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Cluster Analysis on Floristic Composition and Forest Structure of Hilly Lowland Forest in Lok Kawi, Sabah State of Malaysia

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Abstract: The purpose of this study was to carry out a vegetative study on the slope of Lok Kawi Hill. A total of 12 plots were laid between 20 to 350 m altitude on the slope of lowland hilly forest at Lok Kawi in Sabah State of Malaysia. These plots were subjected to cluster analysis using Ward Linkage Method (WLM) and Euclidean Distance Measurement (EDM). This similarity analysis classified them into five cluster groups (CGS). These CGS, denoted by three most dominant species in term of importance value were respectively named as *Hevea brasiliensis-Parastemon urophyllum-Antidesma ghaesembilla* Association (CGI); *Chionanthus pachyphyllus-Parastemon urophyllum-Adinandra dumosa* Association (CGII); *Pithecellobium ellipticum-Calophyllum inophyllum-Arenga undulatifolia* Association (CGIII); *Calophyllum inophyllum-Croton oblongus-Cratoxylum arborescens* Association (CG IV) and *Oncosperma tigillarium-Sarcotheca glauca-Calophyllum inophyllum* Association (CG V). The species diversity of these CGS were relatively poor. CGII and CGIII were each represented by 19 species, whereas CGIV, CGI and CGV comprised of 18, 10 and 6 species. In term of Basal Area Contribution (BAC), CGIII recorded the highest BAC, followed by CGII, CGIV, CGI and CGV. Density of trees between CGS was recorded highest in CGII, followed by CGIV, CGIII, CGI and CGV. Based on the species composition, CGI is an abandoned rubber plantation; CGII is a coastal vegetation with the presence of *Oncosperma tigillarium*; CGIII is a disturbed primary forest with the presence of *Macranga hypoleuca*, *Macaranga gigantea* and *Mallotus paniculatus*; CGIV is a disturbed primary forest with the presence of *Vernonia arborea*, *Adinandra dumosa*, *Vitex pubescens* and *Macranga triloba*; CGV is a disturbed primary forest with the presence of *Macaranga gigantea*. The value of species diversity differed between CGS. CGII have the highest R, H and E-values, 2.12, 2.393 and 0.813, followed by CGIII, CGIV, CGI and CGV. CGV possessed the lowest R, H and E-values among the five CGS that is 0.96, 0.814 and 0.454.

Key words: Ward linkage method, euclidean distance measurement, importance value, diversity, tropical lowland, Malaysia

INTRODUCTION

The study which was carried out in 2005 at Lok Kawi in Sabah State of Malaysia is the few remaining lowland hilly forests found around Kota Kinabalu. The fast development occurring around Kota Kinabalu is the potential threat on the existence of these forests. The current research carried out will provide the base line data on the forest structure of the area and future reference to other scientists carrying similar research in other hilly forest around Kota Kinabalu. This hill stands at 350 m above sea level and is located about 10 km from Kota Kinabalu town. The preliminary surveyed showed that this area have been disturbed by human activities in the past resulting in the formation of secondary forests representing different succession stages and disturbed primary forest. Lower section of the study area showed the existence of small area of abandoned rubber plantation. The young secondary forest along the road embankment was dominated by common secondary species of trees such as *Macaranga javanica*, *Mallotus paniculatus*, *Trema orientalis*, *Vitex pubescens*, *Croton oblongus* and *Vernonia arborea*; common shrub species includes *Cassia alata*, *Melastoma malabathricum*, *Dillenia suffructicosa*; Ferns observed were *Blechnum orientale*, *Dicranopteris linearis* and

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Pteridium caudatum. In older secondary forest and disturbed primary forest, the common observed species were *Oncosperma tigillarium*, *Parastemon urophyllum*, *Cratoxylum arborescens*, *Adinandra dumosa*, *Kibbesia elmeri* and *Porterandia anisophylla*. Other evidence the study area have been disturbed by human is the presence of fruit trees such *Artocarpus integer*, *Artocarpus odoratissimu* and *Nephelium lappaceum*. Primary forest also occupied the study area particularly along the gentle slope to the summit.

The purpose of this study was to carry out a vegetation study on the slope of Lok Kawi Hill with particular emphasis being placed on the composition of their tree floras and classification of heterogeneous forest tree species composition into homogeneous groups using clustering analysis. Few researchers have been carried out by previous workers out on classification of forests using cluster analysis along the slope of the hills and highland vegetation in Sabah (Adam and Enning, 1996; Adam, 1997).

MATERIALS AND METHODS

The study to classify the heterogeneous vegetation along the slope of Lok Kawi Hill have been carried out in 2005. In order to accomplish the objective of the study, twelve plots, 10×50 m (0.05 ha or 500 m^2) were set from the foot of the hill at 20 m altitude up to the summit of hill at 350 m. Every plot (P) was set at about 30 m altitude interval. There were laid at 20 m (P1), 50 m (P2), 80 m (P3), 110 m (P4), 140 m (P5), 170 m (P6), 200 m (P7), 230 m (P8), 260 m (P9), 290 m (P10), 320 m (P11) and 350 m (P12). In order to determine the frequency (f) and relative frequency (R_f) of each species, every plot was subdivided into 10 subplots, each measuring 5×10 m in each plot, all trees ≥5 cm diameter at breast height (dbh) have their dbh measured. The Basal Area (BA), Density (D), importance value (I_V), species richness, species diversity and species evenness were determined using the following equations below:

(a) Basal area (BA) = $0.7857 \times D^2$ (cm^2)

where, D = diameter at breast height (Cintron and Novelii, 1984).

(b) The importance values (I_V) of every species in each plot was determined using the following Eq. below:

I_V = Relative density (R_d) + Relative frequency (R_f) + Relative dominance (R_D)

Where:

$$R_d = \frac{\text{No. of trees of species x}}{\sum \text{number of trees of all species}} \times 100$$

$$R_f = \frac{\text{Frequency of species x}}{\sum \text{Frequency of all species}} \times 100$$

$$R_D = \frac{\text{BA of species x}}{\sum \text{BA of all species}} \times 100$$

(Cintron and Novelii, 1984).

(c) Measure of species diversity was measured by the following indices of species diversity (Brower and Zar, 1977; Ludwig and Reynolds, 1988):

- Menhinick Richness Index (R) = (S)/(vn)

  Where, S = ΣNo. of species in each plot
  N = ΣNo. of trees in each plot

- Shannon-Weiner Diversity Index (H')
  $$= -\sum_{i=1}^{s}[(ni/n)\ \mathrm{In}(ni/n)]$$
- Species Evenness Index (E) = (H)/ln(S)

(d) Similarity of species between study plots using density was determined by Ward Linkage Method (WLM) and Euclidean Distance Measurement (EDM). These data was analyzed using SPSS-Minitab software licensed to UKM.

RESULTS AND DISCUSSION

To divide the vegetation into homogeneous formation, all the twelve plots were subjected to similarity analysis using WLM and EDM. This analysis divided the vegetation along the slope of the study area which stretched from 20 m up to 350 m (summit) into five cluster groups (CGS) at 49.66 similarity level (Table 1, Fig. 1). This CGS was denoted by three species association having the three highest importance values among the species present in every CG. Figure 1 showed that CGI comprised of P1 (20 m altitude); CGII comprised of P2, P3 and P6 at 50, 80 and 170 m altitude; CG III comprised of P4 (110 m), P5 (140 m), P10 (290 m) and P11 (320 m); CG IV is represented by P9 (260 m) and P12 (350 m); CGV comprised of P7 (200 m) and P8 (230 m). These CGS represent five different forest types denoted by species

Table 1: Similarity level and distance level using Euclidean and Ward Linkage of floristic and forest structures at twelve different altitudes on hilly forest at Lok Kawi

Step	No. of cluster	Similarity level	Distance level	Clusters joined	Clusters joined	New cluster	No. of observations in new cluster
1	11	90.95	4.243	7	8	7	2
2	10	80.57	9.110	10	11	10	2
3	9	75.77	11.358	4	5	4	2
4	8	60.48	16.841	4	10	4	4
5	7	62.08	17.776	2	6	2	2
6	6	60.37	18.579	2	3	2	3
7	5	49.66	23.601	9	12	9	2
8	4	43.96	26.274	2	4	2	7
9	3	31.67	32.036	2	9	2	9
10	2	21.14	36.973	2	7	2	11
11	1	-34.30	62.965	1	2	1	12

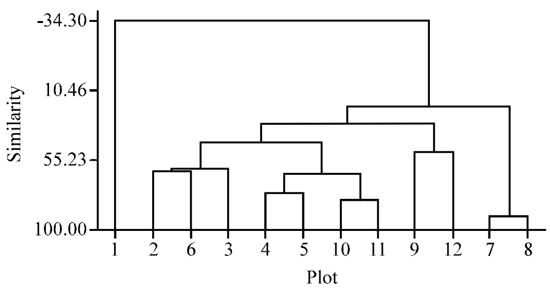

Fig. 1: Dendrogram of the index of similarity between plots using Ward Linkage Method (WLM) and Euclidean Distance Measurement (EDM)

association based on three highest importance values. This criteria for classification of forest formation have been used by past researchers (Adam and Enning, 1996; Adam, 2000; Mahmud *et al*., 1992; Soepadmo, 1987). Adam and Enning (1996) divided the forest along the slope at Danum in Sabah into *Shorea pauciflora-Shorea fallax* zone (150-250 m), *Shorea leprosula-Vatica dulitensis* forest zone (350-550 m), *Shorea parvifolia-Vatica dulitensis* forest zone (600-700 m) and *Schima wallichii-Ternstroemia aneura* forest zone (820 m), Adam (2000) found out the forest formation of Mt. Murud in Sarawak was dominated by different species; forest formation at 1100 m was dominated by *Shorea brunnescens* and *Agathis borneense*, forest formation at 1800 m by *Vatica alboramis* and *Hopea dryobalanoides* and forest formation at 2400 m by *Dacrycarpus imbricatus* and *Dacrydium beccarii*. Soepadmo (1987) who studied on the tree flora of Gunung Janing in Johore, Malaysia have used dominant and co-dominant species with the highest and second highest values to assign the different forest formations of heterogeneous composition identified in his study area. However he did not used cluster analysis to explain his classification. Ohsawa *et al*. (1985) distinguished each of their study plots according to their dominant species derived by dominance analysis (Ohsawa, 1984). The dominance analysis is based on the least deviation between the share obtained by a given species, as a percentage of the total basal area and its calculated share if all species were equally represented. Ohsawa *et al.* (1985) used Motyka's Index (Bray and Curtis, 1957) to classify the forest formation on the slope of Mount Kerinci, Sumatra into four forest zones. Other researchers found it very helpful to classify the heterogeneous forest formation of the tropical regions using cluster analysis using Ward Linkage Method (Adam, 1997; Adam and Enning, 1996; Mahmud *et al*., 1992; Ohsawa, 1984).

Cluster Group I (CGI): *Hevea brasiliensis-Parastemon urophyllum-Antidesma ghaesembilla* association, CG1, P1 (20 m): This forest formation is characterized by poorer in species compared with the other four CGS. Table 2 listed 10 species of trees with a dbh of ≥5 cm in study area of 0.05 ha. This study also revealed the forest formation at 20 m altitude was dominated by *Hevea brasiliensis* with 41 individuals, followed distantly by *Parastemon urophyllum* with 11 individuals. Eight species have between 1-3 trees. The total tree density enumerated was 65 in 0.05 ha or estimated 1300 ha^{-1} and 0.13 m^{-2}. The abundance of rubber trees strongly indicated the forest formation of CGI is the abandoned rubber plantation and slowly succeeded by other species such as *Parastemon urophyllum*.

The Basal Area Contribution (BAC) of trees is very small, 8905 cm^2 or estimated 178,100 ha^{-1} and 17.81 m^{-2}. The low BA area obtained can be explained by the small sizes of the trees obtained in CGI. Table 7 showed that *Hevea brasiliensis* and *Antidesma ghaesembilla* contributed 57.23% of the total BAC. In addition, *Sarcotheca glauca* contributed 18.76% of the total BAC. Seven other species combined contributed 24.01 of the total BAC.

Six dominant species were found to have their importance value greater than 10%. There were *Hevea brasiliensis*, *Parastemon urophyllum*, *Antidesma ghaesembilla*, *Sarcotheca glauca*, *Adinandra dumosa* and *Kibbesia elmeri*. These species contributed 269.9% of the total I_V of the total 300% (Table 2). Four other

Table 2: Basal area, relative dominance (R_D), density (D), relative density (R_d), frequency (R_f) and importance values (I_V) of all species in CGI of P1 at 20 m altitude in Lok Kawi

Species	Family	BA (cm²)	R_D (%)	D	R_d (%)	F	R_f (%)	I_V (%)
Hevea brasiliensis	Euphorbiaceae	2792	31.27	41	63.14	6	30	124.41
Parastemon urophyllum	Sapotaceae	866	9.70	11	16.94	4	20	46.64
Antidesma ghaesembilla	Euphorbiaceae	2318	25.96	2	3.08	1	5	34.04
Sarcotheca glauca	Oxalidaceae	1675	18.76	2	3.08	2	10	31.84
Adinandra dumosa	Theaceae	529	5.92	3	4.62	2	10	20.54
Kibbesia elmeri	Rubiaceae	388	4.35	2	3.08	1	5	12.43
Eugenia alcinae	Myrtaceae	171	1.91	1	1.54	1	5	8.45
Semecarpus cinerea	Anacardiaceae	86	0.96	1	1.54	1	5	7.50
Nauclea subdita	Rosaceae	40	0.45	1	1.54	1	5	6.99
Dehaasia cuneata	Euphorbiaceae	40	0.45	1	1.54	1	5	6.59
Σ10 species	Σ8 families	8905	100.00	65	100.00	20	100	300.00

Table 3: Basal area, relative dominance (R_D), density (D), relative density (R_d), frequency (R_f) and importance values (I_V) of all species in CGII of P2, P3 and P6 at 50, 80 and 170 m altitude in Lok Kawi

Species	Family	BA (cm²)	R_D (%)	D	R_d (%)	F	R_f (%)	I_V (%)
Chionanthus pachyphyllus	Oleaceae	9118	28.27	20	18.20	9	18	64.47
Parastemon urophyllum	Sapotaceae	2480	7.69	29	26.39	9	18	52.08
Adinandra dumosa	Theaceae	4257	13.10	8	7.28	3	6	26.38
Kibbesia elmeri	Rubiaceae	1681	5.20	11	10.00	5	10	25.20
Oncosperma tigillarium	Arecaceae	470	1.46	12	10.92	3	6	18.38
Eugenia alcinae	Myrtaceae	2510	7.78	10	9.10	5	10	16.88
Sarcothea glauca	Oxalidaceae	2754	8.54	3	2.73	2	4	15.27
Calophyllum inophyllum	Guttiferae	1559	4.83	2	1.82	2	4	10.65
Hevea brasiliensis	Euphorpbiaceae	1451	4.50	3	2.73	1	2	9.23
Elaeocarpus mastersii	Elaeocarpaceae	1804	5.60	1	0.91	1	2	8.51
Glochidion borneense	Euphorbiaceae	1451	4.50	1	0.91	1	2	7.41
Semecarpus cinerea	Anacardiaceae	397	1.23	2	1.82	2	4	7.05
Garcinia beccarii	Guttiferae	939	2.90	1	0.91	1	2	5.81
Beilschimiedia micrantha	Lauraceae	723	2.24	1	0.91	1	2	5.15
Xanthophullum ellipticum	Polgylaceae	266	0.83	2	1.82	1	2	4.65
Sterculia macrophylla	Sterculiaceae	276	0.86	1	0.91	1	2	3.77
Croton heterophyllus	Euphorbiaceae	266	0.83	1	0.91	1	2	3.74
Barringtonia macrostachya	Lecythidaceae	143	0.44	1	0.91	1	2	3.35
Polyalthia sumatrana	Anonaceae	68	0.21	1	0.91	1	2	3.12
Σ19 genus	Σ16 families	32613	100.00	110	100.00	50	100	300.00

species have their I_V less than 10%. However none of the species was found to have the I_V less than 1%. Based on the I_V, forest formation of CGI can be called as *Hevea brasiliensis-Parastemon urophyllum-Antidesma ghaesembilla* Association.

***Chionanthus pachyphyllus-Parastemon urophyllum-Adinandra dumosa* association, CGII, P2 (50 m), P3 (80 m) and P6 (170 m):** CGII as shown in Fig. 1 comprised of P1, P3 and P6. These plots covered the total area of 0.15 ha or 1500 m². Table 3 and 7 showed that a total of 110 trees with a dbh of ≥5 cm were enumerated in CGII. Thus, this finding give us the estimated density of 0.073 m^{-2} or 733 ha^{-1}. These trees belonged to 10 species, 19 genus and 16 families. CGII is the heterogeneous forest formation despite the record low in species richness.

In term of density, *Parastemon urophyllum* and *Chionanthus pachyphyllus* were the dominant species. These species contributed 26.39 and 18.20% of the total density. Four species, each containing between 8-12 individuals were *Oncosperma tigillarium, Kibbesia elemeri, Eugenia alcinae* and *Adinandra dumosa.* These species contributed 37.3% of the total density in CGII. Thirteen species were of rare occurrence in CGII, each of them contained between 1-3 individuals. These heterogeneous distribution of trees among species in CGII contributed E-value of 0.781 which is less than 1. However, this E-value is greater than that of CGIV (E = 0.732), CGI (E = 0.571) and CGV (E = 0.454). The higher E-value was due to high species diversity value of H' = 2.299 in CGII compared to CGIV (H' = 2.115), CGI (H' = 1.313) and CGV (H' = 0.814) (Table 7). The E-value was higher in CGII which have the H' value of 2.115. The E-value for CGIII was 0.813.

The total basal area contribution of all trees was 32613 cm² or estimated 217,420 ha^{-1} and 21.742 m^{-2}. The most dominant species was *Chionanthus pachyhyllus.* This species contributed 28.27% of the total BA. Other dominant species was *Adinandra dumosa*, contributed 13.1% of the total BA. Other species contributing more than 5% of total BA includes *Sarcotheca glauca, Eugenia alcinae* and *Parastemon urophyllum.* Five species contributed the BA of between 5-10%; 7 species contributed the total BA between 1-5% and five species contributed less than 1% of the total BA.

Table 4: Basal area, relative dominance (R_D), density (D), relative density (R_d), frequency (R_f) and importance values (I_V) of all species in CGIII of P4, P5, P10 and P11 at 100, 130, 280 and 310 m altitude in Lok Kawi

Species	Family	BA (cm^2)	R_D (%)	D	R_d (%)	F	R_f (%)	I_V (%)
Pithecellobium ellipticum	Leguminosae	17957	38.97	15	18.75	9	18	75.72
Calophyllum inophyllum	Guttiferae	4300	9.30	15	18.75	7	14	42.05
Arenga undulatifolia	Areacaceae	2950	6.40	11	13.75	4	8	28.15
Parastemon urophyllum	Sapotaceae	1001	2.17	9	11.25	5	10	23.42
Cratoxylum arborescens	Hypericaceae	4578	9.93	4	5.00	3	6	20.93
Chionanthus pachyphyllus	Oleaceae	5889	12.78	3	3.75	2	4	20.53
Eugenia alcinae	Myrtaceae	598	1.29	5	6.25	3	6	13.54
Elaeocarpus mastersii	Elaeocarpaceae	2873	6.23	2	2.50	2	4	12.73
Barringtonia macrostachya	Lecythidaceae	824	2.79	2	2.50	2	4	9.29
Beilschimedia micrantha	Lauraceae	2691	5.85	1	1.25	1	2	9.11
Macaranga gigantea	Euphorbiaceae	164	0.36	3	3.75	2	4	8.11
Sarcotheca glauca	Oxalidaceae	636	1.38	2	2.50	2	4	7.88
Vitex pubescens	Verbenaceae	254	0.55	2	2.50	2	4	7.05
Litsea cordata	Lauraceae	1004	2.18	1	1.25	1	2	5.43
Canthium confertum	Rubiaceae	143	0.31	1	1.25	1	2	3.56
Mallotus paniculatus	Euphorbiaceae	86	0.19	1	1.25	1	2	3.44
Aporusa elmeri	Euphorbiaceae	60	0.13	1	1.25	1	2	3.38
Macaranga hypoleuca	Euphorbiaceae	37	0.08	1	1.25	1	2	3.33
Intsia palembanica	Leguminosae	37	0.08	1	1.25	1	2	3.33
Σ18 genus	Σ14 families	46082	100.00	80	100.00	50	100	301.77

The importance value of the 19 species enumerated in CGII ranged between 3.12-64.47%. Four main dominant species with I_V greater than 20% was *Chionanthus pachyphyllus*, *Parastemon urophyllum*, *Adinandra dumosa* and *Kibbesia elmeri*. Four other important species with I_V greater than 10% was *oncosperma tigillarium*, *Eugenia alcinae*, *Sarcotheca glauca* and *Calophyllum inophyllum.*

***Pithecellobium ellipticum-Callophyllum inophyllum–Arenga undulatifolia* association, CGIII, P4 (110 m), P5 (140 m), P10 (290 m) and P11 (320 m):** A total 80 trees with a dbh of ≥5 cm belonging 19 species were recorded in CGIII of 2000 m^2 (0.2 ha), giving an estimated density of 400 ha^{-1} or 0.04 m^{-2} (Table 4 and 7). In term density, four dominant species containing between 9-15 trees were *Pithecellobium ellipticum* (15, 18.75%), *Calophyllum inophyllum* (15, 18.75%), *Arenga undulatifolia* (11, 13.75%) and *Parastemon urophyllum* (9, 11.25%). The remaining 15 species are of rare occurrence in CGII. Each of these species contained between 1-5 trees. Of these, 7 species contained 1 tree each. The distribution of trees among these 19 species contributed the E-value of 0.813 in CGIII. The highest E-value obtained for CGIII compared to CGI, CGII, CGIV and CGV was due to its higher diversity level. The H’ and R for CGIII was 2.393 and 2.12 which is relatively higher than the H’ values for CGI, CGII, CGIV and CGV.

The total BAC of all trees in CGIII was 46082 cm^2 in 0.2 ha, thus giving us the estimated BAC of 230,410 cm^2 ha^{-1} and 23.041 cm^2 m^{-2}. *Pithecellobium ellipticum* and *Chionanthus pachyphyllus* were two dominant species. Each of them contributed 38.97 and 12.78% of the total BAC (Table 7). Species contributed more than 5% of the total BAC were *Cratoxylum arborescens* (9.93%), *Calophyllum inophyllum* (9.3%), *Arenga undulatifolia* (6.4%), *Elaeocarpus mastersii* (6.23%) and *Beilschmiedia micrantha* (5.85%) (Table 4). These five species combined gave us 83.61% of the total BAC. Six of the species were found to contribute less than 1% of the total BAC. These species were small tress thus elucidated the low BAC contribution of these species.

In term of importance value, the most dominant species was *Pithecellobium ellipticum* with I_V of 75.72%; five other importance species with I_V between 20-42.05% were *Calophyllum inophyllum* (I_V = 42.05%), *Arenga undulatifolia* (I_V = 28.15%), *Parastemon urophyllum* (I_V = 23.42%), *Cratoxylum arborescens* (I_V = 20.93%) and *Chionanthus pachyphyllus* (I_V = 20.53%). No species was found to have I_V of ≤1%. The lowest I_V recorded was 3.33% for *Macaranga hyopleuca* and *Intsia palembanica.*

***Calophyllum inophyllum-Croton oblongus-Cratoxylum arborescens* association, CGIV, P9 (260 m) and P12 (350 m):** CGIV comprised of P9 and P12 and it covered the area of 0.1 ha or 1000 m^2. These two plots were set at 260 and 350 m. This study recorded a total of 82 trees with a dbh of ≥5 cm in CGIV (Table 5 and 7). Based on this result, the estimated density of trees in CGIV was 0.082 m^{-2} or 820 ha^{-1} (Table 7). These trees were represented by 18 species, 18 genus and 14 families.

Two dominant species contributed more than 10 trees were *Calophyllum inophyllum* and *Croton oblongus.* These two species combined contributed 55.47% of the total density of trees enumerated in CGIV. The total of 10 species were rare and each of them contained one individual; other two species were also rare each of

Table 5: Basal area, relative dominance (R_D), density (D), relative density (R_d), frequency (R_f) and importance value (I_V) of all species in CGIV of P9 and P12 at 260 and 350 m altitude in Lok Kawi

Species	Family	BA (cm^2)	R_D (%)	D	R_d (%)	F	R_f (%)	I_V (%)
Callophyllum inophyllum	Guttiferae	8699	44.63	29	36.07	8	20.0	100.30
Croton oblongus	Euphorbiaceae	736	3.78	18	19.40	8	20.0	43.18
Cratoxylum arboescens	Hypericaceae	4799	24.62	6	7.38	4	10.0	42.00
Macaranga gigantea	Euphorbiaceae	443	2.27	7	8.61	4	10.0	20.88
Parastemon urophyllum	Rosaceae	426	2.19	4	4.92	2	5.0	12.11
Adinandra dumosa	Theaceae	1374	7.05	2	2.46	1	2.5	12.01
Vernonia arborea	Compositae	215	1.11	4	4.88	2	5.0	11.03
Glochidion borneense	Euphorbiaceae	817	4.19	1	1.23	1	2.5	7.92
Buchania arborescens	Anacardiaceae	525	2.69	1	1.23	1	2.5	6.42
Elaeocarpus mastersii	Elaeocarpaceae	555	2.85	1	1.23	1	2.5	6.58
Pithecellobium ellipticum	Leguminosae	176	0.91	2	2.46	1	2.5	5.87
Vitex pubescens	Verbenaceae	266	1.37	1	1.23	1	2.5	5.10
Eugenia alicinae	Myrtaceae	130	0.67	1	1.23	1	2.5	4.40
Oncosperma tigillarium	Arecaceae	130	0.67	1	1.23	1	2.5	4.40
Evodia punctata	Rutaceae	116	0.59	1	1.23	1	2.5	4.32
Sapium indicum	Euphorbiaceae	31	0.16	1	1.23	1	2.5	3.89
Macaranga triloba	Euphorbiaceae	29	0.15	1	1.23	1	2.5	3.88
Beilschmiedia micrantha	Lauraceae	24	0.12	1	1.23	1	2.5	3.85
Σ18 genus	Σ14	19491	100.00	82	100.00	40	100.0	300.00

Table 6: Basal area, relative dominance (R_D), density (D), relative density (R_d), frequency (R_f) and importance values (I_V) of all species in CGV comprising of P7 (200 m) and P8 (230 m) in Lok Kawi

Species	Family	BA (cm^2)	R_D (%)	D	R_d (%)	F	R_f (%)	I_V (%)
Oncosperma tigillarium	Areaceae	2267	47.94	31	79.5	4	33.2	160.64
Sarcotheca glauca	Oxalidaceae	449	9.50	3	7.8	3	24.9	42.20
Callophyllum inophyllum	Guttiferae	1215	25.70	1	2.6	1	8.3	36.60
Cratoxylum arboescens	Hypericaceae	593	12.53	2	5.2	2	16.6	34.33
Parastemon urophyllus	Sapotaceae	137	2.89	1	2.6	1	8.3	13.79
Macaranga gigantea	Euphorbiaceae	68	1.44	1	2.6	1	8.3	12.34
		4729	100.00	39	100.0	12	100.0	300.00

them comprised of 2 individual. Four species were less dominant, each of them contained between 4-7 individuals.

The total BAC of all trees in CGIV was 19,491 cm^2 or estimated 24.36 m^{-2} or 243,637 ha^{-1}. The most Two most dominant species contributing more than 20% of total BAC were *Calophyllum inophyllum* (44.63%) and *Cratoxylum arborescens* (24.62%). Other notable species was *Adinandra dumosa*, contributing 7.05% of the total BAC. These three species combined contributed 76.3% of the total BAC. The other fifteen species contributed 23.7% of the total BA and each of them contributed between 0.12-4.19%.

The analysis on importance value showed that *Calophyllum inophyllum*, *Croton oblongus* and *Cratoxylum arborescens* were three main dominant species. These species respectively have their I_V of 100.30, 43.18 and 42% (Table 5 and 7). Four other notable species having I_V between 12-20.88% were *Macaranga gigantea*, *Parastemon urophyllum*, *Adinandra dumosa* and *Vernonia arborea.* Five species have their I_V between 5-10% and six species with I_V below 5%. However no species have the I_V less than 1%.

The values of R, H' for species diversity were relatively low. The values were 1.99 and 2.12. On the other hand, the E-value obtained for CGIV was 0.752. The maximum possible E-value obtained for forest formation is 1. This value can be obtained when the number of trees are distributed evenly among the species recorded in each CG. The CG will have E = 0 when the CG is dominated only one species of trees only. It is impossible to obtained the maximum and minimum value of E in tropical rainforest. Two of the main attributes of the tropical rain forests is the heterogeneity of their species composition and heterogeneous distribution of individuals among species. These two characteristic features of the tropical rainforest can be explained by the findings past researchers working on the floristic composition and forest structures (Adam and Zahiruddin, 2005; Adam, 1997, 2000, 2001; Adam and Norseha, 2000; Adam and Enning, 1996; Kochummen, 1982; Martin, 1977; Ohsawa *et al*., 1985; Proctor *et al*., 1988; Soepadmo, 1987).

***Oncospermum tigillarium-Sarcotheca glauca-Calophyllum inophyllum* association, CGV, P7 (200 m) and P8 (230 m):** CGV comprised of P7 and P5 which is located at 190 and 220 m altitude. A total of 39 trees with dbh of ≥5 cm were recorded in 0.1 ha thus this enumeration gave us an estimated density of 390 ha^{-1} and 0.039 m^{-2} (Table 6). These trees belong to 6 species, 6 genus and 6 families. Table 6 indicated that *Oncosperma tigillarium* is the most abundant with 21 individuals. Five

Table 7: Summary of the CGS data: Floristic and forest structure in lowland hilly forest at Lok Kawi, Sabah

Floristic and forest structure	CGI	CGII	CGIII	CGIV	CGV
Plot (P) and altitude (m)	P1 (20 m)	P2 (50 m), P3 (80 m), P6 (170 m)	P4 (110 m), P5 (140 m), P10 (290 m), P11 (320 m)	P9 (260 m), P12 (350 m)	P7 (200 m), P8 (230 m)
Plots area (m^2 or hectare)	500 or 0.05	1500 or 0.15	2000 or 0.2	1000 or 0.1	1000 or 0.1
No. of species (S)	10	19	19	18	6
No. of genus	10	19	18	18	6
No. of family	8	16	14	14	6
1st dominant species (I_V %)	*Hevea brasiliensis*, 119.1	*Chionanthus pachpyllus*, 64.47	*Pithecellobium ellipticum*, 75.72	*Calophyllum inophyllum*, 100.30	*Oncosperma tigillarium*, 160.64
2nd dominant species (I_V %)	*Parastemon urophyllum*, 46.64	*Parastemon urophyllum*, 52.08	*Calophyllum inophyllum*, 42.05	*Croton oblongus*, 43.18	*Sarcotheca glauca*, 42.20
3rd dominant species (I_V %)	*Antidesma ghaesembilla*, 39.35	*Adinandra dumosa*, 26.38	*Arenga undulatifolia*, 28.15	*Cratoxylum arborescens*, 41.00	*Calophyllum inophyllum*, 36.60
Density (N)	65	110	80	82	39
Density (m^{-2})	0.13	0.073	0.04	0.082	0.039
Density (ha^{-1})	1300	733	400	820	390
1st dominant species (D)	*H. brasiliensis*, 41 (63.14%)	*P. urophyllum*, 29 (26.39%)	*P. ellipticum* and *C. inophyllum*, 15 (18.75%)	*C. inophyllum*, 29 (36.07%)	*O. tigillarium*, 31 (79.5%)
2nd dominant species (D)	*P. urophyllum*, 11 (16.94%)	*C. pachyphyllus*, 20 (18.2%)	*Arenga undulatifolia*, 11 (13.75%)	*Croton oblongus*, 18 (19.40%)	*Sarcotheca glauca*, 3 (7.8%)
BAC (cm^2)	8905	32613	46082	19491	4279
BAC (m^{-2})	17.81	21.742	23.041	24.36	4.279
BAC (ha^{-1})	178,100	217, 420	230,410	243637	42,790
1st dominant species (BAC)	*H. brasiliensis*, 2792 (31.27%)	*C. pachyphyllus*, 9118 (28.27%)	*P. ellipticum*, 17,957 (38.97%)	*C. inophyllum*, 8699 (46.33%)	*O. tigillarium*, 2267 (47.94%)
2nd dominant species (BAC-cm^2)	*A. ghaesembilla*, 2318 (25.96%)	*A. dumosa*, 4257 (13.1%)	*Chionanthus pachyphyllus*, 5889 (12.78%)	*Cratoxylum arborescens*, 4799 (24.62%)	*Calophyllum inophyllum*, 1215 (25.7%)
Menhinick index $R = S/\sqrt{N}$ (Rank)	1.24 (4)	1.81 (3)	2.12 (1)	1.99 (2)	0.96 (5)
Shannon-weiner index (H') (Rank)	1.313 (4)	2.299 (2)	2.393 (1)	2.115 (3)	0.814 (5)
Evenness index (E) = H'/ln (S) (Rank)	0.571 (4)	0.781 (2)	0.813 (1)	0.732 (3)	0.454 (5)

species is rare, each of them contained 1-3 individuals. The paucity in species composition and low in tree density in CGV explained the low values of R, H and E compared to CGI, CGII, CGIII and CGIV (Table 7).

BAC of these trees is very low, 4729 cm^2 or estimated BAC of 42, 790 m^{-2}. The most dominant species in term of BAC is also *Oncosperma tigillarium* with BAC of 47.94%, distantly followed by *Calophyllum inophyllum* with BAC of 25.7% and *Cratoxylum arborescens* with BAC of 12.52%. Three other species have BAC of less than 10%. The low BAC recorded in CGV compared with other CGS is due to low in tree density and small tree sizes.

The importance values of tree species determined in CG are greater than 10%. No species is recorded with I_V less than 10%. In tropical lowland primary forest with high species diversity, many species have their I_V less than 10% and some of the species have their $I_V \leq 1\%$ (Adam, 2000, 2001; Adam and Norseha, 2000; Adam and Enning, 1996; Adam and Zahiruddin, 2005). This study also revealed that the most dominant species have very high I_V of 160.64%. This represents 60% of the total I_V of 300. The second most dominant species is *Sarcotheca glauca* with I_V of 42.20% and it followed closely by *Calophyllum inophyllum* and *Cratoxylum arboerscens*.

Forest structure between CGS: Table 7 listed the floristic and forest structure of five CGS located between 20 to 350 m altitude in Lok Kawi. The Table 7 showed that the floristic and forest structure differed or the same between CGS. In term of floristic, CGII is the most diverse in term of species, genus and family representation, followed by CGIII, CGIV, CGI and CGV. The first and third dominant species in term of importance value is different between CGS; the second dominant species is the same between CGI and CGII but differed between CGIII, CGIV and CGV. The density of trees per hectare and per m varied between CGS; the highest estimated density per hectare was the highest in CGI, followed by CGIV, CGII, CGII and CGV. Similarly, BAC of trees with a dbh of ≥5 cm varied between CGS; the highest estimated BAC ha^{-1} is the highest in CGIV, followed by CGIII, CGII, CGI and CGV. The low in BAC at CGV was attributed to its low in density and small tree sizes compared to the other four CGS. This study also showed that the first and second dominant species in term of BAC differed between CGS. The indices of species diversity which include R, H' and E showed the highest in CGIII, followed by CGII, CGIII, CGI and CGV. The variation in floristic composition and forest structure is attributed to the degree of disturbance of the forest in the study area. The indication of disturbance is exemplified by the presence of the common tree species growing in secondary and disturbed forest such as *Mallotus paniculatus*, *Macaranga triloba*, *Macaranga gigantea*, *Macaranga hypoleuca*, *Vitex pubescens* and *Adinandra dumosa*.

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