LIANA ABUNDANCE, DIVERSITY AND TREE INFESTATION IN THE IMBAK CANYON CONSERVATION AREA, SABAH, MALAYSIA

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KAMMESHEIDT L, BERHAMAN A, TAY J, ABDULLAH G & AZWAL M. 2009. Liana abundance, diversity and tree infestation in the Imbak Canyon Conservation Area, Sabah, Malaysia. We investigated the liana diversity and liana–tree relationship in lowland dipterocarp forest at Imbak Canyon, a recently designated conservation area in the heart of Sabah, Malaysia and compared the results with similar studies in the region. In the two 0.1-ha plots, a total of 23 liana species were found growing canopy-ward on trees ≥ 10 cm diameter at breast height (dbh); dipterocarps were less infested by lianas than non-dipterocarps. The liana species belonged to 12 families and 16 genera. Fabaceae followed by Annonaceae and Icacinaceae were the most abundant and species-rich families. The floristic pattern and the stem density of lianas > 1 cm dbh were similar to other studies conducted in Sabah and northern Sarawak at comparable elevation and site conditions but were distinct from other sites in tropical Asia where Annonaceae is the prevalent climber family. The dominance of species of the genus *Spatholobus* (Fabaceae) may be a conspicuous feature of lowland dipterocarp forests in Sabah under mesotrophic conditions.

Keywords: Borneo, geographical pattern, liana-tree relationship, lowland mixed dipterocarp forest, other climbers, *Spatholobus*, taxonomic diversity

KAMMESHEIDT L, BERHAMAN A, TAY J, ABDULLAH G & AZWAL M. 2009. Kelimpahan serta kepelbagaian liana dan infestasinya pada pokok di Kawasan Pemuliharaan Lembah Imbak di Sabah, Malaysia. Kami menyiasat kepelbagaian liana dan hubungan antara liana dengan pokok di hutan dipterokarpa tanah pamah di Lembah Imbak iaitu sebuah kawasan pemuliharaan di tengah-tengah Sabah, Malaysia yang baru diwartakan. Keputusan yang diperoleh kemudiannya dibandingkan dengan kajian yang serupa di rantau ini. Dalam kedua-dua plot yang setiap satunya bersaiz 0.1 ha, sebanyak 23 spesies liana didapati tumbuh ke arah kanopi pokok yang berdiameter aras dada (dbh) ≥ 10 cm. Infestasi liana pada pokok dipterokarpa kurang daripada pokok bukan dipterokarpa. Spesies liana tergolong dalam 23 famili dan 16 genus. Fabaceae merupakan famili yang paling tinggi kelimpahan serta paling banyak spesiesnya diikuti oleh Annonaceae serta Icacinaceae. Corak flora dan ketumpatan batang liana > 1 cm dbh adalah serupa dengan keputusan kajian lain yang dijalankan pada ketinggian serta keadaan tapak yang lebih kurang sama di Sabah serta utara Sarawak. Namun nilai-nilai ini sangat berbeza jika dibandingkan dengan tapak lain di Asia tropika yang mempunyai Annonaceae sebagai famili pepanjat yang paling dominan. Kedominan spesies genus *Spatholobus* (Fabaceae) mungkin merupakan ciri jelas hutan dipterokarpa tanah pamah di Sabah dalam keadaan mesotrof.

INTRODUCTION

"Lianas, i.e. woody, relatively thick stemmed climbers that begin life as terrestrial seedlings and are capable of growth in mature forests, are likely the most undercollected of any major habit group of plants" (Gentry 1991). While this statement is no longer valid for tropical America, where numerous studies in recent years have enhanced our knowledge about the diversity and ecology of lianas in forest ecosystems (e.g. DeWalt *et al.* 2000, Mascaro *et al.* 2004, Rice *et al.* 2004, Campanello *et al.* 2007), it still applies to South-East Asia.

Although lianas are an important structural component of tropical forests which make a major contribution to the taxonomic diversity in these ecosystems (Gentry 1991), the few floristic analyses of forest vegetation in South-East Asia

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have focused, in general, on tree species diversity (Sist & Saridan 1999, Uuttera *et al.* 2000, Slik *et al.* 2003, Wilkie *et al.* 2004). Studies on liana diversity and ecology in forest ecosystems have been particularly carried out in the Malaysian states of Sarawak and Sabah, located on Borneo island (Figure 1). A research was carried out on the taxonomic diversity of lianas and their distribution pattern at different elevations and liana–tree relationships at Lambir National Park (Putz & Chai 1987). Appanah *et al.* (1993) compared liana diversity and species richness in lowland and hill dipterocarp forests in Peninsular Malaysia with two sites in Sarawak. Chai (1997) studied, among other woody plants, the biomass and diversity of lianas in secondary forest. The ecological relationships between lianas and trees in lowland rainforest at Danum Valley, Sabah was investigated by Campbell and Newbery (1993). DeWalt *et al.* (2006) studied liana habitat association and community structure in lowland tropical forest in Sepilok.

The research works of DeWalt *et al.* (2006) and Campbell and Newbery (1993) were carried out in the northern and eastern parts of Sabah respectively. This paper reports on a liana study in the Imbak Canyon Conservation Area (henceforth referred to as Imbak Canyon), located in the interior of Sabah (Figure 1). The fieldwork was done during the second scientific expedition to Imbak Canyon in May 2004, organized by the Sabah Foundation. In this study we test to what extent the floristic pattern of lianas differ from other sites in insular and mainland Asia. Also we investigate the role of lianas in forest structure, their taxonomic diversity and liana–tree relationships.

MATERIALS AND METHODS

Study area

Besides Danum Valley and the Maliau Basin, Imbak Canyon (5° 0' N, 117° 0' E) with a total area of 30 000 ha, is the third largest designated conservation area within the 1-million ha concession area of the Sabah Foundation (Figure 1). Imbak Canyon is one of the last remaining pristine lowland rainforests in Sabah. The valley is hemmed in by sandstone ridges from three sides which reach an altitude of 500–700 m above sea level. The Imbak River flows in the central part of the valley, constituting one of the headwaters of the Kinabatangan, the longest river of Sabah. The area receives 2500–3500 mm of precipitation per year (Sabah Statistics Department 2002). Mean monthly temperature ranges from 28–32 C°.

The scientific expedition of 2004 set up its base camp in the central part of Imbak Canyon.

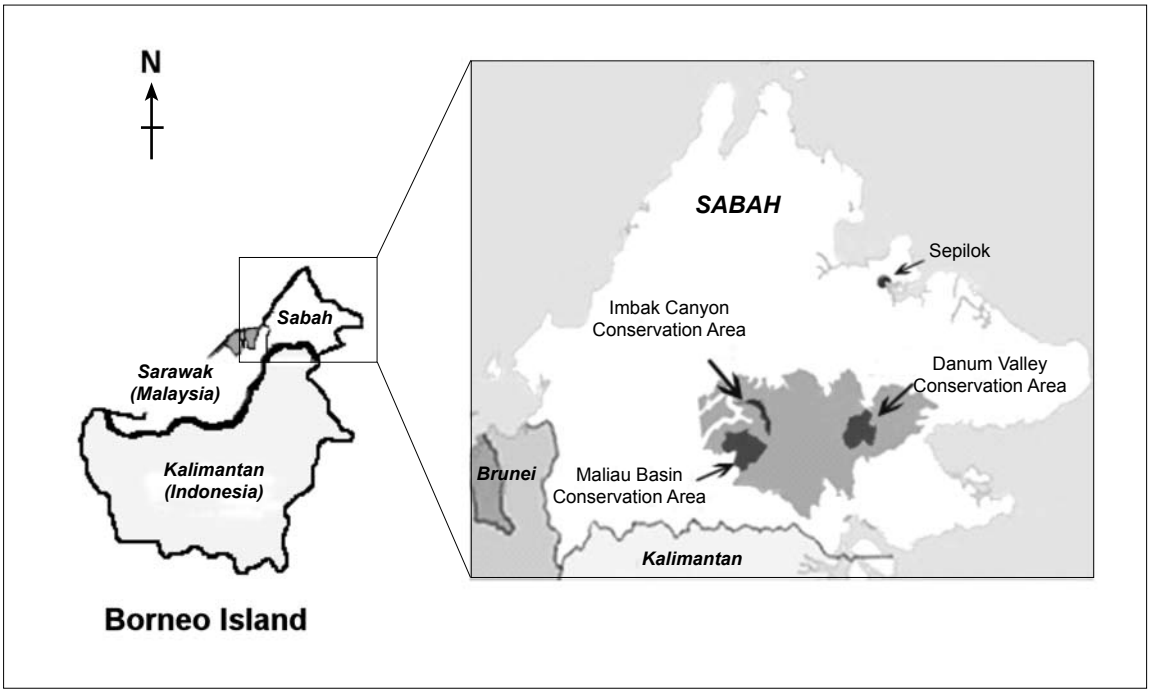

Figure 1 Map of Borneo and Sabah showing the conservation areas within the concession holding of Sabah Foundation

About 200 m north of the base camp, we established two 0.1-ha sample plots (each 20 × 50 m) in an undulating landscape, ranging from 200–220 m above sea level. Soils were derived from sandstone, mudstone and miscellaneous rocks and have a fine to coarse texture, reddish colour and sometimes contain stony material.

Tree composition

Parallel to the liana study, all trees ≥ 10 cm diameter at breast height (dbh) were sampled in the plots. Species of the Dipterocarpaceae, especially *Dryobalanops beccarii*, *Dipterocarpus caudiferus* and *Shorea macroptera* dominated the upper canopy layer and accounted for more than 60% of the total basal area (36 m^2 ha^{-1}). A total of 21 families representing 50 species were recorded in the total sample area of 0.2 ha. In terms of taxonomic diversity, the Euphorbiaceae was the most species-rich family with 13 species in 8 genera, followed by the Dipterocarpaceae (12 species and 6 genera), Burseraceae (3, 2), Lauraceae (2, 2), Tiliaceae (2, 2) and Myrtaceae (2, 1). All other families had only a single species (Tay *et al.* 2004).

Liana sampling

In the two 0.1-ha sample plots we measured the dbh of all lianas ascending to the canopy of trees ≥ 10 cm dbh. A pair of callipers was used to measure lianas < 4 cm dbh and cloth diameter tapes for larger stems. Flattened or irregular stems were measured twice at right angles and the geometric average was calculated. Voucher specimens were taken for all species sampled. Identification of voucher specimens was done in the herbarium of the Forest Research Centre in Sepilok, Sabah. Stems that could not be identified even to the family level (there were 12 individuals, i.e. 8% of all lianas sampled) were only considered in the size-class distribution of lianas. To fully document whether an individual tree supported lianas or not, we also counted lianas that crossed from the crowns of adjacent trees. The number of all bamboos and rattans climbing on trees ≥ 10 cm dbh were also recorded.

RESULTS AND DISCUSSION

Abundance and size-class distribution of lianas and occurrence of other climbers

Most lianas were found in smaller size classes (< 2 cm) (Table 1). Only two individuals attained diameters > 10 cm; maximum dbh observed was 11.0 cm in *Bauhinia* sp. The ridge sites of Putz and Chai (1987) in Lambir National Park, Sarawak and the present study show a similar abundance of lianas, except for the smallest size class (< 1 cm dbh). There were 440 individuals ha^{-1} between 1–10 cm dbh in the lowland dipterocarp forest of Gunung Mulu National Park, Sarawak at 200–250 m altitude (Proctor *et al.* 1983). This number is close to the figure for Imbak Canyon ($\bar{x}$ = 430.3 ± 187.6, n = 20; all individuals ≥ 1 cm dbh). The data for alluvial sites reported by Proctor *et al.* (1983) show a much higher number of lianas in all size classes compared with both the valley plots of Putz and Chai (1987) and this study. In alluvial sites, inundation several times a year may cause higher tree fall frequency contributing to the proliferation of lianas (cf. DeWalt *et al.* 2006).

The number of rattans in this study is low (Table 1). The fact that only rattans of the non-commercial genus *Korthalsia* were found points to selective collection of commercial genera,

Table 1 Number of lianas by size class, rattans and bamboos in 0.1-ha plots in the Imbak Canyon Conservation Area, Sabah, Malaysia

Altitude (m asl)	Climbing liana (dbh) (0.1 ha)				Rattan	Bamboo	Reference
	< 1 cm	1–2 cm	2–5 cm	> 5 cm			
200–220	23	16	14	5	6	15	This study
	45	26	19	6	4	62	
50*	210	55	35	5	4	-	Putz and Chai (1987)
100–140*	96	29	16	2	6	-	

* In comparison with a similar study in Lambir Hills National Park, Sarawak; figures are mean values, comprising five 0.1-ha plots for each site type (valley and ridge); bamboos were not considered in the reference study.

especially *Calamus*, rather than indicating naturally low numbers of rattan. Similar observations were made by Putz and Chai (1987). In one of the sampling areas a high number of bamboos were found. Bamboo-laden trees were common in areas adjacent to smaller treefall gaps. In addition, large numbers of climbing bamboos were recorded in trees with larger lianas close to canopy openings (L Kammesheidt, personal observation).

Diversity of lianas

In the two 0.1-ha plots 23 liana species with a total of 142 individuals were found (Table 2). These lianas belonged to 12 families and 16 genera. For comparison, Campbell and Newbery (1993) recorded 17 families and 40 genera in an 8-ha plot in Danum Valley. In our study, Fabaceae, Annonaceae and Icacinaceae were the most abundant families. In sandstone hill forest in Sepilok, DeWalt *et al.* (2006) found a similar abundance pattern for Fabaceae and Annonaceae. The other two sites studied by DeWalt *et al.* (2006) showed a distinct pattern. They found that on alluvial sites, the Fabaceae followed by the Connaraceae were the most abundant families. In contrast, in kerangas (heath) forest the Arecaceae was the predominant family. In northern Sarawak, at sites similar to our study area in terms of elevation and pedological conditions, the Fabaceae and Icacinaceae had the highest number of individuals (Putz & Chai 1987), whereas the Fabaceae was only the fourth most abundant family after the Annonaceae, Dilleniaceae and Loganiaceae in southern Sarawak (Appanah *et al.* 1993). A less dominant role of the Fabaceae was also found in Peninsular Malaysia where Arecaceae, Annonaceae and Connaraceae were more abundant (Appanah *et al.* 1993).

The Fabaceae was the most species-rich family followed by Annonaceae and Icacinaceae (Table 2). Within the Fabaceae, *Spatholobus* was

Table 2 Liana species, ordered by abundance, growing canopy-ward at the Imbak Canyon Conservation Area, Sabah, Malaysia

Species	Family	Number of climbing individuals
Spatholobus sp.1	Fabaceae	41
Spatholobus cf. *hirsutus* H. Wiriadinata & J.W.A. Ridder-Numan	Fabaceae	21
Bauhinia sp.	Fabaceae	11
Spatholobus sanguineus Elmer	Fabaceae	9
Artabotrys cf. *costatus* R.A. King	Annonaceae	8
Combretum nigrescens R.A. King	Combretaceae	7
Luvunga minutiflora B.C. Stone	Rutaceae	7
Phytocrene anomala Merrill	Icacinaceae	5
Bauhinia kockiana Korth. var. *angustifolia* K. & S.S. Larsen	Fabaceae	4
Artabotrys sp.	Annonaceae	3
Erycibe sp.	Convolvulaceae	3
Friesodielsia sp.1	Annonaceae	3
Sarcostigma philippinense Merrill	Icacinaceae	3
Willughbeia sp.	Apocynaceae	3
Callicarpa sp.	Verbenaceae	2
Derris trifoliata Lour.	Fabaceae	2
Friesodielsia sp.2	Annonaceae	2
Spatholobus sp.2	Fabaceae	2
Strychnos ignatii Berg	Loganiaceae	2
Amydrium medium (Zoll & Mor.) D.H. Nicholson	Araceae	1
Gnetum sp.	Gnetaceae	1
Phytocrene sp.	Icacinaceae	1
Ventilago dichotoma Merrill	Rhamnaceae	1

Note: Total sampling area 0.2 ha

the most speciose genus. This species pattern is in line with records of the other two studies of liana diversity in Sabah on comparable sites (Campbell & Newbery 1993, DeWalt *et al.* 2006). Again, a different pattern was found in the southern part of Sarawak where the Annonaceae showed the greatest species richness (Gentry 1991) while in northern Sarawak, i.e. Lambir National Park, the Fabaceae, similar to the Sabah sites, was the most species-rich family followed by Annonaceae (Putz & Chai 1987). Gentry (1991) found in other tropical Asian sites including New Guinea that Annonaceae was the most species-rich family followed by legumes and rattan palms.

The dominance of the genus *Spatholobus* is a conspicuous feature of the sample plots. Based on a general area-cladogram (i.e. a diagram that delineates the branching sequences in an evolutionary tree), Ridder-Numan (1998) suggested that the genus *Spatholobus* came from around India and invaded the dry Sunda Shelf during a period of low sea level and speciated due to the isolation of the area after the sea level rose. If true, *Spatholobus* would show a biogeographical history similar to the tree family Dipterocarpaceae (cf. Ashton 1982). *Spatholobus* consists of 29 species of lianas in South-East Asia (Ridder-Numan 1998). It is not clear from the available literature whether Borneo is one of the areas of speciation of *Spatholobus*.

Liana–tree relationship

Of the 107 trees sampled, 64 individuals were infested by lianas and/or other climbers (Figure 2). Out of 51 dipterocarps recorded, 26 individuals were found to be climber-free while only 16 individuals from 56 non-dipterocarps were not infested by climbers. Non-dipterocarps were significantly more infested by lianas than dipterocarps ($G = 5.64$, $df = 1$, $p < 0.05$). Most infested trees (88%) hosted either exclusively lianas or both lianas and other climbers, i.e. rattans and/or bamboos. Campbell and Newbery (1993) also reported on a considerably lower proportion of liana-infested dipterocarps than in most non-dipterocarp families. However, based on the analysis of a large data set, they found that the susceptibility to lianas is largely species, rather than family specific. The fact that dipterocarps are generally less susceptible to liana infestation may be ascribed to their change from monopodial to sympodial growth when reaching the main canopy and while doing so shedding branches continuously (Hallé *et al.* 1978). The 'crown shyness' of dipterocarps may also constitute a hindrance to the crossing over of lianas (Whitmore 1984). The continuous shedding of branches, thereby attaining a long clear bole, seems to be one of the major factors to keep lianas off (Putz 1984, Campbell & Newbery 1993, Kammesheidt 1999).

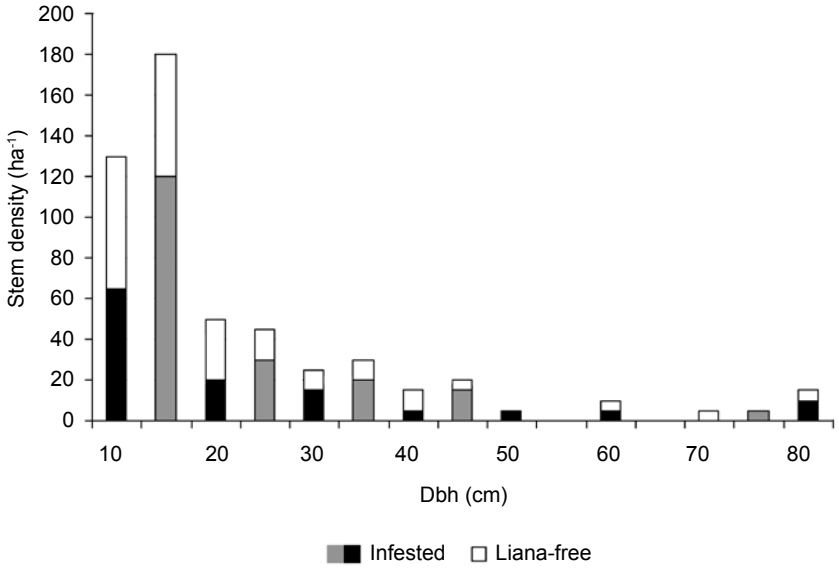

Figure 2 Size-class distribution of infested and liana-free dipterocarps (black and white bars) and non-dipterocarps (grey and white bars) trees in the Imbak Canyon Conservation Area, Sabah, Malaysia

We did not detect any clear pattern whether trees once having a liana increase accessibility to more lianas, as suggested by other authors (Putz & Chai 1987, Campbell & Newbery 1993). This may be due to the small sample size. However, aggregation of lianas in individual trees was common close to gaps and neighbouring trees which died or suffered from liana dislodgement.

CONCLUSIONS

The 23 liana species recorded contributed about one-third to the diversity of woody species in the sample plots, indicating the importance of lianas. The general pattern in liana–tree relationship concurs with the only other study about this aspect in insular Asia (Campbell & Newbery 1993). However, we need more inventories in contrasting forest types in different regions which consider all woody components to obtain a more comprehensive picture about the ecological role and diversity of lianas in forest ecosystems in South-East Asia.

Our study confirms the biogeographical pattern of some liana taxa, particularly the dominance of the Fabaceae and its most species-rich genus *Spatholobus* in mesotrophic forests in northern Borneo.

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REFERENCES

Appanah S, Gentry AH & LaFrankie JV. 1993. Liana diversity and species richness of Malaysian rain forests. *Journal of Tropical Forest Science* 6: 116–123.

Ashton PS. 1982. Dipterocarpaceae. Pp. 237–552 in Steenis CGGJ (Ed.) *Flora Malesiana*. Martinus Nijoff Publ, The Hague.

Campanello PI, Garibaldi JF, Gatti MG & Goldstein G. 2007. Lianas in a subtropical Atlantic Forest: host preference and tree growth. *Forest Ecology and Management* 242: 250–259.

Campbell EJB & Newbery D. 1993. Ecological relationships between lianas and trees in lowland rain forest in Sabah, East Malaysia. *Journal of Tropical Ecology* 9: 469–490.

Chai FYC. 1997. Above-ground biomass estimation of a secondary forest in Sarawak. *Journal of Tropical Forest Science* 9: 359–368.

DeWalt SJ, Schnitzer SA & Denslow JS. 2000. Density and diversity of lianas along a chronosequence in a central Panamanian lowland forest. *Journal of Tropical Ecology* 16: 1–19.

DeWalt SJ, Ickes K, Nilus R, Harms KE & Burslem DFRP. 2006. Liana habitat association and community structure in a Bornean lowland tropical forest. *Plant Ecology* 186: 203–216.

Gentry AH. 1991. The distribution and evolution of climbing plants. Pp. 3–49 in Putz FE & Mooney HA (Eds.) *The Biology of Vines*. Cambridge University Press, Cambridge.

Hallé F, Oldemann RAA & Tomlinson PB. 1978. *Tropical Trees and Forests: An Architectural Analysis*. Springer-Verlag, Berlin.

Kammesheidt L. 1999. Liana infestation of trees: some observations in a neotropical lowland forest. *Ecotropica* 5: 217–220.

Mascaro J, Schnitzer SA & Carson WP. 2004. Liana diversity, abundance, and mortality in a tropical wet forest in Costa Rica. *Forest Ecology and Management* 190: 3–14.

Proctor J, Anderson JM, Chai P & Vallack HW. 1983. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. 1. Forest environment, structure and floristics. *Journal of Ecology* 71: 237–260.

Putz FE. 1984. How trees avoid and shed lianas. *Biotropica* 16: 19–23.

Putz FE & Chai P. 1987. Ecological studies of lianas in Lambir National Park, Sarawak, Malaysia. *Journal of Ecology* 75: 523–531.

Rice K, Brokaw N & Thompson J. 2004. Liana abundance in a Puerto Rican forest. *Forest Ecology and Management* 190: 33–41.

Ridder-Numan JWA. 1998. Historical biogeography of *Spatholobus* (Leguminosae-Papilionoideae) and allies in SE Asia. Pp. 259–277 in Hall R & Hollowa JD (Eds.) *Biogeography and Geological Evolution of SE Asia*. Backhuys Publishers, Leiden.

Sabah Statistics Department. 2002. *Yearbook of Statistics*. Kota Kinabalu, Sabah.

Sist P & Saridan A. 1999. Stand structure and floristic composition of primary lowland dipterocarp forest in East Kalimantan. *Journal of Tropical Forest Science* 11: 704–722.

Slik JWF, Poulsen AD, Ashton PS, Cannon CH, Eichhorn KAO, Kartawinata K, Lanniari I, Nagamasu H, Nakagawa M, Van Nieuwstadt MGL, Payne J, Purwaningsih, Saridan A, Sidiyasa K & Verburg RW. 2003. A floristic analysis of the lowland dipterocarp forests of Borneo. *Journal of Biogeography* 30: 1517–1531.

Tay J, Berhaman A, Abdullah G, Azwal M & Kammesheidt L. 2004. Tree structure and diversity of a lowland

dipterocarp forest in the Imbak Canyon, Sabah, Malaysia. Malaysian–German Forestry Education Project. (Unpublished report)

Uuttera J, Tokola T & Maltamo M. 2000. Differences in the structure of primary and managed forests in East Kalimantan, Indonesia. *Forest Ecology and Management* 129: 63–74.

Whitmore TC. 1984. *Tropical Rain Forests of the Far East.* Second edition. Clarendon Press, Oxford.

Wilkie P, Argent G, Cambell E & Saridan A. 2004. The diversity of 15 ha of lowland dipterocarp forest, Central Kalimantan. *Biodiversity and Conservation* 13: 695–708.