# TROPICAL FORESTS OF THE CARDAMOM MOUNTAINS: SPECIES COMPOSITION AND VERTICAL STRUCTURE

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## Introduction

Vegetation studies have been conducted in Cambodia from the middle of the last century, mainly by French botanists. These resulted in the floristic summary "Flore Generale de l´Indochine" (Lecompte, 1907-1942), as well as the works by Rollet (1972) and Dy Phon (1982 and also 1970, 1999, 2000 - cited by Webb, 2005). From the national declaration of independence in 1954 until the mid 1990's, little botanical research was undertaken and only some of this was published. This included a survey of lowland forests west of the Cardamom Mountains by Ashton (1971). From the mid 1990s onwards, floral and faunal studies were undertaken in the Cardamom Mountains to justify the development of protected areas. This research continues today through the efforts of international conservation organizations such as Flora & Fauna International (FFI), BirdLife International in Indochina and Worldwide Fund for Nature.

In the published literature, the most informative works are those of Webb (2003, 2005) which include vegetation maps for two regions within the Cardamom Mountains: Phnom Aural Wildlife Sanctuary and Phnom Samkos Wildlife Sanctuary. In addition, Webb (2003, 2005) and Rundell (1999) cites the work of Dy Phon (1970, 1999, 2000) who is thought by many to have the greatest botanical knowledge for Cambodia. In describing the different types of forest vegetation in the Cardamom Mountains, Webb (2003, 2005) lists dominant families of trees, some genera and in isolated cases species of forest plants. In Momberg and Weiler (1999) and Daltry and Traeholt (2003), such lists are short, while Meng et al. (2000) listed local Khmer names of plants and characteristic plants of differing life forms. As these publications do not describe forests of the Cardamom Mountains in detail, the aim of present work is to fill a gap in knowledge of species composition and vertical structure of primary forests in the region.

## Materials and Methods

Studies of forest vegetation within Phnom Samkos Wildlife Sanctuary of the Cardamom Mountains were undertaken from 10 to 23 December 2010.

In the south-western part of Cambodia, the Cardamom Mountains are folded-block and composed of crystalline rocks and Mesozoic sandstones. The mountains are divided into a number of individual massifs (Alexeeva, 2000) and reach approximately 1,700 m a.s.l. (Webb, 2005), with the dominant height of 1,100-1,200 m a.s.l.

Our studies were conducted in flat areas from 150 to 200 m a.s.l., on the northern slopes of Phnom Samkos, adjacent to the Samkos-Kmoach plateau, and on the plateau itself (north and central part). The vertical extent of the northern macro-slope spans ca. 1,000 m. On the bottom part, the slope is relatively shallow (10-20$^{o}$), while in the middle flat areas alternate with slopes of approximately 40-50 $^{o}$, while the upper slopes (about 200 m below the plateau) are close to vertical. The plains and the bottom part of the slope are predominantly covered by soils developed on schists, while in the middle part of the slope these schists are gradually replaced by sandstone. The hydrological network is poorly developed on slopes; narrow (1-1.5 m wide) and deep (up to 2 m) forest streams sporadically occur in relief beds. The surface of the Samkos-Kmoach plateau surface is slightly undulating. However, terraces varying in height from 70-100 m also occur in this generally flat terrain and are sometimes steep with slopes up to 60°, as do ridges over 400 m in height.

The climate of Cambodia is monsoonal (which is characteristic of Indochina) with two distinct seasons: dry from December to May and wet from June to November. According to Daltry (2002), the average daily temperature each ranges from 25 to 30°C in the plains and is about 20°C in mountain areas over 1,000 m a.s.l., while annual rainfall is about 3,000 mm.

A geo-botanical survey was conducted by compiling descriptions of survey routes up to 5 km in length the periodic recording of geo-coordinates, in addition to sampling of forest plots measuring 60 x 40 m. Methods used followed (Dilis, 1974) and aimed to describe forest stands in sample areas. According to this scheme, routes (transects) extending in different directions were first established. Representative areas of forest stands were selected from these, which were then sampled using forest plots. On forest plots, detailed descriptions of vegetation and vertical structure of forest stands were compiled. The diameter of tree trunks was measured at breast height (DBH: conventionally at 1.30 m from the ground or immediately above buttresses if present). Tree height and crown radius were estimated visually, while fallen trees were measured directly.

Species identification was undertaken using Gardner (2000) and Pham Hoang Ho (1999-2000), who has with more than 20 years of experience studying forest areas in Vietnam, Laos, Indonesia and Malaysia. Plant species names are in accordance with Pham Hoang Ho (1999-2000), while names of families follow Takhtajan (1987).

**Results**

Areas surveyed in the Phnom Samkos area, as well as the adjacent forested plains, differ in the degree of conservation of forest stands. Deforestation for agricultural development has occurred on plains. On the slopes of the Cardamom Mountains, especially lower areas, commercial logging takes place. Primary forest is present on the mountain plateau, though here local people also extract timber and non-timber products such as plants and plant bark for medical purposes, including the sap of certain trees (particularly in the *Garcinia* genus). Forests in lowland areas (150-200 m a.s.l.), on slopes and on the plateau at altitudes of 900-1000 m a.s.l. are dominated by trees in the Dipterocarpaceae family. In the northern part of the plateau and on ridges on the inner plateau, poly-dominant forests of Dipterocarpaceae trees occur.

**Lowland forests**

In lowland areas with outcrops of igneous plain rocks (tuffs), and crystalline schists, low stature forests (4-7 m) dominated by *Dipterocarpus tuberculatus* occur (Fig. 1). Co-dominants in these forests include trees such as *Shorea obtusa* (Dipterocarpaceae), *Terminalia* cf. *mucronata* (Combretaceae), *Aporusa villosa* (Euphorbiaceae) and *Morinda tomentosa* (Rubiaceae). The palms *Corypha lecomtei* also occurs, reaching up to 10 m in height. In areas with thin medium-clay soils underlain by schist, tree heights range from 14-18 m and forest stands are stratified into two storeys. The first or upper (canopy) storey is nearly complete, the second fragmentary. In the upper layer, *D. tuberculatus*, *D. obtusifolius*, *Shorea obtusa* (Dipterocarpaceae) and *Irvingia malayana* (Irvingiaceae) co-dominate, while the following species are also present: *Bombax anceps* (Bombacaceae), *Careya arborea* (Lecythidaceae), *Haldina cordifolia* (Rubiaceae) and *Parinari anamens* (Chrysobalanaceae). Among understorey trees, the presence of species such as *Buchanania siamensis* (Anacardiaceae) and *Phyllanthus emblica* (Euphorbiaceae) is remarkable.

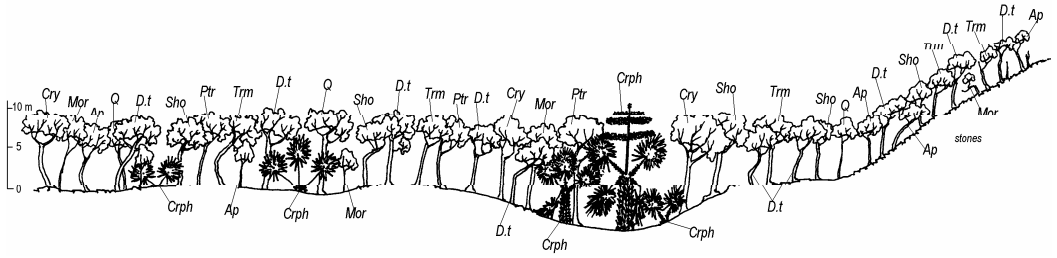


**Fig. 1.** Vertical profile of the light lowland forest on basalts, 150-200 m a.s.l.

Ap - *Aporusa* cf. *villosa*, Crph - *Corypha* cf. *lecomtei*, Cry - *Careya arborea*, D.t - *Dipterocarpus tuberculatus*, Mor - *Morinda* cf. *tomentosa*, Ptr - *Pterocarpus macrocarpus*, Q - *Quercus*, Sho - *Shorea* cf. *obtusa*, Trm - *Terminalia* cf. *mucronata.*

In lowland areas with deep lateritic soils underlain by metamorphosed shists, forests attain a height of 40-45 m and posses five storeys (Fig. 2). *Dipterocarpus alatus* dominates the upper tree layer and the following trees also occur: *D. costatus*, and, presumably, *D. dyeri* (Dipterocarpaceae), *Artocarpus* cf. *chaplasha* (Moraceae) and *Bombax* cf. *ceiba* (Bombacaceae). The second storey comprises tree species including *Anisoptera costata*, *Hopea odorata*, *Shorea* cf. *roxburghii* (Dipterocarpaceae), *Combretum quadrangulare*, *Terminalia* sp. (Combretaceae), *Lagerstroemia calyculata* (Lythraceae), *Parinari anamensis* (Chrysobalanaceae), *Swintonia floribunda* (Anacardiaceae), *Tarrietia javanica* (Sterculiaceae), *Tetrameles nudiflora* (Datiscaceae) and members of the *Ficus* genus (Moraceae), the latter being semi-epiphytes transformed into large (sometimes enormous) trees. In the third layer, the following trees are found: *Parkia* cf. *sumatrana*, *Peltophorum pterocarpum*, *Dalbergia* spp. (Leguminosae), *Spondias pinnata* (Anacardiaceae), *Calophyllum* sp., *Garcinia* sp. (Guttiferae), *Cinnamomum* sp. (Lauraceae), *Elaeocarpus* sp. (Elaeocarpaceae), *Nephelium* sp., *Xerospermum noronhianum* (Sapindaceae), *Syzygium* sp. (Myrtaceae), cf. *Chisocheton*, Gen. sp. (Meliaceae), Gen. sp. (Bignoniaceae). In the fourth layer, *Hibiscus macrophyllus* (Malvaceae) and *Knema* sp. (Myristicaceae) dominate, while the following also occur: *Acronychia pedunculata* (Rutaceae), *Carallia brachiata* (Rhizophoraceae), *Diospyros buxifolia*, *Diospyros* sp. (Ebenaceae), *Fagraea fragrans* (Gentianaceae), *Livistona* cf. *saribus* (Palmae), *Sterculia urena*, *Pterospermum* sp. (Sterculiaceae), *Suregada multiflora*, *Aporusa* sp., *Baccaurea* sp. (Euphorbiaceae), *Colona* sp. (Tiliaceae), *Dillenia* sp. (Dilleniaceae), *Ficus* spp. (Moraceae), *Polyalthia* spp. (Annonaceae), *Syzygium* sp. (Myrtaceae), *Vitex* sp. (Verbenaceae), cf. *Barringtonia* (Lecythidaceae). Finally, the fifth storey or understorey (1.5-5 m) includes such tree species as *Caryota mitis*, *Didymosperma* cf. *caudatum*, *Pinanga* cf. *quadrijug*a, Gen. sp. (Palmae), *Cratoxylum formosum* (Guttiferae), *Euodia lepta*, *Clausena* sp. (Rutaceae), *Leea rubra* (Leeaceae), *Memecylon floribundum*, *Memecylon* sp. (Melastomataceae), *Goniothalamus elegans* (Annonaceae), *Psychotria* cf. *adenophylla*, *Lasianthus* sp. (Rubiaceae), *Rinorea anguifera* (Violaceae), *Streblus ilicifolia* (Moraceae), *Syzygium longifolia* (Myrtaceae), *Allophyllus* sp. (Sapindaceae), *Antidesma* spp., *Breynia* sp., *Croton* sp., *Glochidion* sp., *Phyllanthus* sp., *Trigonostemon* sp. (Euphorbiaceae), *Ardisia* spp. (Myrsinaceae), *Grewia* sp. (Tiliaceae) and cf. *Walsura* (Meliaceae).

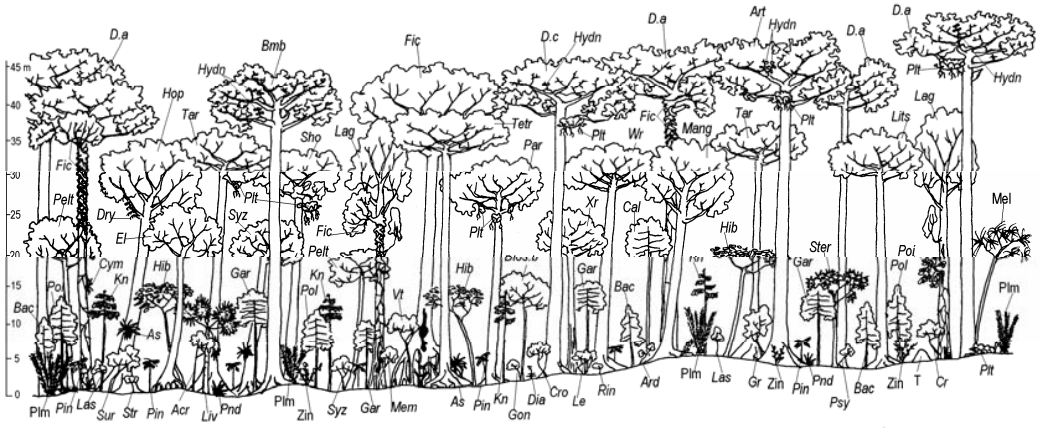


**Fig. 2.** Vertical profile of the high stem lowland forest, 200 m a.s.l.

Acr - *Acronychia pedunculata*, Ard - *Ardisia*, Art - *Artocarpus* cf. *chaplasha*, As - *Asplenium*, Bac - *Baccaurea*, Bmb - *Bombax* cf. *ceiba*, Cal - *Calophyllum*, Cr - *Carallia brachiata*, Cro - *Croton*, Cym - *Cymbidium*, D.a - *Dipterocarpus alatus*, D.c - *Dipterocarpus costatus*, Dia - *Dianella nemorosa*, Dios.b - *Diospyros buxifolia*, Dry - *Drynaria quercifolia*, Fic - *Ficus*, Gar - *Garcinia*, Glo- *Glochidion*, Gon - *Gonithalamus elegans*, Gr - *Grewia*, Hib - *Hibiscus* cf. *macrophyllus*, Hop - *Hopea odorata*, Hydn - *Hydnophytum formicarum*, Kn - *Knema*, Lag - *Lagerstroemia* cf. *calyculata*, Las - *Lasianthus*, Le - *Leea*, Liv - *Livistona* cf. *saribus*, Mang - *Mangifera*, Mel - Meliaceae, Mem - *Memecylon* cf. *floribundum*, Par - *Parinari annamense*, Pelt - *Peltophorum* cf. *pterocarpum*, Pin - *Pinanga* cf. *quadrijuga*, Plm - Palmae, Plt - *Platycerium* cf. *grande*, Pnd - *Pandanus*, Poi - *Poikilospermum* cf. *suaveolens*, Pol - *Polyalthia*, Psy - *Psychotria*, Rin - *Rinorea*, Rub - Rubiaceae, Sho - *Shorea* cf. *roxburghii*, Ster - *Sterculia* cf. *urena*, Str - *Streblus*, Syz - *Syzygium*, Sur - *Suregada* cf. *multiflora*, T - termits, Tar - *Tarrietia javanica*, Tetr - *Tetrameles nudiflora*, Vt - *Vitex*, Wr - *Wrightia*, Xr - *Xerospermum*, Zin - Zingiberaceae.

The complexity of the forest vertical structure determines the abundance of plant forms such as lianas, epiphytes and semi-epiphytes. Lianas belonging to the following genera were found: *Abrus*, *Acacia*, *Bauhinia*, *Caesalpinia*, *Dalbergia*, *Entada*, *Pterolobium* (Leguminosae), *Adenia* (Passifloraceae), *Alyxia*, *Strophanthes*, *Vallaris* (Apocynaceae), *Ampelopsis*, *Cissus*, *Tetrastigma* (Vitaceae), *Argyreia*, *Ipomoea*, *Neuropeltis* (Convolvulaceae), *Artabotrys*, *Desmos*, *Fissistigma*, *Uvaria* (Annonaceae), *Calamus*, *Korthalsia*, *Daemonorops* (Palmae), *Calycopteris*, *Combretum* (Combretaceae), *Congea*, *Gmelina*, *Sphenodesma* (Verbenaceae), *Connarus*, *Rourea* (Connaraceae), *Dioscorea* (Dioscoreaceae), *Fibraurea*, *Stephania*

(Menispermaceae), *Flagellaria* (Flagellariaceae), *Gnetum* (Gnetaceae), *Jasminum* (Oleaceae), *Lygodium* (Schizeaceae), *Ventilago*, *Ziziphus* (Rhamnaceae), *Piper* (Piperaceae), *Pothos*, *Raphidophora* (Araceae), *Stemona* (Stemonaceae), *Strychnos* (Loganiaceae), *Streptocaulon*, *Toxocarpus* (Asclepiadaceae), *Tetracera* (Dilleniaceae), *Thunbergia* (Acanthaceae), *Trichosanthes* (Cucurbitaceae), *Uncaria* (Rubiaceae) and *Harrisonia perforata* (Simaroubaceae).

The following epiphytic plants develop in the tree crowns of the upper tree layer: ferns *Drynaria quercifolia*, *Platycerium* cf. *grande*, *Pyrrosia* sp. (Polypodiaceae), and also *Hedychium bousigonianum* (Zingiberaceae) and *Hydnophytum formicarum* (Rubiaceae), the latter including large specimens with tuberous stem diameter of up to 20 cm; *Remusatia vivipara* (Araceae), *Aeschinanthus* sp. (Gesneriaceae), and a variety of orchids including *Dendrobium secundum*, *Dendrobium* spp., *Trichotosia dasyphylla*, *Cymbidium* sp. and *Luisia* sp. Among semi-epiphytes, *Poikilospermum* cf. *suaveolens* (Cecropiaceae), *Fagraea auriculata* (Gentianaceae) and *Ficus* spp. (Moraceae) can also be usually found.

At forest gaps and along forest trails, several large (up to 4 m high) herbaceous plants are abundant: *Cenolophon* cf. *oxymitrum*, *Ahasma* sp., *Zingiber* sp., cf. *Alpinia* (Zingiberaceae); *Calatea clossoni*, *Donax cannaeformis* (Marantaceae), *Costus speciosus* (Costaceae) and *Lindernia* sp. (Scrophulariaceae). Under the tree canopy, herbs are fragmentary with a typical coverage of less than 10% and include *Aglaonema* cf. *fumeum*, *Alocasia* cf. *grata*, *Homalomena* sp. (Araceae), *Amischolotype* spp., *Cyanotis* spp., *Murdannia* spp. (Commelinaceae), *Biophytum* sp. (Oxalidaceae), *Clerodendrum* sp. (Verbenaceae), *Cyclacanthus coccinensis* (Acanthaceae), *Cyperus* spp., *Mapania* sp. (Cyperaceae), *Dracaena* sp. (Dracaenaceae), *Hedyotis* sp., *Ophiorrhiza* spp. (Rubiaceae), *Hupersia* sp. (Lycopodiaceae), *Pandanus* sp. (Pandanaceae), *Pellionia* sp. (Urticaceae), *Selaginella* sp. (Selaginellaceae), *Tacca* cf. *chantrieri* (Taccaceae), ferns *Bolbitis* cf. *anamensis* and *Tectaria* sp.

**Forests on mountain slopes**

Forest stands with a complex vertical structure (four storeys) which attain a height of 35 m occur on gentle mountain slopes. In the uppermost storey, *Dipterocarpus costatus*, *D. alatus* (up to 300 m a.s.l.), *Hopea odorata* and *Shorea* cf. *roxburghii* (up to 500 m a.s.l.) (Dipterocarpaceae) co-dominate, while *Tarrietia javanica* (Sterculiaceae), *Wrightia* sp. (Annonaceae) and *Ficus* spp. (Moraceae) are

also present. The subordinate storeys are well developed. The second layer is characterized by the presence of *Balakata baccata* (Euphorbiaceae), *Gironniera* cf. s*ubaequalis* (Ulmaceae), *Parinari anamensis* (Chrysobalanaceae), *Peltophorum pterocarpum*, Gen. sp. (Leguminosae), *Swintonia floribunda*, *Mangifera* sp. (Anacardiaceae), *Artocarpus* sp. (Moraceae), *Calophyllum* sp. (Guttiferae), *Cinnamomum* sp., cf. *Litsea* (Lauraceae), *Elaeocarpus* sp. (Elaeocarpaceae), *Terminalia* sp. (Combretaceae) and Gen. sp. (Apocynaceae). In the third storey (6-14 m), *Knema* sp. (Myristicaceae) dominates, while *Diospyros buxifolia*, *Diospyros* sp. (Ebenaceae), *Livistona saribus* (Palmae), *Nageia* cf. *wallichiana* (Podocarpaceae), *Garcinia* spp. (Guttiferae), *Schefflera* sp. (Araliaceae), cf. *Chisocheton* (Meliaceae) and Gen. sp. (Rubiaceae) also occur. In the fourth storey, the palm *Pinanga* cf. *sylvestris* is common. The tree-fern *Cyathea* sp. (Cyatheaceae) also occurs from 500 m a.s.l. upwards.

Lianas are also numerous, and the following species are most characteristic: *Acacia* cf. *pinnata*, *Entada phaseoloides*, *Abrus* sp., *Bauhinia* sp. (Leguminosae), *Fibraurea tinctoria* (Menispermaceae), *Raphidophora* cf. *decursiva* (Araceae), *Thunbergia grandiflora*, *T. geoftrayi* (Acanthaceae), *Ampelopsis cantoniensis* (Vitaceae), *Artabotrys* sp., *Fissistigma* spp. (Annonaceae) and *Ancistrocladus* sp. (Ancistrocladaceae). Among the herbs, large ferns from *Cibotium* and *Tectaria* genera dominate, while the following plants also occur: *Asplenium normale* (Aspleniaceae), *Donax cannaeformis* (Marantaceae), *Egenolfia asplenifolia* (Lomariopsidaceae) and *Dracaena* sp. (Dracaenaceae).

**Forests on the Samkos - Kmoach plateau**

*Southern plateau*

The southern part of the Samkos-Kmoach plateau is shielded from air masses from the north and drizzling rains and mists are frequent even in the dry season.

On light sandy soils on sandstone underlain by metamorphosed schists, forest stands 25-40 m in height occur with a complex vertical structure of four storeys (Fig. 3), all of which are well developed. In the upper storey, the following trees occur: *Dipterocarpus turbinatus*, *Dipterocarpus* sp. (Dipterocarpaceae), *Podocarpus imbricatus* (Podocarpaceae), *Schima wallichii* (Theaceae), *Castanopsis* sp. (Fagaceae), *Ficus* sp. (Moraceae) and cf. *Wrightia* (Apocynaceae). In the second storey, tree species include *Anneslea fragrans* (Theaceae), *Sloanea* cf. *sinensis*, *Elaeocarpus* sp. (Elaeocarpaceae), *Quercus* sp. (Fagaceae), *Sterculia* sp.

(Sterculiaceae), cf. *Canarium* (Burseraceae) and *Syzygium* spp. (Myrtaceae). In the third storey, *Garcinia* species (Guttiferae) dominate, while *Archidendron* cf. *quocense* (Leguminosae), *Brassaiopsis* cf. *hainla*, *Schefflera* sp. (Araliaceae), *Diospyros buxifolia* (Ebenaceae), *Podocarpus neriifolius*, *Nageia* cf. *wallichiana* (Podocarpaceae), *Baccaurea* sp. (Euphorbiaceae), *Grewia* sp. (Tiliaceae), *Michelia* sp. (Magnoliaceae), *Polyalthia* sp. and Gen. sp. (Annonaceae) also occur. The palm *Livistona* cf. *saribus* is generally confined to temporary streams and depressions in the terrain though it is also found sporadically in the forest. Trees within the fourth layer include *Euodia* cf. *lepta* (Rutaceae), *Pinanga* cf. *sylvestris* (Palmae) and representatives of *Ardisia* (Myrsinaceae), *Lasianthus* (Rubiaceae), *Leea* (Leeaceae) and *Tabernaemontana* (Apocynaceae).

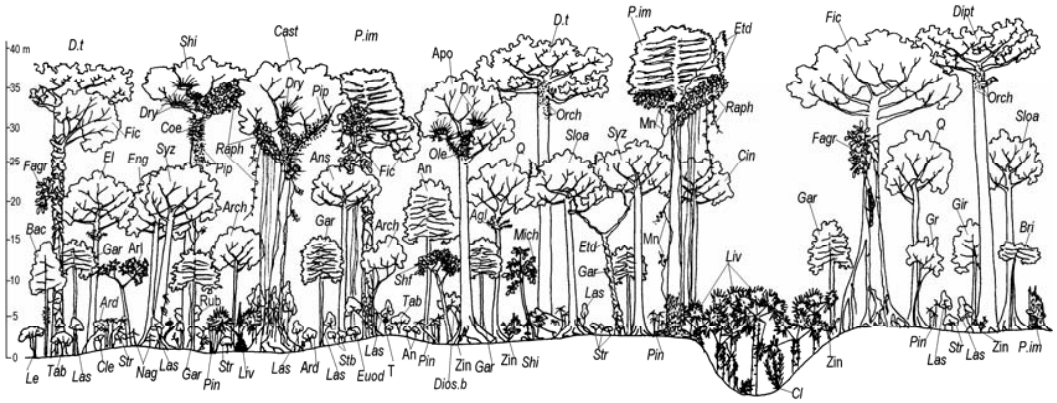


**Fig.3.** Vertical profile of the forest of southern part of mountain plateau, 1000 m a.s.l.

Agl - *Aglaomorpha* cf. *coronans*, An - Annonaceae, Ans - *Anneslea fragrans*, Apo - Apocynaceae, Arch - *Archidendron* cf. *quocense*, Ard - *Ardisia*, Arl - Araliaceae, Bac - *Baccaurea*, Bri - *Bridelia*, Cast - *Castanopsis*, Cin - *Cinnamomum*, Cl - *Calamus*, Cle - *Clerodendrum*, Coe - *Coelogyne*, D.t - *Dipterocarpus turbinatus*, Dios.b - *Diospyros buxifolia*, Dipt - *Dipterocarpus*, Dry - *Drynaria rigidula*, El - *Elaeocarpus*, Eng - *Engelchardtia* cf. *spicata*, Etd - *Entada* cf. *phaseoloides*, Euod - *Euodia* cf. *lepta*, Fagr - *Fagraea*, Fic - *Ficus*, Gar - *Garcinia*, Gir - *Girroniera*, Gr - *Grewia*, Las - *Lasianthus*, Le - *Leea*, Liv - *Livistona* cf. *saribus*, Mich - *Michelia*, Mn- Menispermaceae, Nag - *Nageia wallichiana*, Orch - Orchdaceae, Ole - *Oleandra* cf. *pistillaris*, P.im - *Podocarpus imbricatus*, Pin - *Pinanga* cf. *silvestrys*, Pip - *Piper* cf. *baccatum*, Q - *Quercus*, Raph- *Raphidophora*, Rub - Rubiaceae, Shf - *Schefflera*, Shi - *Schima wallichii*, Sloa - *Sloanea* cf. *sinensis*, Str - *Strobilanthes*, Syz - *Syzygium*, T - termits, Tab - *Tabernaemontana*, Zin - Zingiberaceae.

Lianas include *Fibraurea tinctoria* (Menispermaceae), *Piper* cf. *baccatum* (Piperaceae) and *Raphidophora* sp. (Araceae), and the following species are also present: *Acacia* cf. *pinnata*, *Entada* cf. *phaseoloides* (whose stems reach 40 cm in diameter), *Abrus* sp. (Leguminosae), *Anadendrum montanum*, *Pothos scandens* (Araceae), *Streptocaulon* cf. *horsfieldii* (Asclepiadaceae) and liana-like bamboo (Gen. sp.). The herb layer is fragmented and includes the following species: *Alocasia* cf. *grata* (Araceae), *Anoectochilus* cf. *roxburghii* (Orchidaceae), *Egenolfia asplenifolia* (Lomariopsidaceae), *Strobilanthes* cf. *maingayi* (Acanthaceae), *Taenitis blechnoides* (Adiantaceae), *Alpinia* spp., *Curcuma* sp., *Globba* sp. (Zingiberaceae), *Ardisia* sp. (Myrsinaceae), *Chirita* sp. (Gesneriaceae), *Clerodendrum* sp. (Verbenaceae), *Liriope* sp., *Peliosanthes* sp. (Convallariaceae), *Mapania* sp. (Cyperaceae), *Phrynium* sp. (Marantaceae), *Sonerilla* sp. (Melastomataceae) and *Tectaria* sp. (Dryopteridaceae).

Epiphytes are plentiful on the trunks and crowns of trees, mainly in the upper storey, and are particularly diverse in the crowns of *Schima wallichii*. The following epiphytic plants were observed in the crown of a fallen *Schima wallichii* (which previously occupied the first storey): *Bulbophyllum ignevenosum*, *Ceratostylis* cf. *subulata*, *Cleisostoma* cf. *williamsonii*, *Coelogyne* cf. *trinervis*, *Dendrobium* cf. *ellipsophyllum*, *D.* cf. *terminale*, *D.* cf. *parciflorum*, *Eria pannea*, *Microsaccum griffithii*, *Trichotosia dasyphylla*, *Luisia* sp. and *Oberonia* sp. (Orchidaceae), *Drynaria rigidula*, *Pyrrosia* sp. (Polypodiaceae), *Nephrolepis* sp. (Nephrolepidaceae) and *Oleandra* cf. *pistillaris* (Oleandraceae).

*Central and northern plateau*

Forest stands in central and northern parts of the plateau are poly-dominant, attain up to 25 m in height (rarely 35 m) and comprise three layers (Fig. 4). Tree trunks are covered with mosses and filmy ferns belonging to the Hymenophyllaceae family. The upper storey is composed of *Anneslea fragrans*, *Schima wallichii*, *Gordonia* sp., *Ternstroemia* sp. (Theaceae), *Kmeria duperreana* (Magnoliaceae), *Sloanea* cf. *sinensis*, *Elaeocarpus* sp. (Elaeocarpaceae), *Lithocarpus* sp., *Quercus* sp. (Fagaceae), *Podocarpus imbricatus* (Podocarpaceae); *Cinnamomum* sp., *Litsea* sp. (Lauraceae), *Syzygium* spp. (Myrtaceae) and *Dipterocarpus* trees (Dipterocarpaceae) occur sporadically. *Garcinia* sp. (Guttiferae) and *Livistona saribus* (Palmae) co-dominate the second storey, which also includes *Acronychia pedunculata*, *Euodia* cf. *pasteuriana* (Rutaceae), *Archidendron* cf. *quocense* (Leguminosae), *Betula alnoides* (Betulaceae), *Podocarpus neriifolius* (Podocarpaceae), *Rhododendron* cf. *moulmainense* (Ericaceae), *Aglaia* sp. (Meliaceae), *Baccaurea* sp. (Euphorbiaceae), *Grewia* sp. (Tiliaceae), *Michelia* sp. (Magnoliaceae), *Phoebe* sp. (Lauraceae), *Schefflera* sp., Gen. sp. (Araliaceae), *Symplocos* sp. (Symplocaceae) and members of the Annonaceae and Rubiaceae. *Pinanga* cf. *sylvestris* (Palmae) and *Eurya* sp. (Theaceae) dominate the third storey.

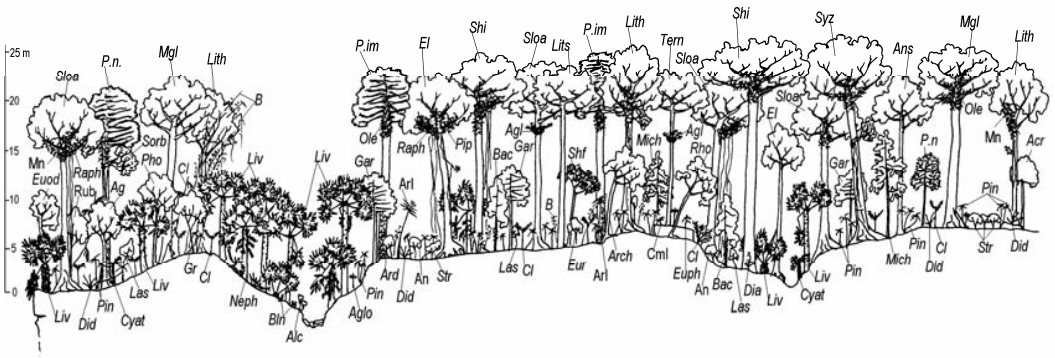


**Fig. 4.** Vertical profile of the forest of central part of the plateau, 1200 m a.s.l.

Acr - *Acronychia pedunculata*, Ag- *Aglaia*, Agl - *Aglaomorpha* cf. *coronans*, Aglo - *Aglaonema*, Alc - *Alocasia*, An - Annonaceae, Ans - *Anneslea fragrans*, Arch - *Archidendron* cf. *quocense*, Ard - *Ardisia*, Arl - Araliaceae, B - Bambusoideae, Bac- *Baccaurea*, Bln - *Balanophora*, Cl - *Calamus*, Clm - Commelinaceae, Cyat - *Cyathea*, Dia - *Dianella nemorosa*, Did - *Didymosperma* cf. *trucatula*, El - *Elaeocarpus*, Euod - *Euodia* cf. *pasteuriana*, Euph - Euphorbiaceae, Eur - *Eurya*, Gar - *Garcinia*, Gr - *Grewia*, Kme - *Kmeria duperreana*, Las - *Lasianthus*, Lith - *Lithocarpus*, Lits - *Litsea*, Liv - *Livistona* cf. *saribus*, Mgl - *Manglietia*, Mich - *Michelia*, Mn - Menispermaceae, Neph - *Nephrolepis*, Ole - *Oleandra* cf. *pistillaris*, P.im - *Podocarpus imbricatus*, P.n - *Podocarpus neriifolius*, Pho - *Phoebe*, Pin - *Pinanga* cf. *sylvestris*, Pip - *Piper*, Raph- *Raphidophora*, Rho - *Rhododendron* cf. *moulmainense*, Rub - Rubiaceae, Shf - *Schefflera*, Shi - *Schima wallichii*, Sloa - *Sloanea* cf. *sinensis*, Sorb - *Sorbus*, Str - *Strobilanthes*, Syz - *Syzygium*, Tern - *Ternstroemia.*

Lianas are numerous. Rattan *Calamus* sp. (Palmae) is dominant, and the following also occur: *Anadendrum montanum*, *Pothos scandens*, *Raphidophora* sp. (Araceae), *Embelia* cf. *pulchella* (Myrsinaceae), *Fibraurea tinctoria*, *Stephania* sp. (Menispermaceae), species belonging to *Bauhinia* (Leguminosae), *Cissus*, *Tetrastigma* (Vitaceae), *Ficus* (Moraceae), *Gnetum* (Gnetaceae), *Jasminum* (Oleaceae), *Korthalsia*, *Plectocomia* (Palmae), *Mussaenda* (Rubiaceae), *Smilax* (Smilacaceae) and *Strychnos* (Loganiaceae), as well as members of the Annonaceae and Cucurbitaceae. The herb layer is unevenly developed under the canopy, with less than 10% cover. Monodominant herb areas occur in forest gaps. The following species were observed: *Aglaonema* cf. *fumeum*, *Alocasia* cf. *grata* (Araceae), *Anoectochilus* cf. *lylei*, *A.* cf. *roxburghii*, *Acanthephippium* sp., *Calanthe* sp., *Goodyera* sp.

(Orchidaceae), *Asplenium normale* (Aspleniaceae), *Didymochlaena* cf. *trucatula* (Dryopteridaceae), *Egenolfia asplenifolia* (Lomariopsidaceae), *Strobilanthes* cf. *maingayi* (Acanthaceae), *Alpinia* sp., *Globba* sp., Gen. sp. (Zingiberaceae), *Angiopteris* sp. (Marattiaceae) (confined to the edges of temporary streams), *Ardisia* sp. (Myrsinaceae), *Cibotium* sp. (Dicksoniaceae), *Clerodendrum* sp. (Verbenaceae), and abundant species belonging to the *Elatostema* and *Pellionia* genera (Urticaceae).

Among epiphytes, mosses and filmy ferns belonging to the Hymenophyllaceae are common on tree trunks (up to a height of 7 m). The following species also occur: *Asplenium* cf. *ensiforme* (Aspleniaceae), *Vittaria* cf. *sikkimensis* (Vittariaceae), *Elaphoglossum* sp. (Lomariopsidaceae), *Nephrolepis* sp. (Nephrolepidaceae), *Peperomia* sp. (Piperaceae), *Appendicula* sp. and *Bulbophyllum* sp. (Orchidaceae). The ferns *Aglaomorpha coronans*, *Drynaria rigidula*, *Crypsinus* sp., *Polypodium* sp., *Pyrrosia* sp. (Polypodiaceae), *Oleandra pistillaris* (Oleandraceae) and orchids *Eria paniculata* and *Epigeneium* cf. *annamense* occur in tree crowns. Semi-epiphytes such as *Sorbus granulosa* (Rosaceae) are also common on tree trunks. We also found a parasite *Sapria* (*Rafflesia*) *poilanea* (Rafflesiaceae) in forests among large blocks of sandstone in the northern area (12 $^{o}$09'24 "N and 102$^{o}$58'33" E, Fig. 8). This species was found on roots and lower parts of lianas belonging to the *Tetrastigma* genus.

**Conclusions**

Forest trees belonging to 49 plant families, vines - 33, ground herbs - 28, epiphytes - 16, semi-epiphytes - four, and parasitic plants - three, are revealed.

Forests on lowland territories, gentle slopes and on the southern and central parts of Samkos-Kmoach plateau are formed by trees belonging to the Dipterocarpaceae family: *Dipterocarpus tuberculatus*, *D. obtusifolius*, *Shorea obtusa* (on plains with outcrops of tuffs and crystalline shales); *D. alatus* (on hills composed of shales), *D. costatus*, *Hopea odorata* and *Shorea* cf. *roxburghii* (on gentle slopes) and *D. turbinatus* (on the southern and central parts of plateau). Co-dominants in lowland forests, depending on edaphon, include members of the Irvingiaceae (*Irvingia malayana*), Palmae (*Corypha* cf. *lecomtei*) or Combretaceae (*Terminalia mucronata*) families, while on slopes, this consists of *Tarrietia javanica* (Sterculiaceae) and on the plateau, *Schima wallichii* (Theaceae) and *Podocarpus imbricatus* (Podocarpaceae).

On the northern edge of the plateau permanently moist poly-dominant forests occur. The upper storey comprises the following tree-families: Magnoliaceae (*Kmeria duperreana*), Theaceae (*Anneslea fragrans*), Elaeocarpaceae (*Sloanea* cf. *sinensis*), Podocarpaceae (*Podocarpus imbricatus*) and Palmae (*Livistona saribus*). Montane species found only in this area included: trees - *Betula alnoides* (Betulaceae), *Sloanea* cf. *sinensis* (Elaeocarpaceae), *Kmeria duperreana* (Magnoliaceae) and *Rhododendron* cf. *moulmainense* (Ericaceae); herbs - *Viola* sp. (Violaceae); ferns - *Angiopteris* sp. (Marattiaceae); epiphytes *Aglaomorpha coronans* (Polypodiaceae) and *Vaccinium* cf. *tonkinense* (Ericaceae); semi-epiphytes- *Sorbus granulosa* (Rosaceae); and root parasites - *Sapria poilanea* (Rafflesiaceae) and *Balanophora* sp. (Balanophoraceae).

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## SUMMARY

This paper presents the most complete characterization of primary forests on different land forms (lowland territories, mountain slopes and plateau) of the Cardamom Mountains (Phnom Samkos area) to date. Forest stands on lowland territories (plains), on gentle mountain slopes and on southern and central parts of the Samkos-Kmoach plateau (up to 1,000 m a.s.l.) are characterised by trees in the Dipterocarpaceae family: *Dipterocarpus tuberculatus*, *D. obtusifolius*, *D. alatus*, *D. costatus* and *D. turbinatus*, *Hopea odorata*, *Shorea obtusa*, and *Schorea* cf. *roxburghii*. Co-dominants on plains depending on edaphon include *Irvingia malayana* (Irvingiaceae), *Terminalia mucronata* (Combretaceae) or *Corypha lecomtei* (Arecaceae). On slopes, these include *Tarrietia javanica* (Sterculiaceae), while on the Samkos-Kmoach plateau, these include *Schima wallichii* (Theaceae) and *Podocarpus imbricatus* (Podocarpaceae). The composition of forests on the northern edge of the plateau includes mountain species such as *Betula alnoides* (Betulaceae), *Sloanea* cf. *sinensis* (Elaeocarpaceae), *Kmeria duperreana* (Magnoliaceae) and *Rhododendron* cf. *moulmainense* (Ericaceae). Herbs include *Viola* sp. (Violaceae) and ferns *Angiopteris* sp. (Marattiaceae) while epiphytes include *Aglaomorpha coronans* (Polypodiaceae) and *Vaccinium* cf. *tonkinense* (Ericaceae), semi-epiphyte's include *Sorbus granulosa* (Rosaceae), and root parasites *Sapria poilanea* (Rafflesiaceae) and *Balanophora* sp. (Balanophoraceae). Tall forests exist on the mountain plateau (1,000 m a.s.l.). The occurrence of *Dipterocarpus* species varies with elevation, with *D. alatus* found up to 300 m a.s.l.), *D. costatus* between 200 - 600 m and *D. turbinatus* between 550 - 900 m.


*Keywords: Cambodia, tropical forests, forest structure, forest stands, Dipterocarpaceae.*

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