam support a distinct hemlock-fir forest unlike that present anywhere else in Southeast Asia. This forest habitat characterized by the dominance of *Tsuga dumosa* and *Abies delavayi* var. *nukiangensis* represents the southern biogeographic limit of a conifer forest community more characteristic of temperate China. This tall forest is found on both steep slopes and valleys at elevations up to 2,800 m. *Tsuga dumosa* may reach 50 m in height and *Abies delavayi* var. *nukiangensis* is 30-40 m in height (Hiep and Vidal 1996). Associated with the hemlock and fir are a moderate diversity of broadleaf trees, with the most species belonging to the Aceraceae, Hippocastanaceae, Fagaceae, Magnoliaceae, Lauraceae, Cupressaceae, Podocarpaceae, and Taxaceae. The monotyptic Rhoipteleaceae is also found in this habitat. Dense forests on rocky ridges have a dominance of Fagaceae, Lauraceae, Theaceae, Rosaceae, and Ericaceae. The great majority of species associated with this hemlock-fir forest have strong temperate rather than tropical forest affinities. Vascular plant families and genera with such affinities, in addition to *Tsuga* and *Abies*, include the following (Nguyen Nghia and Nguyen Thi Thoi 1998):

Araliaceae - *Panax*
Betulaceae - *Alnus, Betula*
Ericaceae - *Enkyanthus, Leucothoe, Pieris, Rhododendron, Vaccinium*
Fagaceae - *Castanea, Fagus,* deciduous *Quercus*
Gentianaceae - *Gentiana*
Guttiferae - *Hypericum*
Hippocastanaceae - *Aesculus*
Juglandaceae - *Juglans, Platycarya*
Ranunculaceae - *Coptis, Ranunculus*
Salicaceae - *Salix*
Trilliaceae - *Paris*
Ulmaceae - *Celtis, Ulmus*

Even at these high elevations, the great majority of the forest cover has been removed by human activities. In its place is a mix of shrub savannas and cold montane grasslands.

The floristic composition of these secondary communities has been described by Nguyen Nghia and Nguyen Thi Thoi (1998).

6.3 Azonal Habitats

Azonal habitats are those such as wetlands and areas with unusual edaphic conditions producing conditions of water availaibility and/or soil nutrient availability that differ greatly from the selective factors that would be predicted from the broad climatic regime.

6.3.1 Swamp Forests

Freshwater swamp forests and swamp prairies occupy areas where soils are permanently waterlogged. Such forests were once extensive in the Mekong delta region of southern Vietnam, but have been heavily impacted by a variety of human activites. These swamp forests have not been adequately characterized as to their structure and floristics. They are likely to have a close floristic composition and structure to similar swamp forests of Cambodia. Dry climatic conditions or drainage of these swamp forests leads to a high potential flammability of soil organic material.

6.3.1.1 *Melaleuca* Swamps of the Mekong Delta Region

Paperbark swamps dominated by *Melaleuca leucodendron* (Myrtaceae) once covered large areas of the Mekong Delta region with acid sulphate soils sunjected to seasonal inundation. Today the area of Melaleuca forests has been greatly diminished, although successful reforestation efforts have occurred. The largest remaining stands of Melaleuca forest occur on peat soils of the U Minh area of Minh Hai Province and on the acidic soils of the Plain of Reeds and Ha Tien plain (Kien Giang Province).

Paperbark swamps are low in plant diversity but have a great significance in maintaining natural ecosystem function. These swamps reduce water flow in the wet season and thus minimize flooding, store freshwater water, reduce soil acidification promote biodiversity of many aquatic organisms, anmd provide a sustainable source of wood for construction and fuel.

6.3.1.2 Lowland Swamp Forests

Large areas of swamp forest are present in poorly-drained landscapes of the Haut Chhlong and Blao regions where the water table reaches to the surface. These soils are saturated, with an upper horizon very rich in organic matter. Three formations of swamp forest are present (Schmid 1974). The most widespread of these occurs at an elevation of 600-900 m and is characterized by a dominance of *Livistona cochinchinensis* (Arecaceae). This palm reaches up to 30 m in height. Many associated dicot canopy species have stilt root and/or pneumatophores. These include species of *Eugenia* (Myrtaceae), *Elaeocarpus* (Elaeocarpaceae) and *Calophyllum* (Guttiferae).

A second form of swamp forest is characterized by a complete canopy dominance by *Podocarpus imbricatus* (Podocarpaceae). Associated with this species in a middle strata

10-15 m in height are *Podocarpus neriifolius*, *Elaeocarpus littoralis* (Elaeocarpaceae), *Ficus villosa* (Moraceae), *Calophyllum spectabile* (Guttiferae), and *Dysoxylum juglans* and *D. procerum* (Meliaceae). Arborescent ferns (*Cyathea* - Cyantheaceae) are a notable component of this community. Epiphytes, particularly orchids and ferns, are common.

The third swamp forest association in the humid zone of southern Vietnam is a mixed, broad-leaved dicot community. The dominant tree species observed by Schmid (1974) were *Elaeocarpus littoralis* (Elaeocarpaceae), *Eugenia operculata* (Myrtaceae), a *Quercus* sp. (Fagaceae), and an unidentified Rubiaceae (*Anthocephalus* ?). Palms (*Areca, Pinanga*) and arborescent ferns (*Cyathea*) are characteristic of the understory.

Swamp savannas and prairies are present in alluvial terrain where soils remain saturated for a major part of the year. Tall grasses such as *Phragmites karka*, *Saccharum arundinaceum*, and *Coix gigantea* generally dominate relatively fertile alluvial clay sediments. Less fertile soils are typically characterized by a diverse assemblage of Poaceae and Cyperaceae, as well as other herbaceous species.

Swamp forests cover a relatively small area of basaltic substrates in semi-humid climatic areas of the Dac Lac (Darlac) region. The most important floristic elements of woody species in these swamp forests come from the Elaeocarpaceae, Myrtaceae and Arecaceae. Schmid (1974) mentions the occurrence of *Glyptostrobus pensilis* (Taxodiaceae), a rare species in Vietnam, growing in a swamp forest at 700 m elevation near Ban Me Thuot. Despite the relatively dry climatic regime in the Dac Lac (Darlac) area, swamp forests support a group of relatively mesophytic semi-epiphytic species. These include ferns (*Stenochlaena palustris*, *Nephrolepis* cf. *acuta*) and Araceae (*Epipenum giganteum*).

The following are important swamp forest trees and shrubs on the basaltic substrates of the lower plateaus:

Caryota sp. (Arecaceae)
Elaeocarpus sp. (Elaeocarpaceae)
Eugenia formosa (Myrtaceae)
Eugenia jambolana (Myrtaceae)
Eugenia operculata (Myrtaceae)
Eugenia resinosa (Myrtaceae)
Ficus spp. (Moraceae)
Livistona cochinchinensis (Arecaceae)
Michelia champaca (Magnoliaceae)
Pandanus capusii (Pandanaceae)
Sterculia sp. (Sterculiaceae)
Viburnum odoratissimum (Caprifoliaceae)

Swamp prairies often cover skeletal soils that remain inundated through the majority of the year. These prairies have a rich flora of herbaceous species. The families best represented are the Poaceae, Cyperaceae, Scrophulariaceae, Acanthaceae, and Eriocaulonaceae. Schmid (1974) provides a list of important species present in these habitats.

6.3.2 Montane Swamp Communities

Montane swamp thickets are present in poorly drained areas of the Dalat region at about 1,500 m elevation. Schmid (1974) suggests that these formations are due in large part to past human impacts in this region. Commonly dominating these thickets are species of *Elaeocarpus* (Elaeocarpaceae), *Maesa* (Myrsinaceae), *Aralia* (Araliaceae), *Glochidion* (Euphorbiaceae), and *Cyathea* (Cyathaceae).

The Dalat region also has herbaceous wetlands at simlar elevations. Wetlands saturated with moisture throughout the year and with a high accumulation of soil organic matter support a relatively diverse assemblage of species, with ferns, Poaceae, Cyperaceae, Juncaceae, Xyridaceae, and Orchidaceae as important components. Wetlands less humid and lower in organic matter are generally less diverse, and are dominated by Poaceae and Cyperaceae.

6.3.2 Mangrove Forests

Mangroves once covered an area of about 4,000 km^2 in Vietnam (Spalding et al. 1997). These mangroves were distributed broadly with the largest area of 1,500 km^2 around Camou Point at the southern tip of Vietnam, 400 km^2 in the Mekong delta area, 200 km^2 in south central Vietnam around Cam Ranh Bay, and 400 km^2 in northern Vietnam in the Red River delta area (Cuong 1964). The central coast of Vietnam is largely free of mangroves due to the exposed coastline, absence of major river deltas, and relatively low tidal fluctuations in this area. Extensive stands of mangroves once also occurred around the Red River delta in northern Vietnam. By the beginning of the Vietnam War, this area of mangroves in Vietnam had been reduced to about 2,500 km^2.

The extensive military use of defoliants and napalm during the Vietnam War (1962-1972) destroyed approximately 1,050 km^2 of mangrove area in southern Vietnam (Spalding et al. 1997). Mangrove forests in the south are slowing recovering under active programs of reforestation today, but much of this area has scrubby growth or open mangrove plantations rather than the closed canopy cover which once existed (Williamson 1990). This description is applicable as well to conditions in the Red River delta. The most recent assessment of mangroves in Vietnam estimates a total area of 2,723 km^2, including all conditions of health (Spalding et al. 1997).

Mangrove diversity in Vietnam is relatively high. Of the 50 species of true mangroves which are distributed in South and Southeast Asia, including Indonesia, 29 species occur in Vietnam. However, mangrove forests in the Red River delta and associated estuaries and mud flats are lower diversity than mangrove habitats in the south. This reduction in diversity can be seen in comparing the distributions within the two most important families of mangroves, the Avicenniaceae and Rhizophoraceae (Spalding et al. 1997). All fourteen of the Vietnamese species of mangroves in these families are present in southern Vetnam, but only eight reach the Red River delta area of northern Vietnam. Northern Vietnam contains no mangrove species that are not also present in the south. This depauperate condition of mangrove diversity in the Red River delta area is the result of a combination of cooler growing conditions and a longer and more intense period of human impact. *Sonneratia alba* has an interesting pattern of distribution in that it is common in southern Vietnam and then reaches the southern coast of Hainan Island, but is absent from northern Vietnam.

Mangrove forests typically exhibit strong patterns of zonation. The pioneer species along the open coastline is typically *Avicennia alba* (Avicenniaceae). Next along a gradient ofdecreasing relative exposure and submergence by sea water are *Rhizophora apiculata* and *Brugiera parviflora* (Rhizophoraceae) which become established after 5-6 years and grow to replace *Avicennia* after about 20 years. Higher ground subject to conditions of brakish water rather tha seawater is dominated by *Avicennia officinalis* (Avicenniaceae), *Sonneratia caseolaris* (Sonneratiaceae), *Nypa fruticans* (Arecaceae) and *Phoenix paludosa* (Arecaceae). The upper elevational distribution of mangrove forests grade into swamp forests with dominates that are not classic mangrove species. These include *Melaleuca leucodendron* (Myrtaceae), *Acronychia laurifolia* (Rutaceae), *Canthium didynum* (Rubiaceae), *Alstonia spathulata* (Apocynaceae), and the ferns *Stenochlaena palustris* (Blechnaceae) and *Polybotrya appendiculata* (Aspleniaceae). The environmental conditions and floristics of mangrove forests in the Cape Saint Jacques area of the Mekong delta of southern Vietnam have been described in considerable detail by Cuong (1964).

Floristic Patterns in Southeast Asia

The Classification of Floristic Areas

There is a long history of biogeographers, more specifically phytogeographers, dividing the world up into a hierarchy of floristic units. The highest category of such a hierarchy has been the floristic kingdom or realm. Floristic kingdoms are separated on the basis of the presence of endemic taxa of the highest order - families, subfamilies, and tribes. The number of designated floristic kingdoms has varied somewhat among authors over the past century, but has usually been small. The most commonly cited system of floristic classification today, developed by the Russian botanist Takhtajan (1986), uses just six kingdoms. These are the Holarctic Kingdom, the Paleotropical Kingdom, the Neotropical Kingdom, the Cape Kingdom, the Australian Kingdom, and the Holantarctic Kingdom. Various authors have used criteria of biodiversity and endemism at both higher taxonomic levels and generic levels to further subdivide these six kingdoms into between 29-43 floristic regions. The classification system of Takhtajan subdivides kingdoms into 35 floristic regions, taking a middle approach, and it is this system that is described here.

Southeast Asia lies within the Paleotropical Kingdom of Takhtajan (1986). It covers the Old World tropics with the exception of Australia, including not only tropical Africa, Madagascar, South Asia, and Southeast Asia, but also the great majority of islands in the tropical Pacific Ocean. This vast and highly diverse area is further subdivided into five subkingdoms: African, Madagascan, Indomalesian, Polynesian and Neocaledonian. The Indomalesian Subkingdom, which includes the broad territory of the Indian subcontinent and Southeast Asian, has a flora linked by many common elements at both higher and lower taxonomic rank. Takhtajan (1986) characterizes this subkingdom by its unusually high rates of endemism that include 16 endemic families of vascular plants and a very large number of endemic genera and species. He further states that no other floristic unit in the world contains so many ancient and what he terms archaic forms of flowering plants.

The Indomalesian Subkingdom is further subdivided into four floristic regions: Indian, Indochinese, Malesian, and Fijian. The region of relevance to this study is the Indochinese Region that extends from the southeastern and eastern border areas of Bangladesh and tropical regions of eastern India across Burma and Thailand to Laos, Cambodia and Vietnam. As designated by Takhtajan (1986), the Indochinese Region also includes the Andaman Islands, tropical regions of southwestern and southern China, and Hainan Island, but excepts small areas of northern Thailand and Laos which are placed into the Eastern Asiatic Region of his Holarctic Kingdom.

The Indochinese Region

The Indochinese Region has only a single endemic family, the Rhoipteleaceae, with a single species occurring in southern China and northern Vietnam in the transition between the Indochinese Floristic Region and the eastern Asiatic Floristic Region. Takhtajan (1986) reported the Plagiopteraceae, which is restricted to lower Burma, as an

endemic familyto this region. This family, however, is now generally placed into the Flacourtiaceae, a pantropical family. There are approximately 250 endemic genera of vascular plants that are endemic to the Indochinese Floristic Region. Nearly one third of endemic genera occur entirely or partially within the political boundaries of Indochina (i.e. Laos, Cambodia and Vietnam). Many of these are monotypic genera (i.e. with only a single species). These data, as shown below, are adapted with corrections from those listed by Takhtajan (1986) who in turn largely extracted information from Willis (1985).

Angiosperms – Dicotyledonae

Acanthaceae	*Chroësthes* (3-4, southern China, northern Indochina)
	Parajusticia (1, Indochina)
	Psiloësthes (1, Indochina)
Annonaceae	*Eniocosanthellum* (2, southern China, Vietnam) [not in Willis]
Apocynaceae	*Aganonerion* (1, Indochina)
	Argyronerium (1, Indochina)
	Bousigonia (2, Indochina)
	Hanghomia (1, Indochina)
	Parabarium (20, southern China, Indochina)
	Spirolobium (1, Indochina)
	Xylinabariopsis (2, Indochina)
Aclepiacdaceae	*Costantina* (1, Indochina)
	Gymnemopsis (2, Thailand, Indochina)
	Harmandiella (1, Indochina)
	Spirella (2, Indochina)
Asteraceae	*Camchaya* (4, Thailand, Indochina)
	Colobogyne (1, Indochina)
	Jodocephalus (3, Thailand, Indochina) [not in Willis]
Bignoniaceae	*Hexaneurocarpon* (1, Indochina) [now included in *Fernandoa*]
	Spathodeopsis (2, Indochina) [now included in *Fernandoa*]
Campanulaceae	*Numaeacampa* (1, Indochina)
Capparidaceae	*Neothorelia* (1, Indochina)
	Poilanedora (1, Indochina)
	Tirania (1, Indochina)
Euphorbiaceae	*Deutzianthus* (1, Indochina)
	Glyphostylus (1, Thailand, Indochina) [close to *Exocoecaria*)
	Oligoceras (1, Indochina)
	Poilaniella (1, southern China, Indochina)
	Thyrsanthera (1, Indochina)
Fabaceae	*Endomallus* (1 or 2, Laos and Vietnam) [close to *Cajanus*]
	Lysidice (1, northern Vietnam and southern China
	Zenia (1, northern Vietnam and southern China)
Flacourtiaceae	*Dankia* (1, Indochina)
Hamamelidaceae	*Mytilaria* (1, Indochina)
Icacinaceae	*Pittosporopsis* (1, Yunnan, Burma, Thailand, Laos, Vietnam)
Magnoliaceae	*Kmeria* (2, southern China, Thailand and Indochina)
Malvaceae	*Cenocentrum* (1, Indochina)

Melastomataceae	*Scorpiothyrsus* (1, Indochina, Hainan)
Ochnaceae	*Indosinia* (1, Indochina)
Podostemaceae	*Diplobryum* (1, southern Vietnam)
Rhoipteleaceae	*Rhoiptelea* (1, southern China, northern Vietnam)
Rubiaceae	*Alleizettella* (2, Indochina, Hong Kong)
	Leptomischus (1, Indochina)
	Mouretia (1, Indochina)
	Notodontia (2, northern Vietnam)
	Paedicalyx (1, Hainan, northern Indochina)
	Xanthonneopsis (1, Indochina) [not in Willis]
	Xanthophytopsis (2, southern China, northern Indochina)
Sapindaceae	*Arfeuillea* (1, Thailand, Indochina)
	Boniodendron (1-2, Indochina)
	Cnemidiscus (1, southern Indochina)
	Phyllotrichum (1, Indochina)
Sapotaceae	*Eberhardtia* (3, southern China, northern Indochina)
	Sinosideroxylon (3, southeastern China, Hong Kong, northern Vietnam)
Scrophulariaceae	*Petitmenginia* (2, southern China, Indochina)
	Pseudostriga (1, Indochina)
Solanaceae	*Atrichodendron* (1, Indochina)
Theaceae	*Paranneslea* (1, Indochina)
Thymeleaceae	*Rhamnoneuron* (1, southern China, Indochina)
Tiliaceae	*Sicrea* (1, Thailand, Indochina)
Urticaeae	*Meniscogyne* (2, Indochina)
	Petelotiella (northern Vietnam)
Verbenaceae	*Tsoongia* (1, southern China, Indochina)
Vitaceae	*Acareosperma* (1, Indochina)

Angiosperms-Moncotyledonae

Araceae	***Pseudodracontium* (7, Thailand, Indochina)**
	Pycnospatha (2, Thailand, Laos)
Commelinaceae	*Spatholirion* (2, southern China, Indochina, Thailand)
Convallariaceae	*Antherolophus* (1, Indochina) [close to *Aspidistra*]
Orchidaceae	*Cephalantheropsis* (1, Indochina)
	Schaenomorphus (1, Indochina)
	Smitinandia (1, Thailand, Indochina)
Zingiberaceae	*Gagnepainia* (3, Indochina)
	Siliquamomum (1, Indochina)

Floristic Provinces within the Indochinese Region

The lowest level of floristic hierarchy used by Takhtajan (1986) is that of floristic province with the Indochinese Region subdivided into seven such provinces: South Burmese Province, Andamanese Province, South Chinese Province, Thailandian

Province, North Indochinese Province, Annamese Province, and South Indochinese Province. The political units of Laos, Cambodia, and Vietnam largely falls within the North Indochinese, Annamese, and South Indochinese Provinces, but also extend in northern Vietnam and Laos into the South Chinese Province and in western Laos into the Thailandian Province. Small portions of northern Laos fall within the Sikang-Yunnan Province of the East Asiatic Region of the Holarctic Kingdom (Takhtajan 1986).

The North Indochinese Province

The North Indochinese Province covers the tropical portions of northern Laos and Vietnam, including portions of the northern Annamite Range. Takhtajan (1986) considers this province to be closely related to the Southern Chinese Province, but distinctive in aspects of its species distributions and endemics. Two genera, *Notodontia* (Rubiaceae) and *Petelotiella* (Urticaceae), are endemic to this province. The province also includes the unusual *Platanus kerrii* (Platacaceae) which differs from other species in this genus because of its leaf form that is toothed but not lobed and possesses pinnate vein structure. This area also represents the southern limit of distribution for a diverse assemblage of conifers with northern Chinese affinities.

The Annamese Province

The Annamese Province includes central and southern portions Vietnam and adjacent portions of Laos within the broad area of the Annamite Range. The taxonomically isolated genus *Poilanedora* (Capparaceae) is endemic to this province which is also rich in endemic taxa of Orchidaceae, Fagaceae, Euphorbiaceae, Rubiaceae, Annonaceae, and Celastraceae. Also present are interesting endemic species in the Theaceae, Styraceae, Rosaceae, Ericaceae, Malpighiaceae, and Cycadaceae. The unusual flat-needled pine, *Pinus* (*Ducampopinus*) *kremfii*, is endemic to this province, as is *Pinus dalatensis*.

The Southern Indochinese Province

The Southern Indochinese Province covers Cambodia and the southern parts of Vietnam, Laos, and a small portion of Thailand. This is largely a lowland area with open plains of and dry evergreen forest, dry deciduous dipterocarp woodlands and savanna, and grasslands. Also included are extensive areas of coastal dunes in southeastern Vietnam which are rich in endemic species. Evergreen rainforest vegetation is present, however, in the Cardamom and Elephant Mountains of southeastern Cambodia and adjacent highlands in Thailand. Endemism is lower in this province, but relatively high species-level endemism is present in wetland forests of the Mekong basin and floodplain of Tonle Sap, and in wet evergreen forests of the Cardamom and Elephant Mountains.

The South Chinese Province

The Southern Indochinese Province largely comprises the southern tropical regions of Yunnan, the coastal belt of continental China from Nanning to Macao, and Hainan Island. It also includes small areas of northern Vietnam, Laos, Thailand and the eastern extremity of Burma. This province represents a transition zone from the Holarctic

Kingdom to the north, and is characterized by the presence of many Holarctic elements at their southern limit of distribution. This province is rich in endemic genera, including at many that extend into Indochina – *Rhoiptelea* (Rhoipteleaceae), *Chaydaia* (Rhamnaceae), *Paedicalyx* and *Xanthophytopsis* (Rubiaceae), and *Eberhardtia* and *Sinosideroxylon* (Sapotaceae).

The Thailandian Province

The Thailandian Province includes the larger part of Thailand as well as portions of western Laos and the Tenasserim area of peninsular Burma. This region, as with many of the other floristic provinces, contains a large number of endemic genera. Only *Thysanostigna* among these appears to extend into Laos. Most of this province is characterized by a seasonal monsoon climate, but the southern central highlands and portions of peninsula area of Thailand include areas of evergreen rainforest.

Patterns of Endemism within Woody Plant Families

Cycadaceae

The Indochinese Region contains at least eight species of cycads, all in the genus *Cycas* (Hiêp and Vidal 1996). Two of these appear to be endemic to the Indomalesian Subregion. *Cycas inermis* is localized in distribution to the coastal area of central and southern Vietnam, while *C. balansae* is restricted to calcareous substrates in northern Thailand. Jones (1993) mentions two other endemic species of cycads. *Cycas undulata,* described from "sheltered forests" of Vietnam, was not mentioned by Hiêp and Vidal (1996), while *C. chamberlainii* from northern Vietnam is considered to be synonymous with *C. balansae*. The unusual *C. micholitzii* var. *micholitzii* is largely restricted to northern and central Vietnam, but extends its range into southern China. It occurs in dry deciduous dipterocarp and semi-deciduous forests on basaltic substrates. *Cycas micholitzii* var. *simplicipinna* is known from dry deciduous dipterocarp forests and degraded savannas in northern Thailand and Laos. Jones (1993) indicates that this variety may well be deserving of specific rank, and suggests its habitat as evergreen forests at 600-1100 m elevation.

Indochina Endemics
Cycas inermis – abundant species in coastal areas of central and southern Vietnam
Cycas undulata – Vietnam

Mainland Southeast Asian Endemics
Cycas micholitzii var. *simplicipinna* – northern Thailand and Laos

Southern China – Indochina Endemics
C. micholitzii var. *micholitzii* – southern China, northern and central Vietnam

Pinaceae

There are four genera and nine species of Pinaceae that occur naturally in Indochina, with northern and central Vietnam as the area of greatest diversity for this family (Hiêp and Vidal 1996). Six of these species are pines. The poorly known endemic *Pinus krempfii* is a remarkable pine species with flattened needles, and was once described as a new genus, *Ducampopinus*. It is known only from a limited area at 1200-2000 m elevation in the mountains near Dalat in southern Vietnam. Another local endemic, *P. dalatensis*, is known only from small areas of coniferous forest at 1500-2400 m elevation in southern Vietnam, and is considered critically endangered (Farjon et al. 1993). Two rare pine species from southern China also reach into Vietnam. These are *P. kwangtungensis* with localized populations on calcareous substrates at 700-1800 m elevation in northern Vietnam, and *P. wangii* which is known from Binh Tri Thiên Province in central Vietnam. The latter species is also considered to be critically endangered (Farjon et al. 1993). *Pinus massoniana*, another Chinese species, has been collected in Vietnam, but appears to be introduced. Two additional pines, *P. kesiya* and *P. merkusii*, have widespread ranges across the broad Indomalesian Subkingdom (Richardson and Rundel 1998). Two widespread members of the Pinaceae with a Holarctic pattern of distribution in Asia also reach together into northern Vietnam at Fan Si Pan Mountain in Hoang Liên Son Province. These are *Tsuga dumosa* and *Abies delavayi* var. *nukiangensis*. *Keteleeria evelyniana* is a widespread taxon extending from tropical regions of southern China all along the Annamite Range through central Laos and southern Vietnam from 700-3000 m elevation. It generally occurs in mixed stands of conifer species and broad-leaved evergreens.

Indochina Endemics

Pinus krempfii – 2-needled pine reaching 15-30 m in height; growing in humid evergreen forests at 12-2000 m elevation; known only from Phu Khanh and Lam Dong Provinces in southern Vietnam

Pinus dalatensis – 5-needled pine reaching 40 m in height; growing with other conifers in evergreen montane forests at 1500-2400 m elevation; known only from central and southern Vietnam (Binh Tri Thien, Gia Lai-Cong Tum, Dac Lac and Lam Dong Provinces)

Southern China – Indochina Endemics

Keteleeria evelyniana – southern China, Vietnam

Pinus kwangtungensis - southern China and northern Vietnam

Pinus wangii – southern China and northern Vietnam

Taxodiaceae

There are two genera with two species of Taxodiaceae with natural ranges that extend into Vietnam and Laos. *Cunninghamia konishii* was once considered endemic to Taiwan, but has been recently discovered in northern Laos at Na Ham in Houa Phan Province at 1000-1200 m elevation (Hiêp and Vidal 1996). A widespread Chinese species of this genus, *C. lanceolata*, has been cultivated in northern Vietnam but is not native. The

Chinese species *Glyptostrobus pensilis* is known from Dac Lac Province in southern Vietnam where it grows in open deciduous forests on basalt substrates.

Cupressaceae

There are three genera and with one species each of Cupressaceae native to Indochina (Hiêp and Vidal 1996). *Calocedrus macrolepis*, a Holarctic species extending across southern Asia, occurs along streams and other moist habitats at 800-1500 m elevation along the length of the Annamite Range in Vietnam and in Vientiane Province in Laos. *Fokienia hodginsii* occurs from southeastern China southward along the Annamite Range at elevations of 1000-2000 m into Vietnam and Laos. The widespread Chinese species of *Cupressus tortulosa* extend its range into Vietnam and is known from both Lang Son and Lâm Dông Provinces. *Cupressus duclouxiana* from southwestern China has been widely cultivated in Vietnam but is not native.

Southern China – Indochina Endemics

Fokienia hodginsii – southern China, Vietnam and Laos

Podocarpaceae

There are six species of Podocarpaceae occurring naturally in Indochina. Most of these are widespread species throughout much of the Indochinese Floristic Region but seldom occur in great abundance. *Dacrydium elatum* (700-2000 m), *Podocarpus* (*Dacrycarpus*) *imbricatus* (500-1500 m), *P*. (*Nageia*) *wallichiana* (<2100 m), *P. neriifolia* (650-1600 m), and *P. pilgeri* (100-3000 m) are widespread in evergreen montane forests throughout Laos, Vietnam, Cambodia, and Thailand. All also extend through the Malay Peninsula into the Indomalaysian region. *Podocarpus* (*Nageia*) *fleuryi* extends from southern China into dense montane forests in northern and central Vietnam.

Southern China – Indochina Endemics

Podocarpus (*Nageia*) *fleuryi* – southern China, northern and central Vietnam

Cephalotaxaceae and Taxaceae

The Cephalotaxaceae and Taxaceace are well represented in the Indochinese Region with six species, two of which are endemic. Although up to four species of *Cephalotaxus* have been cited as occurring in Vietnam, only *C. mannii* is considered to be actually present (Hiêp and Vidal 1996). This species is found from eastern India across to Hainan Island, with localized occurrences in northern Thailand and northern and southern Vietnam. It grows on calcareous soils at 500-1500 m elevation. There are four species of *Amenotaxus* in Vietnam, and two of these are endemic to this country. *Amenotaxus hatuyenensis* is a shrubby tree of 4-5 m height whose range is restricted to montane forests at 1000-1500 m elevation on limestone ridges in Ha Tuyên Province in northern Vietnam. *Amenotaxus poilanei* is known only from bamboo forests on granititic soils at about 2300 m on Ngoc Pan in central Vietnam. Two other species are known from southern China and northern Vietnam. *Amenotaxus argotaenia* ranges from the subtropical mountains of southern China into Hoang Liên Son and Cao Bang Provinces

of northern Vietnam at 1000-1800 m elevation in montane forests on rocky or calcareous soils. *Amenotaxus yunnanensis* is known from the Yunnan region of China to Hoang Liên Son Province where it has been found on rocky hills at 1500 m. There are two northern species of *Taxus* that similarly extend into Vietnam from China. *Taxus chinensis* is known from Ha Son Binh Province in northern Vietnam on limestone soils at 900-1500 m elevation. *Taxus wallichiana*, which is widespread from Nepal across to southeastern China, appears again on clay soils at 1400-1500 m elevation in the mountains of Phu Khanh and Lâm Dông Provinces in southern Vietnam.

Indochina Endemics

Amenotaxus hatuyenensis – shrub reaching 4-5 m in height; known only rom calcareous ridges at 1000-1500 m in Ha Tuyen Provence of northern Vietnam

Amenotaxus poilanei – tree reaching 20 m in height, growing in bamboo forest on granitic substrate; known only from Ngoc Pan mountain in Gia Lai-Cong Tum Province of central Vietnam

Southern China – Indochina Endemics

Amenotaxus argotaenia – southern China and northern Vietnam

Amenotaxus yunnanensis - southern China and northern Vietnam

Gnetaceae

There are seven species of the genus *Gnetum* in the Indochinese Region. One of these is an endemic liana, *G. formosum* which is know from shady montane forests up to 2000 m elevation in northern and central Vietnam. Another endemic liana, *G. leptostachyum* var. *elongatum*, is known only from the Annamite Range in Laos and central and southern Vietnam where it grows in humid evergreen forests at 900-1500 m elevation on rocky clay or low nutrient schist soils. Three species (G. *latifolium, G. montanum*, and *G. macrostachyum*) have a widespread distribution as lianas in humid evergreen forests throughout Laos, Vietnam, Cambodia and Thailand, and extend southward into Malaysia. Another liana species, *G. parvifolium* extends in distribution from southern China into northern and central Vietnam and Laos where it is found in humid evergreen forests at 400-700 m elevation. *Gnetum cuspidatum* is an Indomalaysian species which extends northward into Thailand, the Cardamom Mountains of southeastern Cambodia and scattered localities along the Ammanite Range in Vietnam. It generally occurs in humid evergreen forests at 700-1500 m elevation on a variety of soil substrates. The only *Gnetum* in the region with an arborescent growth form, *G. gnemon*, is a widespread species occurring from Malaysia to the Assam region of India. Both the varieties *gnemon* and *griffithii* are present in southern Vietnam at 200-900 m elevation.

Indochina Endemics

Gnetum formosum – Woody liana reaching 25 m in length; growing in shaded humid forests up to 2000 m elevation; known only from Vietnam (Vinh Phu, Ha Son Binh, Ha Nam Ninh, Gia Lai-Cong Tum and Lam Dong Provinces)

Gnetum leptostachyum var. *elongatum* – Woody liana reaching 20-40 m in length; growing in evergreen forests at 900-1500 m elevation; known from Laos

(Louang Prabang, Savannakhet, Saravane and Champassak Provinces) and Vietnam (Ha Son Binh, Binh Tri Thien and Quang Nam-Da Nang Provinces)

Southern China – Indochina Endemics

Gnetum parvifolium – southern China, Laos and Vietnam

Alangiaceae

The Alangiaceae is represented in Indochina by six woody species of the genus Alangium (Tardieu-Blot 1968). One of these species and a variety of another are endemic to Vietnam.

Indochina Endemics

Alangium tonkinense – Small tree (?); growing on calcareous soils; known only from northern Vietnam (Lang Son. Bac Gian and Hoa Binh Provinces)

Bignoniaceae

The Bignoniaceae in Indochina comprise 27 indigenous species divided into nine genera (Santisuk and Vidal 1985). Eight of these species are endemic to Cambodia, Laos and Vietnam, with 10 more endemic to the Indochinese Floristic Region. Two genera considered by Takhtajan (1978) to endemic to this floristic region, *Hexaneurocarpon* and *Spathodeopsis*, are now included in *Fernandoa* which is not endemic to this region. The largest genus is *Radermachera* with eight species.

Indochina Endemics

Fernandoa bracteata – Tree; endemic to northern Vietnam (Son La and Ha Son Binh Provinces)

Fernadoa brilletii – Tree; known only from Ha Son Binh Province in Vietnam.

Fernadoa serrata – Tree reaching 25 m in height; grows in secondary forest on rocky soils at 600-800 m elevation; endemic to Vietnam (Ha Son Binh, Phu Khanh and Thuan Hai Provinces)

Radermachera boniana – Tree; known only from Mt. Mu Bong in Vietnam (province unknown)

Radermachera eberhardtii – Tree reaching 4-10 m in height; growing in forest habitats at 300-600 m; restricted to Binh Tri Thien and Quam Nam-Da Nang Provinces in central Vietnam

Radermachera inflata – Tree; growing in thickets in sandy soil; known only from Quang Ninh Province in northern Vietnam

Radermachera stellata – Large tree; known only from Lang Son Province in northern Vietnam

Stereospermum annamense – Large tree reaching to 30 m in height; known only from Ninh Thuan Province in central Vietnam

Mainland Southeast Asian Endemics

Dolichandrone columnaris – Cambodia, Vietnam and Thailand

Dolichandrone serrulata – Laos, Vietnam, Thailand and Burma

Fernandoa collignonii – Laos, northern Vietnam and northern Thailand
Heterophragma sulfureum – Cambodia, Laos, Thailand and Burma
Markhamia stipulata – Cambodia, Laos, Vietnam, Thailand and Burma
Millingtonia hortensis - Cambodia, Laos, Vietnam, Thailand and Burma
Pauldopia ghorta - Laos, Vietnam, Thailand and Burma
Stereospermum cylindricum – Cambodia, southern Vietnam and Thailand
Stereospermum fimbriatum – Laos, Thailand, Burma and the Malay Peninsula
Stereospermum neuranthum - Cambodia, Laos, Vietnam, Thailand and Burma

Cochleospermaceae

There is only a single widespread species representing the Cochleopspermaceae in Indochina (Lescot 1970). This species has a variety endemic to Cambodia.

Indochina Endemic
Cochlospermum gossypium var. *cambodiana* – Small tree; known only from Kompong Thom Province in Cambodia

Combretaceae

The Combretaceae form an ecological significant family of woody species with six genera and 29 species naturally distributed in Indochina. Only three of these (and one variety of a widespread species) are restricted in distribution to Indochina, but an additional four are endemic to mainland Southeast Asia and two occur in southern China and mainland Southeast Asia. Species of *Terminalia* form some of the largest forest trees of Southeast Asia, reaching to 45 m in height and several meters in diameter. Shrubby and viney species of *Combretum* are often major components of secondary forest communities and thickets. Two species of Lumnitzera are important trees in mangrove forests.

Indochina Endemics
Anogeissus rivularis – Tree 5-10 m in height; growing along streams; known only from Pakse and Attopeu Provinces in Laos
Quisqualis indica var. *pierrei* – Deciduous shrub becoming a liana with age; this variety is known only from Bien Hoa Province in southern Vietnam
Terminalia harmandii – Tree or shrub (?); known only from Attopeu and Mulu Prey Provinces in Laos
Terminalia darfeuillana – Tree reaching 30-40 m in height and 60-100 cm in diameter; known from Cambodia (Pursat and Kandal Provinces), Laos (Savannakhet Province) and southern Vietnam (Cholon and Baria Provinces)

Mainland Southeast Asian Endemics
Combretum quadrangulare – Cambodia, Laos, Vietnam, Thailand and Burma
Combretum tetralophum – Laos, Vietnam, Thailand and Malay Peninsula
Terminalia cambodiana – Cambodia and Thailand
Terminalia corticosa – Cambodia, Laos, Vietnam and Thailand

Southern China – Indochina Endemics

Terminalia myriocarpa – northern Vietnam and southern China

Terminalia nigrovenulosa - Cambodia, Laos, Vietnam, Thailand, Hainan Island and Malay Peninsula

Cornaceae

The Cornaceae is represented in Indochina by three genera and nine species (Tardieu-Blot 1968). Three of these species are endemic to Vietnam, and one additional species is restricted in distribution to southern China and northern Vietnam.

Indochina Endemics

Cornus oligophlebia – tree reachjing 12-15 m in height; known only from Laokay Province in northern Vietnam

Cornus tonkinensis – Tree reachin 12-15 m in height and 30-50 cm in diameter; growing on clay soils in humid montane forests at 1,600=1,800 m elevation; known only from Langson Province in northern Vietnam

Mastixia poilanei – Tree 4-10 m in height; known only from Thua Thien and Quang Tri Provinces in northern Vietnam

Southern China – Indochina Endemics

Cornus gigantea – northern Vietnam and southern China

Fabaceae – Caesalpinoideae

The Caesalpinoideae subfamily of the legumes forms a particularly important group of forest trees, shrubs and woody lianas in Indochina. Species of Caesalpinoideae form important components of many forest communities, including lowland evergreen rainforest, mixed deciduous forest, dry evergreen forest, dry deciduous dipterocarp forest, and swamp forest. Other species are important in secondary formations following forest disturbance and thus are increasing in numbers today. From an economic standpoint, many of species in this group are important forest trees for lumbering and construction.

The most recent monograph of this group lists 22 genera and 112 species for this subfamily in Indochina. Of this group, 20 genera and 95 species appear to be indigenous, with the remainder introduced. The largest genus is *Bauhinia*, a pantropical genus, with 37 indigenous species of trees, shrubs and lianas in Indochina. Eight of these species are endemic to Laos, Cambodia and Vietnam, and a further seven species are endemic to mainland Southeast Asia. Following in size are *Caesalpinia* with 18 indigenous species (two endemic to Vietnam) and *Cassia* with 9 indigenous species.

There are xx species of Caesalpinoideae that appear to be endemic to the area of Laos, Cambodia and Vietnam:

Indochina Endemics

Bauhinia calycina – Liana; endemic to Mount Krewanh in Kompong Speu Province of Cambodia.

Bauhinia clemensiorum - Climbing shrub characteristic of forest edges; known only from Binh Tri Thien Provinces in central Vietnam.

Bauhinia coccinea – Large woody liana; grows on granite soils from 200-1000 m elevation in southern Laos (Attopeu Province) and northern and central Vietnam (Hoang Lien Son, Ha Tuyen, Bac Thai, Vinh Phu, Ha Son Binh, Binh Tri Thien, Quang Nam-Da Nang, and Gia Lai-Cong Tum Provinces).

Bauhinia godefroyi – Woody shrub; known only from Pursat Province in western Cambodia.

Bauhinia involucrans – Liana; grows in gallery forests along streams on laterite soils derived from basalt; known only from Blao in Lam Dong Province in southern Vietnam.

Bauhinia lorantha – Liana; grows in montane evergreen forests at 800-1400 m elevation; known only from southern Laos (Khammouane, Saravane and Sedone Provinces).

Bauhinia ornata var. *balansae* – Large woody liana; endemic to northern Vietnam (Hoang Lien Son, Ha Bac and Ha Son Binh Provinces). *Bauhinia ornata* var. *ornata* is widespread across southern and southeastern Asia.

Bauhinia ornata var. *subumbellata* – Large woody liana; endemic to northern Laos (Louang Prabang and Attopeu Provinces) and northern Vietnam (Ha Son Binh Province). *Bauhinia ornata* var. *ornata* is widespread across southern and southeastern Asia.

Bauhinia oxysepala – Liana; grows on calcareous soils; known only from Ha Son Binh and Thanh Hoa Provinces in northern Vietnam.

Bauhinia rubro-villosa – Large woody liana; restricted to Laos (Louang Prabang , Khammouane and Savannakhet Provinces) and northern Vietnam (Lai Chau Province).

Caesalpinia nhatrangensis – Liana in secondary forests; known only from Phu Khanh Province in northern Vietnam.

Caesalpinia rhombifolia – Woody species; known only from Quang Ninh Province in southern Vietnam.

Cynometra dongnaiensis – Tree reaching 20 m in height; grows in gallery forests along streams and in swamp forests; known only from Cambodia (Kompong Thom and Kompong Cham Provinces) and southern Vietnam (Dong Nai and Ho Chi Minh Ville Provinces).

Gleditsia pachycarpa – Tree; known only from Mt. Bavi in Ha Son Binh Province of northern Vietnam.

Gymnocladus angustifolia – Tree; known only from Vinh Phu Province in northern Vietnam.

Saraca dives - Tree reaching 7-8 m; restricted to evergreen gallery forests in Laos (Louang Prabang Province) and northern to central Vietnam (Lai Chau, Hong Lien Son, Ha Tuyen, Bac Lai, Quang Ninh, Ha Son Binh, Ha Noi, Ha Nam Ninh, Thanh Hoa, and Nghe Tinh Provinces).

Saraca scmidiana - Tree reaching 20 m height; known only from 650 m on the Col de Blao in Lam Dong Province of southern Vietnam.

Sindora laotica – Tree reaching 25 m in height; of local distribution in dense forest habitats at 300-1000 m elevation in Laos (Vientiane Province) and central Vietnam (Gia Lai-Cong Tum Province).

Sindora tonkinensis – Tree reaching 15 m in height; restricted in distribution to dense forest habitats in Cambodia (Kandal Province) and Vietnam (Quang Ninh, Binh Tri Thien, and Phu Khanh Provinces).

A further group of 16 species are endemic to mainland Southeast Asia, with broader distributions that extend into Thailand and Burma:

Mainland Southeast Asian Endemics

Bauhinia glabrifolia – rare in Laos, Thailand and Burma
Bauhinia harmsiana – Cambodia and Thailand
Bauhinia lakhonensis – Laos, Vietnam and Thailand
Bauhinia penicilliloba – Laos, Vietnam and Thailand
Bauhinia pulla – Cambodia and Thailand
Bauhinia saccocalyx – Laos and Thailand
Bauhinia similis – Laos, Thailand and Burma
Caesalpinia godefroyana - Cambodia, Vietnam and Thailand
Cassia garrettiana - Cambodia, Laos, Vietnam and Thailand
Crudia chrysantha - Cambodia, Laos, Vietnam and Thailand
Cynometra craibii – Laos and Thailand
Dialium cochinchinense – Cambodia, Laos, Vietnam and Thailand
Erythrophleum succirubrum – Cambodia and Thailand
Erythrophleum teysmannii – Cambodia and Thailand
Pterolobium integrum - Cambodia, Laos, Vietnam and Thailand
Sindora siamensis - Cambodia, Laos, Vietnam, Thailand and rarely on the Malaysian Peninsula

The third group of biogeographic interest are species with a primary range in southern China but extending into northern Vietnam, and occasionally to northern Laos and down the Annamite Ranges in Vietnam. These species are a part of the Southern Chinese Floristic Province.

Southern China – Indochina Endemics

Bauhinia carcinophylla – northern Vietnam and southern China
Bauhinia championii – Vietnam and southern China
Bauhinia corymbosa – northern Vietnam and southern China
Bauhinia pyrrhoclada – northern Vietnam and southern China
Lysidice rhodostegia – northern Vietnam and southern China; monotypic genus
Erythrophleum fordii – Vietnam and southern China
Gleditsia australis – Vietnam and southern China
Gleditsia rolfei – Laos, Vietnam and southern China
Zenia insignis - Vietnam and southern China; monotypic genus

Fabaceae - Mimosoideae

The subfamily Mimosoideae of the legumes includes 11 genera and 65 native species in Indochina. There are no endemic genera to the region, but 25 species are endemic to Cambodia, Laos, and Vietnam. There are two genera make up more than half of the species of Mimosoideae in Indochina. One of these is the ecologically important *Acacia*, with 14 species in the region. Only two of these are endemic to Indochina, but six more species are endemic to mainland Southeast Asia. A second genus with 19 species is *Archidendron,* which is rich in local endemics. Fourteen of these endemics are restricted in distribution to Indochina, particularly northern and central Vietnam.

Indochina Endemics

Acacia tonkinensis – Woody liana or scandent shrub; known only from Hoang Lien Son and Ha Son Binh Provinces in northern Vietnam

Acacia vietnamenis – Climbing shrub or liana; restricted to Laos (Savannakhet Province) and southern Vietnam (Thuan Hai, Dong Nai and Song Be Provinces)

Albizia poilanei – Deciduous tree reaching 20 m in height; endemic to dry forests of southern Vietnam in Gia Lai-Cong and Lam Dong Provinces

Archidendron balansae – Tree reaching 7-8 m in height; dry evergreen forests at 400-1300 m elevation; known only from northern and central Vietnam (Hoang Lien Son, Cao Bang, Vinh Phu, Ha Son Binh and Binh Tri Thien Provinces)

Archidendron bauchei – Shrub or small tree; known only from Vietnam (Thanh Hoa, Binh Tri Thien, Phu Khanh and Thuan Hai Provinces)

Archidendron dalatense – Small tree; occurring at 800-1400 m elevation; known only from southern Vietnam (Gia Lai-Cong and Lam Dong Provinces)

Archidendron eberhardtii – Tree reaching 15-18 m in height; restricted to northern Vietnam (Bac Thai, Ha Son Binh and Thanh Hoa Provinces)

Archidendron occulatum – Tree reaching 8-10 m in height; hill evergreen forests at 1000-1200 m elevation; known only from Cambodia (Kandal Province) and central Vietnam (Binh Tri Thien Province)

Archidendron pellitum – Tree reaching 10 m in height; secondary forests, dry deciduous dipterocarp woodlands, savanna thickets and dry river beds below 1500 m elevation; restricted to Laos (Champassak Province) and southern Vietnam (Gia Lai-Cong and Lam Dong Provinces)

Archidendron robinsonii – Tree reaching 7-8 m in height; evergreen forests at 800-1000 m elevation; known only from Vietnam (Lang Son, Binh Tri Thien, Lam Dong and Thuan Hai Provinces)

Cambodia, Laos, Vietnam and Thailand *tetraphyllum* – Tree reaching from 2,5-10 m in height; below 500 m elevation; known only from Vinh Phu and Thanh Hoa Provinces in central Vietnam

Archidendron tonkinense – Small tree reaching 5-6 m in height; evergreen forests; known only from Quang Ninh Province in northern Vietnam

Archidendron sp. nov. – Tree; known only from Lam Dong Province of southern Vietnam

Archidendron sp. nov. – Tree; known only from Ha Son Binh Province in northern Vietnam

Entada reticulata – Bushy shrub; known only from Cambodia (Stung Treng and Kompong Speu Provinces) and southern Laos (Champassak Province)
Neptunia oleracea – Aquatic herb; widespread in Cambodia, Laos and Vietnam
Pithecellobium vietnamense – Shrub; know only from the Col de Blao in Lam Dong Province of southern Vietnam

Mainland Southeast Asian Endemics
Acacia comosa - Cambodia, Laos, Vietnam and Thailand
Acacia harmandiana - Cambodia, Laos, Vietnam and Thailand
Acacia thailandica – Cambodia and Vietnam
Albizia crassiramea - Laos, Vietnam, Thailand and Burma
Albizia vialeana - Cambodia, Laos, Vietnam and Thailand
Archiedendron laotica – Laos, Vietnam, and likely in Thailand and Burma
Archidendron quocense - Cambodia, Vietnam and Thailand
Entada glandulosa - Cambodia, Vietnam and Thailand

Southern China – Indochina Distributions
Archidendron chevalieri – Vietnam and southern China
Archidendron kerrii – northern Vietnam, northern Laos and southern China
Archidendron turgidum– northern Vietnam and southern China
Archidendron utile - northern Vietnam and southern China

Fabaceae - Papilionoideae

The subfamily Papilionoideae of the legumes forms a large and ecologically significant group in Indochina. Among this subfamily, endemism in the three Indochina nations is high among woody species but surprisingly low among herbaceous species (Van Thuan et al. 1987). For example 10 of the 19 species of the tree genus *Ormosia* in Indochina are endemic Vietnam and/or Cambodia and Laos, with a particularly high diversity in Vietnam. Another eight species are also part of the Indochinese Floristic Region with a distribution extending from southern China into the northern Indochinese region.

Dalbergia, a large pantropical genus which includes more than 100 species, has one of its centers of distribution in Indochina where there are 28 indigenous species (Niyomdham et al. 1997). Three of these species are endemic to Laos, Cambodia and Vietnam, and a further 15 species are endemic to the Indochinese Floristic Region. Notable is a strong floristic connection with five species occurring in northern Vietnam and southern China. Many species of *Dalbergia* are valued as a hardwood resource for fine furniture.

In contrast to these high levels of endemism, there are relatively few endemic species among herbaceous perennial species of legumes. This is tru not just for small genera but for speciose groups as well. Only two of the 21 indigenous species *Indigofera* in Indochina are endemic to this region, and similarly only three of the 30 indigenous species of *Crotalaria* are endemic to Indochina (four endemic to the Indochinese Floristic Region).

Indochina Endemics

Campylotropis bonii – Shrub; endemic to northern Vietnam (Ha Son Binh and Ha Nam Ninh Provinces)

Campylotropis splendens – Shrub reaching 1.5 m in height; growing on disturbed sites up to 2000 m elevation; endemic to southern Vietnam (Lam Dong Province)

Christia constricta – Subshrub reaching to 1 m in height; growing in open places and along the coast; known from Phu Khanh, Dong Nai and Ho Chi Minh Ville Provinces of southern Vietnam

Christa convallaria – Herbaceous perennial to subshrub 0.2-0.5 m in height; growing at low elevations along roads and in open forests; known only from Thuan Hai Province in southern Vietnam

Christa lychnucha – Perennial herb; growing in mngrove areas and in open communities up to 700 m elevation; known only from Thuan Hai and Ho Chi Minh Ville Provinces in southern Vietnam

Crotalaria annamense – Woody perennial reaching 0.2-0.4 m in height; growing on open sandy-clay soil; known only from Phu Khanh Province in southern Vietnam

Crotalaria cambodiaensis – Spindly herb reaching 0.3-0.4 m in height; growing in sandy soils at low elevations; known from Cambodia (Battambang Province) and Laos (Louang Prabang Province)

Crotalaria phyllostachya – Annual or perennial herb; disturbed sittes with sandy soil at low and middle elevations; known from Cambodia (Oddor Meanchey Province), Laos (Louang Prabang and Savannakhet Provinces) and Vietnam (Ha Noi, Quang Ninh, Thanh Hoa, Quang Nam-Da Nang, Lam Dong and Tay Ninh Provinces)

Dalbergia dialoides – Climbing shrub reaching to 10 m in height; endemic to Khanh Hoa and Dong Nai Provinces in southern Vietnam

Dalbergia thorelii – Climbing shrub or liana; growing in mixed deciduous forests near the coast; known from Cambodia (Stung Treng, Kompong Thom and Kandal provinces) and Vietnam (Khanh Hoa Province)

Dalbergia vietnamensis – Climbing shrub reaching to 15 m in height; growing in thickets on sandy soil at 100-200 m elevation; known from Cambodia (kandal province) and southern Vietnam (Khang Hoa and Ninh Thuan Provinces)

Euchresta horsfieldii var. *laotica* – Subshrub reaching 0.6 m in height; known from Savannakhet Province Laos; the typical variety occurs throughout Southeast Asia and parts of Indonesia

Indigofera banii – Perennail herb; known only from Dac Lac Province in southern Vietnam

Indigofera longicauda – Subshrub 0.5-1 m in height; growing in disturbed areas and recently burned pine forersts from seal level to 1200 m elevation; known only from southern Vietnam (Phu Khanh, Lam Dong and Thuan Hai Provinces)

Ormosia cambodiana – Tree reaching 10 m in height; known only from Mount Ta Lung in Kampot Province, Cambodia

Ormosia chevalieri – Tree reaching 10-12 m in height; growing in mountainous regions up to 1500 m elevation; known only from southern Cambodia (Kampot Province) and central Vietnam (Phu Khanh Province)
Ormosia crassivalvis – Tree of medium height; known only from low elevations in southern Vietnam (Dong Nai and Tay Ninh Provinces)
Ormosia ellipticum – Tree reaching 10-12 m in height; known only from Nghe Tinh Province of north-central Vietnam
Ormosia hoaensis – Tree reaching to 20 m in height; growing on sandy soils in forests at about 1200 m elevation; widespread in Vietnam (Lai Chau, Thanh Hoa, Gia Lai-Cong, Lam Dong and Dong Nai Provinces)
Ormosia laosensis – Tree reaching 15 m in height; growing in forests at low elevations in northern Laos (Houa Phan Province) and central Vietnam (Binh Tri Thien Province)
Ormosia poilanei – Tree reaching 10-12 m in height; growing on rocky soils in forests at about 1000 m elevation; known only from central Vietnam (Phu Khanh and Thuan Hai Provinces)
Ormosia tonkinensis – Small tree recahing 5-6 m in height; known only from forests on Mt. Bavi in Ha Son Binh Province of northern Vietnam
Ormosia tsangii – Small tree; known only from the coastal area of Quang Ninh Province in northern Vietnam
Ormosia vietnamensis – Tree (?); known only from Dac Lac Province in southern Vietnam
Smithia finetii – Perennial herb or subshrub; growing marshy habitat at about 800 m elevation; endemic to southern Vietnam (Lam Dong province)
Uraria balansae – Upright woody herb; known only from Son La province in northern Vietnam
Uraria cochinchinensis – Subshrub reaching 0.6-1 m in height; growing in rocky soils of pine forests at about 500 m elevation; known from Cambodia (Kompong Speu Province), Laos (Louang Prabang Province) and Vietnam Thuan Hai and Dong Nai Provinces)

Mainland Southeast Asian Endemics
Crotalaria melanocarpa - Cambodia, Laos, Vietnam and Thailand
Dalbergia cana – Laos, Thailand and Burma
Dalbergia cochinchinensis - Cambodia, Laos, Vietnam and Thailand
Dalbergia entatoides – Cambodia, Laos, Vietnam and Thailand
Dalbergia foliacea - Laos, Vietnam, Thailand and Burma
Dalbergia godefroyi – Cambodia and Thailand
Dalbergia horrida - Cambodia, Laos, Vietnam, Thailand and Burma
Dalbergia nigrescens - Cambodia, Laos, Vietnam and Thailand
Dalbergia oliveri - Cambodia, Laos, Vietnam, Thailand and Burma
Dalbergia ovata - Laos, Vietnam, Thailand and Burma
Droogmansia godefryana – Southeast Asia
Phylacium majus – Laos, Thailand and Burma
Uraria poilanei – Laos and Thailand

Southern China - Indochina Endemics

Campylotropis bonii – Laos and southern China
Campylotropis pinetorum – Laos, Vietnam, Thailand, Burma and southern China
Crotalaria kurzii - Laos, Vietnam, Thailand, Burma and southern China
Dalbergia dyeriana - northern Vietnam and southern China
Dalbergia hainanensis - northern Vietnam and Hainan Island
Dalbergia hancei - northern Vietnam and southern China
Dalbergia henryana – northern Vietnam and southern China
Dalbergia polyadelpha – Vietnam and southern China
Dalbergia stipulacea – mainland SE Asia and southern China
Dalbergia tonkinensis – northern Vietnam and Hainan Island
Indigofera caudata – northern Laos and southern China
Ormosia balansae - northern Vietnam and southern China
Ormosia emarginata – northern Vietnam and southern China
Ormosia fordiana – Thailand, Burma, Vietnam and southern China
Ormosia inflata - northern Vietnam and southern China
Ormosia pinnata – Vietnam, Thailand and southern China
Ormosia simplicifolia – northern Vietnam and southern China
Ormosia xylocarpa – Laos, Vietnam and southern China

Flacoutiaceae

The Flacourtiaceae is represented in Indochina by nine genera and 42 species (Lescot 1970). Nine of these species are endemic to Indochina. Two additional species are endemic to mainland Southeast Asia, and six additional species are restricted in distribution to southern China and Indochina.

Indochina Endemics

Bennettiodendron cordatum – Tree 5-6 m in height; growing in open forests; known only from northern Vietnam (Lang Son and Mon cay Provinces)
Casearia annamensis – Shrub or tree up to 25 m in height; growing on basalt and clay soils in forests up to 1,200 m elevation; known only from Tuyen Duc Province in southern Vietnam
Casearia tardieuae – Tree reaching 12 m in height; known only from near Nha Trang in Khanh Hoa Prvince of southern Vietnam
Casearia virescens – Tree 5-12 m in height; growing in open forests on moderately rich clay-schist soils at 400-1,600 m elevation; known from both northern and southern Vietnam (Lao kay, Son Tay Thua Thien and Quang Nam Provinces)
Homalium brevidens – Shrub or small tree; growing in forest habitats; known only from Cambodia (Stung Treng, Kompong Cham and Kompong Chnang Provinces)
Homalium cochinchinense – Shrub or small tree of polymorphic growth-form reaching 2-6 or rarely 20 m in height; growing in old forests on hill slopes and wooded valleys up to 1,500 m elevation; widespread in Vietnam (Mon cay, Quang Yen, Ha Dong, Tonkin, Quang Tri, Thua Thien, Khanh Hoa, Tuyen Duc, Ninh Thuan and Soc Trang Provinces)

Homalium myriandrum – Tree; growing on calcareous slopes at about 300 m elevation; known only from northern Vietnam (Vinh Yen and Ninh Bing Provinces)
Hydnocarpus annamensis – Tree 8-10 m in height; growing on ric clay soils at about 300 m elevation; known only fro northern Vietnam (Lao Kay, Son Tay, Thanh Hoa and Nghe An Provinces)
Hydnocarpus saigonensis – Tree 8-10 m in height; known only from southern Vietnam (Tay Ninh and Phuoc Tuy Provinces)

Mainland Southeast Asian Endemics
Casearia flexuosa – Laos, southern Vietnam and Thailand
Hydnocarpus anthelminthica – Cambodia, southern Vietnam and Thailand

Southern China – Indochina Endemics
Casearia membranacea – Vietnam and southern China
Homalium petelotii – northern Vietnam and southern China
Hydnocarpus hainanensis – northern Vietnam and Hainan Island
Itoa orientalis – northern Vietnam and southern China
Scolopia buxifolia – southern Vietnam and Hainan Island
Scolopia saeva – southern Vietnam and Hainan Island

Hamamelidaceae

There are nine genera and 16 indigenous species of the Hamamelidaceae in Indochina. Seven of these species are endemic to Indochina, with a further one endemic to mainland Southeast Asia and two restricted to southern China and Indochina.

Indochina Endemics
Altingia cambodiana – Tree 8-10 m in height and 30 cm in diameter; wet soils on the edge of waterfalls; known only from the Elephant Mountains in Kampot Province, Cambodia
Altingia poilanei – Tree of pyramidal form reaching 10-11 m in height; known on ly from Hoang Lien Son Province in northern Vietnam
Altingia takhtajanensis – Tree 15-30 m in height and 30 cm in diameter;
Distylium annamicum – Tree reaching 7-10 m in height or liana to 2 m; growing in clay forest soils at 1,100-1,800 m elevation; known only from the Massif du Baian in Haut Donnai Province, southern Vietnam
Embolanthera glabrescens – Shrub or small tree; known only from Tien Yen Province in northern Vietnam
Eustigma balansae – Small tree reachin 6-8 m; known from four provinces in Vietnam (Lao Kay, Ninh Binh, Sontay and Quang Nam)
Symingtiona tonkinensis – Tree, 20-30 m in height; growing in dense humid forests at 1,500-2,000 m elevation; known from Laos (Xieng Khouang Province) and Vietnam (Hoang Lien Son, Kontum, Quang Nam-Da Nang, Thua Thien and Haut Donnai Provinces)

Mainland Southeast Asian Endemics
Altingia siamensis – Laos, Vietnam and Thailand

Southern China – Indochina Endemics
Altingia yunnanenis – Vietnam and southern China
Mytilaria laosensis – Laos and southern China

Hernandaceae

There are three genera and eight species of the primitive family Hernandaceae in Indochina (Kuitzki 1970). Two of these species are endemic to mainland Southeast Asia and one to southern China and mainland Southeast Asia.

Mainland Southeast Asia Endemics
Illigera pierrei – Vietnam and Thailand
Illigera thorelii – Cambodia, Laos, Vietnam and Thailand

Southern China – Indochina Endemic
Illigera rhodantha – Cambodia, Laos, Vietnam and southern China

Nyssaceae

There are just two species of the genus *Nyssa* in Indochina representing this family, and one of these is restricted to southern China and northern Vietnam.

Southern China – Indochina Endemics
Nyssa sinensis – northern Vietnam and Hainan Island

Rhizophoraceae

There are 15 species of Rhizophoraceae in Indochina where the family includes the genera *Rhizophora* (3 species), *Brugiera* (4 species), *Ceriops* (2 species) and *Kandelia* (1 species) which are widespread and significant components of coastal mangrove forests. Two other upland genera, Anisophyllea (1 species) and Corallia (4 species), are probably better placed into the Anisophyllaceae. Only a single endemic species is present.

Indochinese Endemics
Anisophyllea perrinervata – Tree; growing in montane forests up to 2,000 m elevation; known only from Haut Donnai Province in southern Vietnam

Sabiaceae

The Sabiaceae include two genera and 35 species in Indochina, with indications of active speciation in this region in Vietnam and southern China. A remarkable 22 of these (plus two varieties of a widespread species), largely in the genus *Meliosma*, are endemic Indochina and an additional 11 species are restricted to southern China and Indochina.

Indochina Endemics
Meliosma cambodiana
Meliosma caudata
Meliosma cinerea
Meliosma clemensiorum
Meliosma coriacea
Meliosma doliobotrys
Meliosma kontumensis
Meliosma longepaniculata
Meliosma longipes
Meliosma icrocarpa var. angustata
Meliosma microcarpa var. chapensis
Meliosma nana
Meliosma ochraceae
Meliosma pakhaensis
Meliosma petelotii
Meliosma quangnamensis
Meliosma simang
Meliosma spathulata
Meliosma stenophylla
Meliosma thorelii
Meliosma tonkinmensis -
Sabia kontumensis –
Sabia parviflora var. harmandiana -
Sabia uropetala -

Southern China – Indochina Endemics
Meliosma angustifolia - Vietnam and southern China
Meliosma buchananifolia – northern Laos and Vietnam and southern China
Meliosma depauperata - northern Vietnam and southern China
Meliosma dumicola – northern Vietnam and southern China
Meliosma forrestii - northern Vietnam and southern China
Meliosma harmandiana - northern Vietnam and southern China
Meliosma lauii – southern Vietnam and southern China
Meliosma paupera – southern Vietnam and southern China
Meliosma velutina - northern Vietnam and southern China
Sabia fasciculata – Vietnam, Burma and southern China
Sabia olacifolia – northern Vietnam and southern China

Sonneratiaceae

Four species of Sonneratiaceae occur in Indochina, including *Sonneratia* (3 species) which are widespread and important trees in mangrove forests throughout the Old World tropics and *Duabanga* (1 species) which is a large wind-dispersed tree widespread throughout humid Southeast Asia. None of these species are endemic to Indochina or mainland Southeast Asia.

Symplocaceae

The Symplocaceae are represented in Indochina by a single genus *Symplocos* with 33 indigenous species (Nooteboom and Vidal 1977). This is a group with strong affinities to montane communities of China to the north, which shares 18 of these species. There are seven species of *Symplocos* endemic to Indochina and a total of nine species including these that are endemic to mainland Southeast Asia.

Indochinese Endemics

Symplocos annamensis – Shrub or small tree; submontane forests at 700-900 m elevation; known only from southern Vietnam (Lam Dong and Khanh Hoa Provinces)

Symplocos banaensis – Shrub or small tree reaching to 10 m in height; grows in forests at 700-1200 m elevation; known only from Vietnam (Quam Nam and Khanh Hoa Provinces)

Symplocos cambodiana – Shrub or tree reaching to 10 m in height; forest at 400-1300 m elevation; known only from Cambodia (Kandal, Kompong Speu and Koh Kong Provinces), Laos (Champassak and Nong Ban Cao Provinces), and Vietnam (Vinh Phuc, Quang Nam, Kontum, Khanh Hoa, Tuyen Duc and Lam Dong Provinces)

Symplocos disepala – Tree reaching to 12 m in height and 70 cm in diameter; 400 m elevation; known only from single location on Dong Ché massif in Quang Tri Province of central Vietnam

Symplocos guillanminii – Shrub reaching 6 m in height; growing up to 1800 m elevation; Vietnam (Ninh Thuan, Long Khanh, Bihn Thuan, Phuoc Tuy and Bien Hoa Provinces)

Symplocos olivacea – Known only from Mau Son massif in Lang Son Province of northern Vietnam.

Mainland Southeast Asian Endemics

Symplocos longifolia – Cambodia, Laos, Vietnam and Thailand

Symplocos megalocarpa – southern Vietnam and Thailand

Southern China – Indochina Endemics

Symplocos atriolivacea – southern Vietnam and southern China

Symplocos dolichotricha – northern Vietnam and southern China

Symplocos groffii – northern Vietnam and southern China

Flora of Cambodia, Laos and Vietnam

There are no accurate estimates of the size of the total flora of vascular plants naturally occurring in Cambodia, Laos and Vietnam. Schmid (1989) suggests that there are presently about 10,000 species known to be present in this area. Given the imperfect history of collecting over the region, he suggests that the total flora of native species

might be between 12,000 and 15,000. Bibliographies of published studies of the Indochina flora have been published, each covering sequential periods of time (Pételot 1955, Vidal 1972, Vidal et al. 1988, 1994). In progress at this time is an international flora project for Indochina, *Flore du Cambodge, Laos et du Viêt-Nam*, published by the Musém National D'Histoire Naturelle in Paris. Beginning in 1960, this series had completed 29 volumes through 1997. These volumes include 74 families of vascular plants, less than 20% of the expected total. An earlier series, *Flore Generale de L'Indochine*, was published in Paris from 1907-1950.

Conservation Priorities - Regions of Indochina of Particular Floristic and Ecological Significance

1 Principles for the Selection of Conservation Areas

The following principles should be considered in designating regions of particular floristic significance for conservation:

a. Habitats not well represented outside of Indochina;
b. Habitats with high floristic diversity;
c. Habitats with high levels of endemism;
d. Habitats with significant rare and endangered species.

At a broader scale of consideration, critical habitats to be protected should have:

a. Protection of landscape areas which allow maintenance of critical ecosystem processes;
b. Intact food webs for ecological species interactions;
c. Minimal habitat fragmentation;
d. Sustainable ecological units under future human activities;
e. Viable population sizes and genetic diversity.

Important questions for the future:

a. What are the key data needs in understanding diversity and ecosystem processes for key habitats?
b. What are the uncertainties in establishing and administering conservation priorities?
c. What are the sociological issues that impact questions of resource management?

2. Problems in Designating Priority Areas for Conservation

The criteria described above for the selection of priority areas for conservation are difficult to apply on the basis of available data on the floristic and biogeographic patterns of distribution of vascular plant species across Cambodia, Lao and Vietnam. The paucity of data makes it impossible to adequately assess the comparative levels of species richness and endemism with any degree of confidence across the region. One approach that can be used is to identify broad areas where limited data suggests high levels of species richness and endemism. These would include wet evergreen forest habitats of the Cardamom and Elephant Ranges in Cambodia, the Annamite Range in Vietnam, and the Bolovens Plateau of southern Lao. Endemism in Indochina appears to reach its highest relative levels in montane forest habitats, and these can thus also be considered high priority areas for conservation.

In addition to areas of Indochina with high species richness and endemism, here are broad forest habitats in which the diversity of species is lower and endemism is seen at a regional level more than at a local level. Semi-evergreen forest, deciduous dipterocarp forest, and swamp forests are good examples of these forest habitats where conservation priorities should be aimed at preserving broad areas where natural ecosystem processes can continue to operate. Natural mosaics of semi-evergreen and deciduous dipterocarp forest were once widespread in Indochina, and preservation of these landscape mosaics may be ecologically significant in allowing large animal populations to survive.

While plant species richness and vertebrate species richness may not always be directly linked, it must be kept in mind that plant-animal interactions are critical in the maintenance of functioning forest ecosystems. Significant interactions involving vertebrate animals include pollination and fruit dispersal. The great majority of forest tree species in mainland Southeast Asia are animal dispersed, and this interaction is critical in maintaining forest health.

An important issue in defining appropriate conservation priorities is thorough evaluation of the ecological and evolutionary significance of migration corridors. While migration corridors are commonly discussed in the context of their significance to animal populations in ecological time, they may also be critical elements for plant populations in evolutionary time. Gallery forests in particular appear to be significant in gene flow between wet forest ecosystems in the Greater Annamite Bioregion.

The lack of detailed data on the floristics and ecological structure and functioning of forest ecosystems in Cambodia, Lao, and Vietnam is a serious deficiency in adequate planning for conservation priorities. This region is one of the most poorly known areas floristically in the world despite its remarkable diversity, evolutionary history and unusual forest communities.

3. Areas of Notable Floristic Interest and/or Significance within the Central Indochina Dry Forest, Greater Annamite, and Cardamom Mountains Bioregions

The following annotated list of areas of notable floristic interest and/or significance within the Central Indochina Dry Forest, Greater Annamite, and Cardamom Mountains Bioregions should be considered preliminary. More refinement of priority areas for conservation will require a much more detailed data base on forest structure and diversity.

3.1 Northern Annamite Range - Greater Annamite Bioregion. Diverse area including both lowlands with limestone substrates in Cuc Phuong National Park in Vietnam and extending westward into mountainous areas of northern Lao. Phou Bia reaches 2,819 m at the western margin of this region. Much of this extensive area receives more than 3,000 mm of annual rainfall. Little is known about forest structure or composition in the upland areas of this region. Nam Chuane represents a large forest preserve area within the Lao portion of this region. The low elevation Cuc Phuong National Park in Vietnam, despite relatively limited topographic diversity, has a very high floristic diversity (Thin 1996). **HIGH PRIORITY**

3.2 Nakai Plateau Region - Greater Annamite Bioregion - Extensive areas of relatively pristine dry evergreen forest and montane forest cover this region which lies at the juncture between the central Indochina Dry Forest and Greater Annamite Bioregions. Quantitative data on forest structure and floristic diversity is lacking for this area. This area grades to the south into the central Annamite limestone belt. **HIGH PRIORITY**

3.3 Central Annamite Limestone - Greater Annamite Bioregion. This region of limestone parent material extends as a broad band of marine limestone with karst topography across central Lao and Vietnam. Schmid (1974) suggests that this area is likely rich in endemic species, but provides no data. Other Vietnamese scientists also feel that this area is likely rich in endemic plant species. The karst topography makes access to this region difficult, and thus the area has been relatively protected from heavy human impact. **HIGH PRIORITY**

3.4 Northern Annamite Wet Evergreen Forests - Greater Annamite Bioregion. Wet evergreen forests in the northern Annamite range around Pu Mat and Bu Huong Nature Reserves in Nghe An Province exhibit high species richness and many endemic species. Only preliminary floristic and ecological data is available for these areas. **HIGH PRIORITY**

3.5 Southern Annamite Range in Lao - Central Indochina Dry Forest Bioregion. Xe Kong Nam Kong, and Dong Ampham area are examples of a region in which there is a need to preserve examples of dry evergreen forest and seasonal montane forest with moderate rainfall. **MODERATE PRIORITY**

3.6 Kontum Massif - Greater Annamite Bioregion. The Kontum Massif presents a large area of granite basement rock as a primary substrate. This region at the southern portion of the greater Annamite Range is expected to be rich in species diversity and endemism. The Massif includes peaks up to 2,598 m at Ngoc Linh. Much of the Kontum Massif receives high annual rainfall above 3,000 mm. Slopes at about 400-900 m elevation support a rich wet evergreen forest habitat, while higher elevations are dominated by humid montane forests with a diversity of both conifers and hardwoods. Although Schmid (1974) describes this area in some detail, there does not appear to be a thorough botanical survey of the Kontum Massif. Because of the granitic substrate, montane conifer forests would be expected to be well developed. **HIGH PRIORITY**

3.7 Bolovens Plateau - Greater Annamite Bioregion. The Bolovens Plateau of southern Lao combines the environmental conditions of nutrient-rich soils weathered from basalt parent materials and high annual rainfall which exceeds 3,000 mm. Although this area has been heavily impacted by clearance for agriculture because of its rich soils, extensive areas of relatively undisturbed submontane and montane habitat remain. These forest areas are rich in species diversity and endemism. **HIGH PRIORITY**

3.8 **Lower Mekong Wetlands and Swamp Forests in Lao.** Unique areas of wetlands and swamp forests occur along the Mekong in Champasak Province in southern

Lao. These wetlands and swamp forests are not notably rich in species or endemism, but protect unique habitats and peatlands. **HIGH PRIORITY**

3.9 Haut Chhlong and Haut Cochinchine Plateaus - Greater Annamite Bioregion. The west slopes of the Haut Chhlong and Haut Cochinchine region support wet evergreen rainforest habitat with more than 3,000 mm annual precipitation. This area is largely formed of basalt parent material, and this substrate combined with high rainfall produces rich soils which support dense evergreen forests. There has been little study of these wet forests, and they provide a highly restricted component of the high biodiversity of the Greater Annamite Bioregion. Much of this area has been cleared for agriculture. The preservation and restoration of gallery forests along river corridors should be given a high priority. Nam Bai Cat Tien National Park with its rich wetlands covers an area of 36,500 ha at low elevation at the southern margin of this region. **HIGH PRIORITY**

3.9 Dalat Plateau - Greater Annamite Bioregion. This region centers on a montane of granitic area rich in diversity and with interesting endemic species. Dry conifer forests of *Pinus* and *Keteleeria* mix with hardwoods at about 1,200-1,500 m elevation. Wetter mixed conifer-hardwood forests at 1,500-1,800 m elevation contain two pines endemic to this region, as well as the rare *Fokienia hodginsii* and another of other unusual conifers. Overall, there are at least 16 species of conifers known to occur in this area, many with highly restricted distributions. The highest elevation of this region is reached at 2,405 m at Chu Yang Sin. Three small forest reserves provide some protection for this area, but expanding population density and economic development threaten these forests. **HIGH PRIORITY**

3.10 Coastal dune forests near Cam Ranh Bay - Greater Annamite Bioregion. Stabilized red dunes support a coastal forest with two locally endemic species of Dipterocarpaceae. Schmid (1974) describes this area in some detail. **MODERATE PRIORITY**

3.11 Dangrek Range - Central Indochina Dry Forest Bioregion. This low range along the border between Cambodia and Thailand is poorly studied, and the danger from landmines has kept biologists out of this area in recent years. Schmid (1974) suggested that the Dangrek Range may harbor interesting endemics, but there is no field data to support this claim. This area likely retains good but not unique examples of dry evergreen forest. No reasonable database on floristic diversity exists. **LOW TO MODERATE PRIORITY.**

3.12 Eastern Cambodia along the foothills of the Annamite Range - Central Indochina Dry Forest Bioregion. A relatively low population density in eastern Cambodia along the border area with Vietnam provides a mosaic of dry evergreen forest, deciduous dipterocarp woodlands, and agricultural areas. These areas provide good but not unique examples of these forest types, but the scale of occurrence of these habitats provides a landscape of potential great value in preserving viable populations of large mammals. Detailed surveys of forest structure and floristic diversity of this area have not been made. **MODERATE PRIORITY**

3.14 Tonle Sap Swamp Forests - Central Indochina Dry Forest Bioregion. The extensive freshwater swamp forests that once surrounded Tonle Sap have been heavily degraded by human activities. While this impact has extended over many centuries, it has accelerated in recent decades. Although the overall species diversity in these swamp forests is not high, as is typical of such habitats, there are important endemic elements that have been identified among the tree species. The ecological role of these swamp forests and wetlands, however, is much more than their plant biodiversity suggests. These are critical habitats for a complex ecosystem structure and function that is critical for wildlife and for the hydrological geomorphological integrity of the region. **HIGH PRIORITY**

3.15 Cardamom and Elephant Mountains - Cardamom Range Bioregion. These mountain ranges in Cambodia have unusually high rainfall and thus support a rich community of wet evergreen rainforest with both Indo-Malaysian and Annamite affinities. Included in these forests are unusual bog communities of dwarf conifers. The region is almost certainly high in endemism and diversity, but is not well studied. Bokor National Park in the Elephant Range has received limited study of community structure and floristic diversity because of its access, but these limited studies indicate a high degree of local endemism among woody plant species. Floristic diversity and endemism is expected to also be high on the southwest face of the Cardamom Range. The Kirirom Plateau on the northern margin of the Elephant Range supports the largest stands of *Pinus merkusii* in Cambodia. While once relatively undisturbed because of their isolation and the absence of hill tribes, these ranges have experienced increasing logging pressure in recent years. **HIGH PRIORITY**.

4. Indochina Regions of High Conservation Value Outside of the Central Indochina Dry Forest and Greater Annamite Bioregions

4.1 Cao Bang Province of Vietnam. This mountainous area along the Chinese border is rich in species of Sino-Himalayan relationship occurring nowhere else in Indochina. The priority for conservation of this area depends on the nature of conservation management of adjacent areas of China. Extensive areas of limestone parent material and karst topography exist in this area, suggesting the possibility of edaphic endemics. Ba Be National Park exists in this area. Much of this region has been heavily impacted by swidden agriculture. No reasonable database on floristic diversity exists. **MODERATE PRIORITY**

4.2 Fan Si Pan Massif. This area of northern Vietnam represents an extension of the Yunnan Mountains into Indochina, and includes the highest mountain of this region. Schmid (1974) reports a high level of endemism in the high mountain flora, but it is likely that many of these species occur in Yunnan Province of China as well. Fir/hemlock forests occurring here at high elevations are unique in Indochina. Much of this region has been heavily impacted by swidden agriculture. **HIGH PRIORITY**

4.3 Mekong Valley near Luang Prabang. Schmid (1974) suggests that this area of Lao once held the best examples of mixed deciduous forest with teak in Indochina. Most of the Mekong valley has been heavily impacted by man in the past century. It is not clear how extensive today are existing examples of mixed deciduous forest. There are similar areas that currently have a protected status in northern Thailand. **HIGH PRIORITY**.

4.4 Mangrove forests of southern Cambodia and Vietnam. These mangrove forests, among the most diverse in Asia, have been heavily impacted by human activities in recent years, and were heavily degraded by spaying with herbicides during the Vietnam War. Large scale efforts at reforestation with mangroves in the Mekong Delta area has been successful in slowly restoring mangrove forest cover, but biodiversity has not adequately recovered. **HIGH PRIORITY**

4.5 Mangrove forests of the Red River delta. Little area of this mangrove forest remains. While it is not floristically unique, mangrove forests provide highly valuable ecosystem services and promote biotic diversity. **HIGH PRIORITY**

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