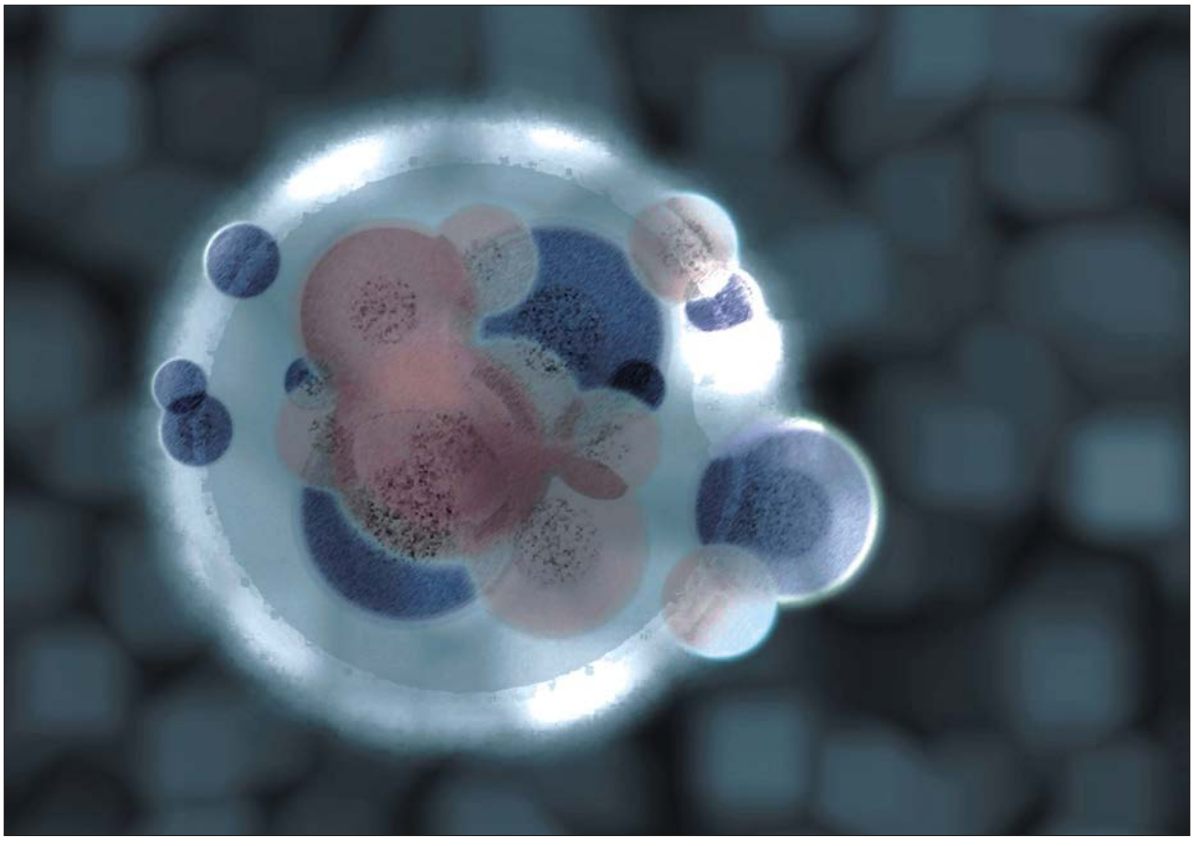

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Floristic Composition and Structural Comparison of Limestone Forests at Three Different Elevations in Bau, Kuching, Sarawak, Malaysia

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Abstract: The study using plot method to determine floristic composition and forest structure of limestone forests at three different altitudes in Bau have been carried out. A total of 1682 trees encompassing an area of 0.75 ha were enumerated. They belong to 129 species in 41 families. Euphorbiaceae, Moraceae, Ebenacaea, Rubiaceae and Violaceae were important families in term of density. Shannon Diversity Index (H'), species richness (R) and species evenness (E) decreases with increasing altitude. The floristic similarity of family composition is higher compare to species composition between altitudes. Moraceae contributed the highest basal area and above ground biomass contribution in all plots at all altitudes; for species *Ficus aurata* is dominant at 15 m (P_1) and 30 m (P_3), whilst *Mallotus oblongifolius* is dominant at 50 m (P_2). Analysis on the importance values (I_v) of all tree species enumerated at all altitudes quantified the dominant and co-dominant species with the highest and second highest I_v. The dominant and co-dominant species is *Arenga borneensis* and *Ficus aurata* 15 m; *Mallotus oblogifolius* and *Artocarpus rigidus* at 30 m and *Ficus aurata Saraca hullettii* in 50. Between 68-77% of all species enumerated have I_v less than 5% at all altitudes.

Key words: Sarawak, limestone flora, species diversity, altitude, importance value

INTRODUCTION

Sarawak's limestone flora is poorly studied both ecologically and taxonomically. According to Anderson[1], a project to study the limestone vegetation of the limestone hills of Sarawak by Sarawak Forest Department has a very low priority. The research done in the past was aimed to gaining knowledge of this little studied but exceeding highly diverse in flora. At least six hundred species of plants have so far been recorded from the limestone forest. It is noted that the limestone forest harbored many rare and endemic species, for example *Nepenthes northiana* is restricted on Bau limestone forest and *Nepenthes mapuluensis* in Kalimantan[2]. Floristic composition of Sarawak limestone vegetation bears some common resemblance to Malayan limestone flora. Families of plants such as Euphorbiaceae, Moraceae, Annonaceae, Gesneriaceae, Begoniaceae are well represented, whereas families such as Dipterocarpaceae, Magnoliaceae, Simaroubaceae and Linaceae are of least important[1,3]. Complexity of limestone vegetation with highly diverse habitat is influenced by multitude of factors, which includes topography, soil, light intensity and moisture of rock faces[1]

Anderson[1] and Anderson and Chai[4] divided the limestone hills in Sarawak into eight different sub-types: alluvial soils at the base of limestone hill and ravines between hills; slopes of limestone hills; limestone cliffs; scree slopes on limestone hills at low elevation; summit of limestone hills at low elevation; submontane forest and secondary vegetation.

Alluvial soils on the foothill of limestone may have sources of origin from other geological formations within the vicinity or from limestone formation. Structurally, the forest on this alluvial plain is stratified into three layers: upper canopy, middle storey and lower storey. The upper canopy is occasionally represented by emergent such as *Eusideroxylon melagangai* (Lauraceae), which may exceed 250 cm in girth and 40 m in height. Other species of the canopy include *Parashorea macrophylla, Octomeles sumatrana* and *Pentaspadon motleyi*. Species such as *Bhesa paniculata, Paranephelium* and *Polyalthia sumatrana* are found in understorey.

At the base of the limestone hills and in ravines with no igneous rock, the forest is less dense and lower in stature than that found in ravines with igneous rock. The typical tree species found in this habitat include

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Artocarpus sericarpus, Saurauria tewnesis and *Caryota mitis*. The tree species growing in ravines with igneous rock present is found to differ. The characteristic species found here include *Eusideroxylon zwageri, Dipterocarpus caudiferus* and *Shorea pauciflora*. Calciphylous herbs of *Monophyllea glauca, monophyllea johnannis-winkleri, Epithema involucratum* and *Pilea calcarea* grow abundantly on rock limestone cervices.

The soil on the slope of limestone hills is negligible or very shallow. The vegetation on gradual slopes is of dense irregular forest. Several emergent species such as *Hopea dasyrachis* exceeds 40 m tall but with main canopy height lower than this. The medium and small trees present under the canopy layer include *Harpullia arborea, Chiosocheton beccarianus* and *Drypetes microphylla*.

The plant communities on the limestone cliff comprise of plant adapted to exposure to direct sunlight, lacking in soil and dry, such plants include *Boea havilandii* and *Paraboea clarkei*. Other plant species of the limestone cliff such as *Nepethes northiana, Salaca rupiucola* is adapted to damp and partial shaded habitat.

Small scree slopes comprised of weathered limestone boulders with soils at the foothill. Species found here include *Harpullia arborea, Trigonostemon malacana* and *Firmiana malyana*. The limestone summit of low elevation is calcifuges in character. The plant species growing here *includes Casuarina sumatrana, Tristania obovata, Shorea coriaceeae, Vaccinium lobbii* and *Nepenthes albomarginata*. Submontane forest is not found in Bau but is found on Gunung Api and Benarat of Melinau Massif with elevation exceeding 1000 m. The plants species can be found here include *Dacrydium gibbsiae, Phyllocladus hypophyllus, Tristania obovata* and *Palaquium gutta*.

Bau limestone hills, has been seriously disturbed mainly due to a century mining activity for gold and antimony deposits, burning due natural or man made fire. The disturbed forest is slowly recovered and the exposed limestone rock may remain bare for Many years. The pioneer species are mosses, succeeded by *Drynaria rigidula, Phymatodes scolopendria, Davallia denticulata*. The shrubs and trees such as *Decaspermum fruticosum, Elaeocarpus griffithii* and *Neocauclea cyrtopoda* grows in places with litter and soil deposited.

The main objectives of this study were to determine tree species composition of the study area; to determine quantitatively the dominant and co-dominant species and to quantify floristic similarity between elevations.

MATERIALS AND METHODS

The study area is located on Bau Hill, which is 40 km from Kuching and 3 km to north west of Bau Town. Three plots designated as P_1, P_2 and P_3 were set at 15, 30 and 50 m altitudes. Each plot has an area of 0.25 ha and was subdivided into 25 of 0.01 ha subplots; this subdivision is for the purpose of calculating the relative frequency (R_F) of each tree species recorded from the plots. An inventory of all tree species with a diameter at breast height (dbh) of ≥5 cm was enumerated in all plots, recording the species and measuring their dbh. All voucher specimens collected were identified in Sarawak Forest Herbarium.

The overall floristic similarities of family and species composition between plots were quantified using the Sorenson's index of similarity (CC)[5]:

$$CC = [\ 2C/\ a+b\ ]\ \ x\ 100$$

In which C = the number of joint taxa in both plots, a = the number of taxa present at 15 m (P_1) and b= the number of taxa present at 30 m (P_2).

The sum of relative frequency, relative density and relative dominance constitute the importance values (I_v) of all tree species inventoried 15 m (P_1), 30 m (P_2) and 50 m (P_3). The values of R_F, R_d and R_D were calculated using standard ecological formulas[2,5,6].

Species diversity, species richness and species evenness were quantified, respectively using Shannon-Wiener Diversity Index (H'), Menhinick Richness Index (R) and Evenness Index (E)[7].

Basal area, tree height and aboveground biomass of tree were calculated using regression equations of Kato *et al.*[8]

RESULTS AND DISCUSSION

They belong to 129 species and 41 families. Five trees unidentified were designated as Taxon 1 and 2, respectively. More than 48% of these recorded families were poor in species representation (Table 1-3). At 15 m, 21 out of 34 families recorded comprises of 1 species (Table 1); whereas at 30 m (P_2), 11 out of 23 families contained 1 species each (Table 2); similarly at 50 m (P_3), 16 of 26 families recorded also contained 1 species each (Table 3). The numbers of diverse families contained more than 5 species were relatively low at all altitudes: at 15 m, these families were represented by Euphorbiaceae, Rubiaceae and Moraceae (Table 1); at 30 m, they were Euphorbiaceae, Sapindaceae and Moraceae (Table 2) and at 50 m, they were Euphorbiaceae and Sterculiaceae. Table 1-3 also showed that the number of families contributing more than 5% of the total density were relatively low at all altitudes: at 15 m, these families were represented by Euphorbiaceae, Rubiaceae, Lauraceae, Moraceae, Meliaceae and Palmae (Table 1); at 30 m, these families includes Euphorbiaceae, Ebenaceae, Moraceae and Violaceae (Table 2) and at 50 m,

Table 1: Number of species, density and percentage of density, Basal Area (BA) and Above Ground Biomass (AGB) of trees with a dbh ≥5 cm for each family recorded in plot 1 at 15 m elevation

Family	No. of species	Density	% Density	BA (cm^2)	% BA	AGB (kg)	% AGB
Euphorbiceae	12	164	30.72	3540	8.45	270.95	4.26
Rubiaceae	8	53	9.93	4037	9.64	32210	7.56
Lauraceae	4	49	9.18	1135	2.71	8948	2.10
Moraceae	5	47	8.80	14095	33.64	180557	42.40
Meliaceae	4	40	7.49	3314	7.91	30712	7.21
Palmae	3	32	5.59	7356	17.56	74154	17.41
Sterculiaceae	2	22	4.12	582	1.39	3412	0.80
Ebenaceae	3	16	3.00	525	1.25	4250	1.00
Dilleniaceae	1	13	2.43	142	0.34	494	0.10
Verbenaceae	2	12	2.25	809	1.93	5843	1.37
Tiliaceae	2	12	2.25	1043	2.49	9494	2.23
Hypericaceae	1	9	1.69	2289	5.46	20909	4.91
Oleaceae	1	9	1.69	211	0.50	1142	0.27
Symplocaceae	1	7	1.31	99	0.24	394	0.09
Bursearaceae	1	6	1.12	1870	4.46	19421	4.56
Vitaceae	1	6	1.12	35	0.08	87	0.02
Annonaceae	3	5	0.94	32	0.08	84	0.02
Leguminosae	1	5	0.94	64	0.15	142	0.03
Anacardiaceae	2	4	0.75	1078	2.57	11825	2.78
Violaceae	2	4	0.75	28	0.07	75	0.02
Guttiferae	1	4	0.75	30	0.07	78	0.02
Rhizophoraceae	1	4	0.75	31	0.07	73	0.02
Saurauiaceae	1	4	0.75	14	0.03	25	0.01
Taxon 1	1	4	0.75	71	0.17	253	0.06
Melastomataceae	1	3	0.56	201	0.48	1172	0.28
Flacourtiaceae	1	2	0.37	16	0.04	40	0.01
Apocynaceae	1	1	0.19	10	0.02	27	0.01
Myrtisticaceae	1	1	0.19	214	0.51	1.805	0.42
Ochnaceae	1	1	0.19	14	0.03	44	0.01
Oleaceae	1	1	0.19	211	0.50	1142	0.27
Polygylaceae	1	1	0.19	28	0.07	66	0.02
Sapindaceae	1	1	0.19	3	0.01	4	0.01
Theaceae	1	1	0.19	2	0.004	2	0.01
Taxon 2	1	1	0.19	5	0.01	4	0.01
Total	70	534	100	41845	100	425,861	100

Table 2: Number of species, density and percentage of density, Basal Area (BA) and Above Ground Biomass (AGB) of trees with a dbh ≥5 cm for each family recorded in plot 2 at 30 m elevation

Family	No. of species	Density	% Density	BA (cm^2)	% BA	AGB (kg)	% AGB
Euphorbiaceae	14	264	41.06	24915	20.59	225054	16.25
Ebenaceae	3	122	18.97	13761	11.37	165797	11.97
Moraceae	5	66	10.26	35692	29.50	459095	33.14
Violacaea	2	38	5.91	484	0.40	2357	0.17
Sapindaceae	6	28	4.35	6278	5.10	70709	5.10
Palmae	2	24	3.73	4905	4.05	49272	3.56
Leguminosae	1	20	3.11	2.846	2.35	26040	1.88
Rubiaceae	2	17	2.64	4220	3.49	44648	3.22
Anacardiaceae	1	14	2.18	14378	11.88	187022	13.50
Annonaceae	4	10	1.56	164	0.14	689	0.05
Meliaceae	1	6	0.93	1212	1.01	11571	0.84
Tiliaceae	2	6	0.93	975	0.81	7604	0.55
Guttiferae	3	5	0.78	94	0.08	471	0.03
Myrtaceae	2	5	0.78	426	0.35	3769	0.27
Lauraceae	2	3	0.47	230	0.20	1600	0.12
Sterculiaceae	1	3	0.47	238	0.20	1647	0.12
Urtiicaceae	1	3	0.47	7	0.01	13	0.01
Verbenaceae	1	2	0.32	199	0.17	1318	0.10
Alangiaceae	1	1	0.16	2	0.01	3	0.01
Apocynaceae	1	1	0.16	7313	6.04	124650	9.00
Monimiaceae	1	1	0.16	16	0.01	53	0.01
Myristicaceae	1	1	0.16	8	0.01	21	0.01
Symplocaceae	1	1	0.16	13	0.01	41	0.01
Total	59	643	100	120949	100	1385373	100

Table 3: Number of species, density and percentage of density, Basal Area (BA) and Above Ground Biomass (AGB) of trees with a dbh ≥5 cm for each family recorded in plot 3 at 50 m elevation

Family	No. of species	Density	% Density	BA (cm^2)	% BA	AGB (Kg)	% AGB
Euphorbiceae	6	122	24.16	2513	5.45	12455	2.63
Sterculiaceae	6	34	6.73	2883	6.30	25369	5.36
Violacaeae	2	57	11.29	868	1.90	2992	0.63
Moraceae	3	56	11.06	15709	34.10	198820	42.03
Leguminosae	1	48	9.50	5138	11.00	46394	9.80
Rubiaceae	4	47	9.31	7505	16.30	77388	15.30
Flaourtiaceae	3	21	4.16	2900	6.30	37084	7.84
Annonaceae	3	21	4.16	177	0.38	585	0.12
Oleaceae	1	15	2.97	956	2.07	8855	1.87
Anacardiaceae	1	14	2.77	2902	6.30	29618	6.17
Meliaceae	4	11	2.18	381	0.83	2317	0.49
Myrtaceae	2	8	1.58	1229	2.67	4711	0.99
Polygylaceae	1	8	1.58	66	0.02	194	0.04
Urticaceae	1	8	1.58	36	0.08	75	0.02
Verbenaceae	1	7	1.39	364	0.79	2948	0.62
Dipterocarpaceae	1	6	1.19	33	0.07	79	0.02
Ebenacaeae	1	6	1.19	50	0.11	149	0.03
Rhizophoraceae	1	4	0.79	6.51	1.41	6219	1.37
Tiliaceae	1	3	0.59	842	1.80	8620	1.82
Apocynaceae	2	2	0.40	157	0.34	980	0.21
Rutaceae	1	2	0.40	5	0.01	8	0.01
Lauraceae	1	1	0.20	14	0.03	44	0.02
Loganiaceae	1	1	0.20	2	0.01	8	0.01
Ochnaceae	1	1	0.20	36	0.08	168	0.04
Palmae	1	1	0.20	607	1.32	6783	1.43
Vitaceae	1	1	0.20	3	0.01	4	0.01
Total	51	505	100	46027	100	472957	100

Table 4: Basal area, biomass contribution, density, mean dbh and mean height of tree species in P_1 at 15 altitude

Species	Basal area (cm^2)	Biomass (kg)	Density	Mean dbh (cm)	Mean height (m)
Ficus aurata	7274	115534	5	30.6	25.4
Areanga borneensis	6834	71789	15	23.8	26.6
Artocarpus sp1	4133	43148	5	14.7	18
Neonauclea excelsa	2316	21146	2	13.1	17.1
Artocarpus rigidus	2248	18206	22	9.7	13.7
Cratoxylum formosum	2289	20910	9	17.5	22
Agalaia bernardoi	1885	18429	12	11.1	14.5
Santiria obolgifolia	1870	19421	6	17.6	20.7
Mallotus dispar	1776	10114	45	6.3	10
Aglaia sp1	1228	11136	20	6.1	9.1
Semecarpus bumburyanus	1071	11814	2	25.6	27.6
Grewia antidesmaefolia	1041	9491	5	15	19.3
Actinodaphne borneeusis	953	7790	32	3.9	6.2
Canthium umbelligerum	816	5587	16	6.2	9.8
Vitex pubescens	771	5716	9	9	12.9
Mallotus oblongus	610	3270	24	4.9	8.1
Pterospermum javanicum	527	3129	20	4.7	7.8
Neonauclea calycina	470	3262	6	9.2	13.7
Caryota mitis	465	2055	16	6	9.9
Dimorphocalyx luzonieusis	455	1829	39	3.3	5.8
Ficus midotis	426	3616	2	16.9	21.2
Diospyros pendula	288	2286	3	9.4	13.4
Macaranga triloba	255	1342	8	5.7	9.2
Sterculia pallidiflora	238	1647	3	4.9	8
Timonius lasianthoides	236	1081	11	4.7	8
Diospyros cauliflora	233	978	12	4.5	7.7
Knema ashtonii	214	1805	1	16.5	21.4
Chionanthus pacyphyllus	211	1143	9	4.5	7.5
Ptenaudra multiflora	201	1172	3	9.2	14.1

*41 Species contributing total basal area below 200 cm^2 is excluded

they were Euphorbiaceae, Sterculiaceae, Violaceae, Moraceae, Leguminosae and Rubiaceae (Table 3). Past researchers showed that many tree taxa are rare in term of density in the tropical rain forest[2,6,9,10]. This study showed that 67.7, 56.5 and 57.7% of the families recorded in P_1, P_2 and P_3 at 15, 30 and 50 m altitudes contained less than 10 trees each (Table 1-3).

Similarly, the number of species contribution basal area and biomass greater than 5% were also relatively in all plots at all altitudes: in P_1 at 15 m, they were

Table 5: Basal area, biomass contribution, density, mean dbah and mean height of tree species in P_2 at 30 m altitude

Species	Basal area (cm^2)	Biomass (kg)	Density	Mean dbh (cm)	Mean height (m)
Mallotus oblongifolius	16196	118460	180	9.7	14.2
Semecarpus bumburyanus	14378	187022	1	34.5	31.6
Alstonia scholaris	7317	124650	1	96.5	46.4
Diospyros cauliflora	6387	40962	118	7.3	11.2
Baccaurea lanceolata	5406	85332	11	11.8	11.3
Arenga borneeusis	4723	48282	18	15.6	18.7
Neonauclea gigamtea	2614	28994	6	21.8	24.5
Pometia pinnata	2575	30288	12	14.2	22.1
Canthium didymium	1606	15654	11	10.7	14.3
Allophyllus sp1	1517	18272	8	9.6	11.7
Dimorphocalyx luzonieusis	1084	7896	14	8.5	12.5
Brownlowia glabrata	758	5770	5	13.9	19
Mallotus dispar	743	4345	17	6.6	10.4
Lepisanthes tetraphylla	742	6087	5	12.6	17
Allophyllus cobbe	679	7786	1	29.4	29.9
Dimocarpus fumatus	586	6842	1	27.3	28.8
Rinorea hornerii	404	2173	21	2.3	4.3
Aporusa caloneura	363	2070	8	5.6	3.5
Drypetes longifolia	292	2030	4	8.4	12.3
Baccanrea racemosa	251	1651	3	10	14.9
Cleistanthus glaber	242	1480	6	6.1	9.6
Grewia antidesmaefolia	217	1834	1	16.6	21.5

*37 Species contributing total basal area below 200 cm^2 is excluded

Table 6: Basal area and above ground biomass contribution of tree species in P_3 at 50 m altitude

Species	Basal area (cm^2)	Biomass (kg)	Density	Mean dbh (cm)	Mean height (m)
Ficus aurata	12835	168900	16	27.6	26.3
Neonauclea peduncularis	5227	53210	21	15.4	19.0
Saraca hullettii	5138	46394	48	9.2	13.0
Semecarpus bumburyanus	2902	29168	14	13.9	17.6
Scolopia spinosa	2854	36953	15	8.0	9.0
Artocarpus rigidus	2511	26362	39	5.5	8.0
Mallotus dispar	1973	10198	75	5.1	8.3
Canthium umbelligerum	1716	14664	22	7.4	10.6
Scaphium	1612	14861	10	11.8	15.4
Pterospermum stapfianum	1037	9515	12	7.3	10.2
Chionanthus pachphyllus	956	8855	15	6.1	9.0
Eugenia sp1	850	8620	5	10.6	13.2
Brownlowia glabrata	842	8620	8	16.3	19.3
Gynotroches axillaris	651	6219	4	11.4	14.8
Arenga borneeusis	607	6783	1	27.8	29.1
Rinorea beugaleusis	547	2089	25	5.2	8.5
Canthium glabrum	403	3476	2	15.5	20.3
Vitex vestita	364	2948	7	6.0	9.1
Ficus forstenii	363	3558	1	21.5	25.2
Rinorea honerii	321	903	32	3.4	5.8
Cleistanthus brideliifolius	275	1454	9	5.5	9.1
Croton oblongifolius	257	895	20	3.8	6.7
Aglaia bernardoi	230	1552	4	7.4	11.4

*27 Species contributed basal area less than 200 cm^2 is excluded

Euphorbiaceae, Rubiaceae, Lauraceae, Moraceae, Meliaceae, Hypericaceae and Palmae (Table 1) and in P_2 (30 m altitude), these families includes Euphorbiaceae, Ebenaceae, Anacardiaceae, Sapindaceae and Moraceae (Table 2); whereas in P_3 they were Moraceae, Leguminosae, Rubiaceae, Flacuortiaceae, Anacardiaceae Sterculiaceae and Euphorbiaceae (Table 3).

Total density of trees enumerated was found varied between plots. This study shows that estimated tree density per ha was recorded highest in P_2 (30 m altitude) with 2573 trees, followed distantly by P_1 (15 m altitude) and P_3 (50 m altitude), respectively with 2136 and 2020 trees. The number of species, values of H', R and E decreases with increasing altitude. A total of 70, 59 and 51 species is enumerated, respectively in P_1, P_2 and P_3 at 15, 30 and 50 m altitude (Table 1-3); values of H' is 3.72, 3.29 and 2.95 for P_1, P_2 and P_3 respectively and R is 3.10, 2.30 and 2.30 in P_1, P_2 and P_3, respectively and E is 0.87, 0.84 and 0.72 in P_1, P_2 and P_3, respectively.

The overall similarity of family composition between P_1, P_2 and P_3 at 15, 30 and 50 m altitude using

Table 7: Relative frequency (R_f), relative density (R_d), relative dominance (R_D) and importance values (I_v) of tree species in P_1 (15 m altitude) with importance values greater than 5%

Species	R_f	R_D	R_D	I_v
Areanga borneensis	2.93	2.81	15.95	21.69
Ficus aurata	1.83	0.94	16.94	19.74
Mallotus dispar	4.40	8.43	4.14	16.97
Artocarpus sp1	2.56	3.18	9.64	15.39
Artocarpus rigidus	4.03	4.12	5.25	13.39
Actinodaphne borneeusis	3.66	5.99	2.22	11.88
Dimorphocalyx luzonieusis	3.30	7.30	1.06	11.66
Neonauclea excelsa	3.30	2.43	5.41	11.14
Mallotus oblongus	4.76	4.49	1.43	10.68
Aglaia sp1	3.66	3.74	2.86	10.27
Cratoxylum formosum	1.83	1.69	5.34	8.86
Canthium umbelligerum	3.66	3.00	1.90	8.56
Aglaia bernardoi	1.83	2.25	4.40	8.48
Pterospermum javanicum	3.30	3.74	1.23	8.27
Santiria oblongifolia	1.83	1.12	4.36	7.32
Caryota mitis	2.93	3.00	1.09	7.01
Antidesma montanum	2.20	4.30	0.25	6.75
Vitex pubescens	2.20	1.69	1.80	5.8
Dillenia sumatrana	2.56	2.43	0.33	5.33

*5, 5, 6, 16 and 19 species, respectively have their I_v range from 4.1-5%, 3.1-4%, 2.1-3%, 1.1-2% and below 1%.

Table 8: Relative frequency, relative density, relative dominance and importance values of tree species in P_2 (30 m altitude) with importance values greater than 5%

Species	R_f	R_D	R_D	I_v
Mallotus oblongifolius	12.20	27.93	14.55	54.74
Artocarpus rigidus	10.06	8.40	19.80	38.26
Diospyros cauliflora	13.11	18.35	5.70	37.20
Semecarpus bumburyanus	3.05	2.18	12.92	18.14
Arenga borneeusis	3.35	2.80	4.24	10.40
Saraca declinata	3.66	3.11	2.56	9.33
Ficus subulata	1.52	0.78	6.85	9.15
Baccaurea lanceolata	1.52	1.71	4.86	8.09
Artocarpus elasticus	1.52	0.78	5.29	7.59
Pometia pinnata	3.05	1.87	2.31	7.23
Alstonia scholaris	0.30	0.16	6.57	7.03
Rinorea bengaleusis	3.35	3.27	0.36	6.98
Mallotus dispar	3.35	2.64	0.67	6.66
Dimorphocalyx luzonieusis	3.05	2.18	0.97	6.20
Rinorea hornerii	3.35	2.64	0.07	6.09
Canthium didymium	3.05	1.71	1.44	6.20
Neonauclea gigantean	1.83	0.93	2.35	5.11
Aporusa caloneura	3.05	1.71	0.33	5.09

*1, 1, 6, 10 and 23 species, respectively have their I_v range from 4.1-5%, 3.1-4%, 2.1-3%, 1.1-2% and bellow 1%

Table 9: Relative frequency, relative density, relative dominance and importance values of tree species in P_3 (50 m altitude) with importance values greater than 5%

Species	R_f	R_D	R_D	I_v
Ficus aurata	3.25	3.17	27.91	34.33
Saraca hullettii	5.69	9.50	11.17	26.37
Mallotus dispar	6.91	14.85	4.29	26.05
Neonauclea peduncularis	5.69	4.16	11.37	21.21
Artocarpus rigidus	6.91	7.72	5.46	20.06
Scolopia spinosa	3.66	2.97	6.21	12.83
Semecarpus bumburyanus	3.66	2.77	6.31	12.74
Canthium umbelligerum	4.47	4.36	3.73	12.56
Rinorea honerii	3.66	6.34	0.70	10.70
Chionanthus pachphyllus	4.07	2.97	2.08	9.12
Pterospermum stapfianum	3.25	2.38	2.26	7.88
Croton oblongifolius	3.25	3.96	0.56	7.77
Scaphium	2.03	1.98	3.51	7.52
Meiogyne virgata	2.85	2.77	0.33	5.94

*4, 6, 5, 12 and 9 species, respectively have their I_v range from 4.1-5%, 3.1-4%, 2.1-3%, 1.1-2% and below 1%

Sorenson's similarity index (CC) were high that is 70, 74 and 76%, respectively between P_1-P_2, P_1-P_3 and P_2-P_3. However CC of species composition between plots was lower that is 38, 25 and 39%, respectively between P_1-P_2, P_1-P_3 and P_2-P_2.

These 3 plots share some common attributes: firstly, in all plots Euphorbiaceae is the most important family in term of species richness and density: 29.96, 41.06 and 24.16% of recorded trees belong to this family in P_1, P_2 and P_3 at 15, 30 and 50 m altitude, respectively (Table 1-3); whereas, a total of 11 and 6 species respectively were represented by this family in P_1, P_2 and P_3 (Table 1-3). Secondly Moraceae is one other species of notable important in term of species richness and density. Thirdly, the percentage of families which contained one species and less than 10 trees each is considerably higher in all plots. The results confirm with the reports of Anderson[1] that certain families such as Euphorbiaceae and Moraceae are well represented on limestone and other families such as Dipterocarpaceae, Simabouraceae and Linaceaea are poorly represented or absent. The results of this study on tree species composition per family agree with the work carried out by Adam and Phillipinus[3] and Gopinanthan[11]. These studies show that Euphorbiaceae is well represented with 25 species. Of these, 10 species were recorded from present study area in Bau.

The result of this study also shows that a high percentage of trees in all plots fall into dbh class 1 (5.0-10 cm) that is 82, 86.5 and 60.5%, respectively in P_1, P_2 and P_3 at 15, 30 and 50 m. Conversely, a very low percentage of trees fall into dbh class 4 (30.1-40 cm), class 5 (40.1-60 cm), class 6 (>50 cm) in all plots. A total of 2.4. 0.8 and 3.8% of all trees enumerated fall into these three dbh classes. The reverse J curve for the dbh class distribution of trees in these plots indicates a regenerating community. The dbh distribution pattern conforms to results of the study of the other workers elsewhere in tropical rain forest[2,6,12,13]. Adam and Ibrahim[2] found that 79% of trees enumerated in one ha plot of Lowland Dipterocarp Forest in Danum, Sabah belong to dbh class 1 and 2 and 12.7% in dbh class 3-4 and 8.1% in dbh class 5.

Basal area, aboveground biomass, density, mean dbh and mean height of trees from the most important to the least important species in term of basal area in P_1, P_2 and P_3 at 15, 30 and 50 m altitude were listed in Table 4-6. The most important species with the highest basal area contribution and aboveground biomass contribution and density differs between plots: in P_1, *Mallotus dispar* have the highest number of trees enumerated with 45 individuals, whereas *Ficus aurata*, respectively contributed the highest total basal area and aboveground biomass that is 7274 cm^2 and 115534 kg, respectively

(Table 4); in P_3, *Mallotus dispar* is the most important species in term of density contribution and *Ficus aurata* in term of basal area and aboveground biomass contribution (Table 6); whereas in P_2, *Mallotus oblogifolius* have the highest basal area contribution and density recorded with 180 trees but for the aboveground biomass contribution, the most dominant species is *Semecarpus bumburyanus* (Table 5).

The species with the largest mean dbh and mean height differs between plots. In P_1 at 15 m altitude, this species was represented by *Ficus aurata* and *Arenga borneensis*, respectively; *Arenga borneensis* in P_3 at 50 m altitude and *Alstonia scholaris* in P_2 at 30 m altitude (Table 4-6).

Table 7-9 provide listing of organized I_v of all species enumerated in P_1, P_2 and P_3 at 15, 30 and 50 m altitude, from most important to least important. All species with I_v lower than 5% were excluded from the tables. These tables show that the dominant and co-dominant species which were quantified using the highest and second highest I_v, respectively differs between plots studied; the dominant and co-dominant species in P_1 were *Arenga borneensis* and *Ficus aurata* with I_v of 21.69 and 19.74%, respectively (Table 7). In P_2 at 15 m altitude, *Mallotus oblongifolius* and *Artocarpus rigidus* contributed a total I_v of 54.74 and 38.26% (Table 8). In P_3 at 50 m altitude, *Ficus aurata* and *Saraca hullettii* contributed the highest and second highest I_v (Table 9). Other notable species in P_1 with I_v more than 10% were *Mallotus dispar, Artocarpus sp1, Artocartpus rigidus, Actinodaphne borneensis, Dimorphocalyx luzoniensis, Neonaulea excelsa, Mallotus oblongifolius* and *Aglaia* sp1 (Table 7) the species in P_2 were *hornerii Diospyros cauliflora, Semecarpus bumburyanus* and *Arenga borneensis* (Table 8); the species in P_3 includes *Mallotus dispar, Neonauclea peduncularis, Artocarpus rigidus, Scolopia spinosa, Semecarpus bumburyanus* and *Canthium umbelligerum* (Table 9). Importance values were also computed for all species in P_1, P_2 and P_3 but the relative ranking of those of lower important are rather insignificant. This study shows that 68, 72 and 77% if these species in P_1, P_2 and P_3 have I_v less than 5%. The study conducted by Mahmud *et al.*[14] on Mt. Tawai in Sabah show no single species dominance in all plots in term of I_v. They also showed that the dominant and co-dominant species differs between four forest zones: The dominant and co-dominant species were *Shorea macroptera-Mesua hexapetala, Shorea venulosa-Shorea andulensis, Casuarina sumatrana-Maclurodendron pubescens* in Zone 1, Zone 2, Zone 3 and Zone 4, respectively. In this study, the forest formations on Bau Hill based on the dominant and co-dominant species can be assigned to *Arenga borneensis*, *Ficus aurata*, *Mallotus dispar, Mallotus oblongifolius*, *Artocarpus rigidus*, *Diospyros cauliflora Ficus aurata-Saraca hullettii* and *Mallotus dispar* association, respectively for P_1, P_2 and P_3 at 15, 30 and 50 m elevation.

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