

CLUSTER ANALYSIS OF SUBMONTANE FOREST ALONG WESTERN SLOPE OF FRASERS' HILL RESEARCH CENTRE IN RAUB DISTRICT, MALAYSIA

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Abstract

Submontane forest at five different altitudes along the western slope of Frasers' Research Centre (FHRC) in Raub District, Pahang State of Malaysia by Ward Linkage Method (WLM) was classified. Five plots were set at 1000 m (P1), 1050 m (P2), 1100 m (P3), 1150 m (P4) and 1200 m (P5), and all the trees with diameter at breast height (DBH) \geq 5 cm have been measured. Cluster analysis by WLM of these plots resulted in the identification of four forest zones (FZ) denoted by FZ1P1, FZ2P2, FZ3P3P4 and FZ4P5. These forest zones were denoted by three most dominant species in term of importance value (I_v) such as *Dacrydium elatum* (Roxb.) Wall. ex Hook.- *Prunus arborea* (Blume) Kalkman - *Adinandra dumosa* Jack (Zone FZ1P1), *Trigonobalanus verticillata* Forman - *Syzygium stapfianum* (King) I.M. Turner - *Syzygium subdecussatum* (Wall. ex Duthie) I.M. Turner (Zone FZ2P2), *Syzygium leptostemon* (Korth.) Merr. & L.M. Perry - *Wikstroemia polyantha* Merr - *Syzygium napiforme* (Koord. & Valetton) Merr. & L.M. Perry (Zone FZ3P3P4) and *Syzygium filiforme* (Wall. ex Duthie) P. Chantaranonthai & J. Parn.- *Decaspermum parviflorum* (Lam.) A.J. Scott - *Litsea machilifolia* Gamble (Zones FZ4P5). Correlation analysis showed that the number of trees in 0.1 ha, density/ha, DBH, mean DBH, number of species, number of family, number of genus, basal area (BA), mean BA, R, H and E and species with the biggest DBH decreased with increasing altitude. The r-values obtained for these 13 attributes were from -0.13 to -0.99. The distribution of trees were found to differ between DBH Class (DBHC) in all FZ. This study revealed that 73.1 to 88.17% of trees in all FZ fall into DBHC1 and DBHC2. On the other hand, 1.02 to 6.28% fall into DBHC5, DBHC6 and DBHC7. The distribution of species was different between I_v Class (I_vC) all the four FZ. It was found that from 77.68 to 93.75% of the species fall into I_vC1 and I_vC2, and between 1.66 to 5.12% of the species fall into I_vC4 and I_vC5.

Introduction

Studies on changes in forest structures due to altitude increment along the slope of hill and montane tropical rain forest have been carried out (Adam 2001, 2000, Adam and Affandi 1993, 2000, Soepadmo 1987, Kochummen 1982). The application of clustering method using species similarity and density to classify diverse species composition along the slope of hill and montane tropical rain forests into different cluster groups have proved helpful (Adam *et al.* 2010, 2007, Adam 1997, Adam and Enning 1996, Adam and Zahiruddin 2005, Mahmud *et al.* 1992, Ohsawa *et al.* 1985).

This study was carried out along the western slope at Universiti Kebangsaan Malaysia (UKMS) FHRC that stood at altitude from 1000 to 1200 m. The Bukit Fraser was formed by molten magma that extruded upon the earth crust as a result of tectonic activities 250 million ago, forming the main terrace of Peninsular Malaysia, Titiwangsa Range (Muhammad *et al.* 2009). The rainfall at these altitudes is approximately 2600 mm/year, daily temperature ranges from 18 - 22°C and relative humidity between 85 and 95% (Adam and Maimon 2009). The forest of the study area is a transition between pristine hill dipterocarp forest at the lower section of the slope and lower montane forest or oak-laurel forest dominates the middle section to the summit. Field survey

showed the presence of *Shorea maxima* and *Vatica umbonata* (Dipterocarpaceae), *Dacrydium elatum* and *Agathis borneensis* (gymnosperms), many oak and highland myrtaceous species, *Prunus arborea* (Rosaceae), *Vaccinium bancanum* (Ericaceae) and a parasitic species of *Balanophora fungosa*. The summit zone of the study area showed the presence of typical montane fern such as *Dipteris conjugata* and thick cover bog mosses of *Sphagnum* of the forest floor. Latiff (2009) reported the domination of the family Lauraceae (42 species), Fagaceae (28 species), Orchidaceae (148 species) and Ericaceae at the summit zone. Adam and Maimon (2009) reported the existence of *Nepenthes gracilis* and *Nepenthes sanguinea* on this hill. Damahuri (2009) reported 172 species of mosses, thick carpet of *Leucobryum*, *Ectropothecium* and *Rhodobryum* on the wet forest floor hill. Haja (2009) reported 210 species of ferns and fern allies; highland species *Cibotium barometz* (Golden chicken fern), *Cyrtia* (tree fern), *Dipteris conjugata* (umbrella fern) and *Belchnum orientale*. Adam *et al.* (2010) studied the forest structures along Pine Trail in Fraser Hill and categorisation of forest by clustering method but the present study area is located outside FHRC. Thus, the current research will provide the base line data of the forest structures, particularly tree species composition at different elevations. The other objectives were classifying the forest along the slope into different cluster groups and to determine the effect of increasing elevation on forest structures by correlation analysis.

Materials and Methods

Classification of the forest at different altitudes on the western slope of FHRC, UKM in Raub District 03°43' and 03°44' N and 101°43' to 101°44' E, Pahang State of Malaysia, was determined by Ward Linkage Method (WLM). Five plots, each measuring 10 m × 100 m were set at 1000, 1050, 1100, 1150 and 1200 m altitudes and were denoted as P1, P2, P3, P4 and P5. In order to determine the frequency count (f) and calculation of relative frequency (R_f) of every tree species, every plot was divided into 10 small compartments, each of them measuring 10 m × 10 m. For density count and basal area (BA) contribution, all trees with a DBH of ≥ 5 cm have been measured.

The BA, density, importance value, species diversity indices were determined by the formulae of Cintron and Novelli (1984).

Species diversity of the tree species was measured following the formulae of Ludwig and Reynolds (1988).

Results and Discussion

Clustering analysis has classified the forest along the western slope of FHRC between altitudes 1000 and 1200 m into four forest zones (FZ) (Fig. 1) and those are *Dacrydium elatum* - *Prunus arborea* - *Adinandra dumosa* zone (FZ1P1, 1000 m), *Trigonobalanus verticillata* - *Syzygium stapfianum* - *Syzygium subdecussatum* Zone (FZ2P2, 1050 m), *Syzygium leptostemon* - *Wikstroemia polyantha* - *Syzygium napiforme* (FZ3P3P4, 1100-1150 m) and *Syzygium filiforme* - *Decaspermum parviflorum* and *Litsea machilifolia* zone (FZ4P5, 1200 m).

I. *Dacrydium elatum* - *Prunus arborea* - *Adinandra dumosa* Zone: The 25 forest attributes of FZ1P1 is summarised in Table 1. A total of 297 trees or estimated 2970/ha with a DBH of ≥ 5 cm was recorded. They were represented by 120 species belonging to 86 genus and 46 families. Guttiferae and Myrtaceae were the two most diverse families, each comprising of 8 species, followed very closely by Fagaceae with 7 species, Lauraceae and Rubiaceae with 6 species and Leguminosae with 5 species. Families with 4 species include Anacardiaceae, Annonaceae, Burseraceae, Euphorbiaceae, Rhizophoraceae and Sapindaceae. A total of 28 families contained between 1 and 2 species. However, in term of density Sapotaceae is the most dominant

contributing 7.06% of the total trees recorded; other dominant families includes Myrtaceae and Moraceae, each contributing 5.05% of the total trees. The species diversity indices obtained in this FZ1P1 is shown in Table 1. The R, H' and E values obtained were 6.97, 4.55 and 0.94, respectively.

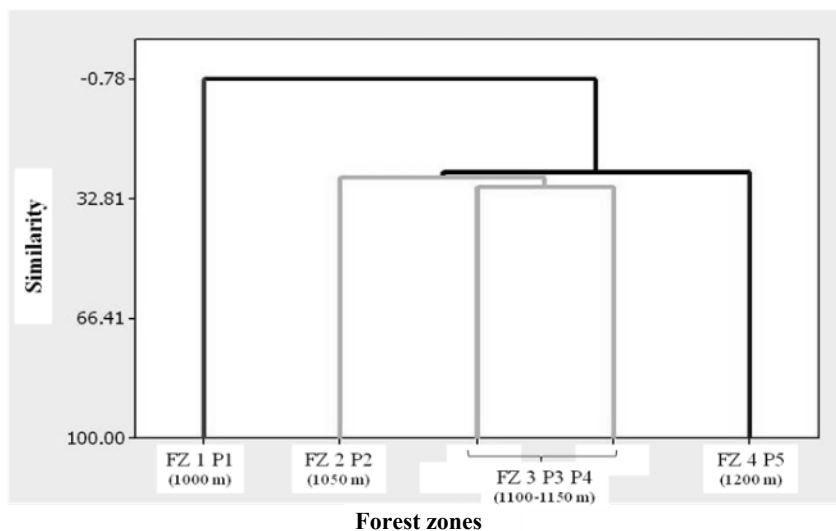


Fig. 1. Forest zones along the western slope of FHRC, Raub, Pahang.

Table 1. Forest attributes of four FZ at FHRC, UKM in Raub District, Pahang.

Forest cluster attributes	FZ1P1 (1000 m)	FZ2P2 (1050 m)	FZ3P3P4 (1100-1150 m)	FZ4P5 (1200 m)
1 Plot area	0.1 ha	0.1 ha	0.2 ha	0.1 ha
2 Altitude (m)	1000	1050	1100-1150	1200
3 No. of trees	297	168	455	198
4 Mean tree height (m)	12.5	12.4	12.95	8.6
5 Density/ha	2970	1680	2750	1980
6 DBH cm	5352	3575	7037	2307
7 Mean DBH cm	18.08	21.3	15.47	11.65
8 Number of species	120	78	144	83
9 Number of family	46	34	47	30
10 Number of genus	89	58	95	54
11 Basal area cm ²	122121	60263	127627	37144
12 Mean basal area cm ²	417.92	358.71	280.50	187.60
13 $R = S/\sqrt{N}$	6.97	6.01	6.75	5.88
14 H'	4.55	4.1	4.62	4.12
15 E	0.94	0.94	0.93	0.93
16 No. and % of species with 1-2 trees	50 63.96%	56 71.68%	85 58.69%	56 67.46
17 Species with highest number of trees	<i>Adinandra dumosa</i> and <i>Knema</i> <i>kunstleri</i> 10	<i>Syzygium</i> <i>subdecussatum</i> 11	<i>Syzygium</i> <i>napiforme</i> 22	<i>Syzygium</i> <i>filiforme</i> 13

(Contd)

(Contd)

18	Family with the highest no. and % of species	Guttiferae 8 and 6.66% Myrtaceae 8 and 6.67%	Myrtaceae 14 17.95%	Myrtaceae 16 11.1%	Myrtaceae 10 12.05%
19	Family with highest no. and % of trees	Theaceae 21 and 7.06%	Myrtaceae 56 and 33.06%	Myrtaceae 122 26.84	Myrtaceae 50 and 25.29%
20	Family with highest DBH % DBH contribution	Podocarpaceae 918 cm 17.45%	Myrtaceae 1423.33 cm 35.39%	Myrtaceae 1841 cm 26.16%	Myrtaceae 484.88 cm 20.85%
21	Dominant species with highest I_v	<i>Dacrydium elatum</i> 19.71%	<i>Trigonobalanus verticillata</i> 13.97%	<i>Syzygium leptostemon</i> 11.96%	<i>Syzygium filiforme</i> 13.02%
22	Co-dominant species with 2nd highest I_v	<i>Prunus arborea</i> 15.36%	<i>Syzygium stapfianum</i> 13.13%	<i>Wikstroemia polyantha</i> 11.33	<i>Decaspermum parviflorum</i> 12.78%
23	Co-dominant species with 3rd highest I_v	<i>Adinandra dumosa</i> 7.73%	<i>Syzygium subdecussatum</i> 12.68%	<i>Syzygium napi-forme</i> 10.24%	<i>Litsea machilifolia</i> 11.63%
24	Dominant family with highest I_v	Podocarpaceae 19.71%	Myrtaceae 79.49%	Myrtaceae 72.01%	Myrtaceae 62.90%
25	Co-dominant family with 2nd highest I_v	Guttiferae 18.46%	Fagaceae 51.86%	Fagaceae 20.91%	Lauraceae 36.94%
26	Co-dominant family with 3rd highest I_v	Rosaceae 17.26%	Thymelaeaceae 21.18%	Guttiferae 20.62%	Fagaceae 25.93%
27	Species with biggest DBH	<i>Dacrydium elatum</i> 135 cm	<i>Trigonobalanus verticillata</i> 98.5 cm	<i>Syzygium leptostemon</i> 100.5 cm	<i>Dacrydium elatum</i> 43 cm

It is revealed that 73.1% of the trees inventoried fall into two small DBHC that is 32.3% fall into DBHC1 and 40.8% fall into DBHC2 (Table 2). The table also indicated that only 0.68% or 2 of the total 297 trees inventoried belonged to DBHC7. These trees were represented by *Dacrydium elatum* (Podocarpaceae) with a DBH of 135 cm and *Prunus arborea* (Rosaceae) with a DBH of 126 cm. The total DBH and BA of all trees recorded in this FA were 5352 cm and 122121 cm², giving us the mean DBH and mean BA area of 18.03 cm and 417.92 cm², respectively.

Table 2. Distribution of trees between seven DBHC in four FZ at FHRC, UKM in Raub, Pahang.

DBH (class)	FZ1P1		FZ2P2		FZ3P3P4		FZ4P5	
	No.	% of trees	No.	% of trees	No.	% of trees	No.	% of trees
5-10 (1)	95	32.3	70	42.7	179	39.02	86	43.86
10.1-20 (2)	120	40.8	51	31.11	175	38.15	87	44.31
20.1-30 (3)	37	12.58	24	14.64	70	15.26	12	6.12
30.1-40 (4)	29	9.86	11	6.71	20	4.36	10	5.10
40.1-50 (5)	9	3.06	2	1.22	7	1.53	2	1.02
50.1-100 (6)	4	1.36	7	4.27	7	1.53	0	0
100.1-150 (7)	2	0.68	0	0	1	0.22	0	0
Total	297		165		459		197	

The importance value of 8 species, exclusive of 112 species with I_v from 0.77 to 5.27% in FZ1P1 (Table 4). The dominant species possessing the highest I_v was *Dacrydium elatum* (Podocarpaceae) with I_v of 19.71%. The first and second co-dominant species having the second and third highest I_v were *Prunus arborea* (Rosaceae) and *Adinandra dumosa* (Theaceae) with I_v of 15.36% and 7.73%, respectively. Two other species with I_v greater than 7% were *Ixonanthes*

icosandra and *Cratoxylum arborescens*. In term of family, Podocarpaceae was the most dominant family having the I_v of 19.71% (Table 1). The first and second co-dominant families were Guttiferae and Rosaceae with I_v of 18.46% and 17.26%, respectively. The Table 3 indicated that 61.42% of the total 120 species recorded fall into I_vC_2 and 31.54% fall into I_vC_1 . The percentage of the species belonged to I_vC_5 is very small, 1.66% or represented by 2 species; these species were the dominant and first co-dominant species having the highest and second highest I_v (Table 4). The second co-dominant species, *Adinandra dumosa* was shown to fall into I_vC_3 .

Table 3. Distribution of species between five I_vC in four FZ at FHRC, UKM in Raub, Pahang.

I_v class	FZ1P1		FZ2P2		FZ3P3P4		FZ4P5	
	No.	% of trees	No.	% of trees	No.	% of trees	No.	% of trees
$I_v C_1: \leq 1$	35	31.54	0	0	43	29.86	0	0
$I_v C_2: 1.1-5$	74	61.42	60	77.68	92	63.89	66	79.2
$I_v C_3: 5.1-10$	8	7.47	14	17.92	4	2.78	13	15.7
$I_v C_4: 10.1-15$	0	0	4	5.12	5	3.47	4	4.9
$I_v C_5: 15.1-20$	2	1.66	0	0	0	0	0	0
Total	120		78		144		83	

Table 4. Percentage of R_f , R_d , R_D and I_v of all tree species with dbh of ≥ 5 cm in FZ1P1 at 1000 m in FHRC, UKM in Raub, Pahang*.

Species	Family	R_f	R_d	R_D	I_v
1 <i>Dacrydium elatum</i>	Podocarpaceae	1.25	1.01	17.45	19.71
2 <i>Prunus arborea</i>	Rosaceae	2.08	2.36	10.92	15.36
3 <i>Adinandra dumosa</i>	Theaceae	1.67	3.70	2.36	7.73
4 <i>Ixonanthes icosandra</i>	Ixonanthaceae	2.92	3.70	1.03	7.65
5 <i>Cratoxylum arborescens</i>	Guttiferae	2.08	2.02	2.95	7.06
6 <i>Lithocarpus lucidus</i>	Fagaceae	1.25	1.68	2.54	5.48
7 <i>Aglaia forbesii</i>	Meliaceae	2.08	2.69	0.67	5.45
8 <i>Artocarpus integer</i>	Moraceae	1.67	2.02	1.65	5.34

*112 species with I_v between 0.77 and 5.27% were excluded from the table.

II. *Trigonobalanus verticillata* - *Syzygium stapfianum* - *Syzygium subdecussatum* Zone: A total of 168 trees or estimated 1680/ha with a DBH of ≥ 5 cm was recorded. They were represented by 78 species belonging to 58 genus and 34 families. Myrtaceae were the most diverse family containing 14 species, followed by Fagaceae with 7 species and Guttiferae with 6 species. 18 families were found to possess 1 species each, 5 and 7 families respectively contained 2 and 3 species. However, in term of density, Myrtaceae is the most dominant contributing 33.06% (56) of the total trees recorded; other dominant families contributing between 7.08 and 7.67% of the total trees includes Thymelaeaceae, Fagaceae and Guttiferae. Families contributing greater than 2% but less than 5% include Burseraceae, Ebenaceae, Euphorbiaceae, Meliaceae and Thymelaeaceae. A total of 20 families were found to contribute less than 2% of the total trees recorded each. The species diversity indices obtained in this FZ2P2 is shown in Table 1. The R, H and E values obtained were 6.01, 4.1 and 0.94, respectively.

This study also revealed that 88.45% of the trees inventoried fall into two small DBHC that is 42.7% fall into DBHC1, 31.11% fall into DBHC2 and 14.64% fall into DBHC3 (Table 2). The table also indicated that 4.27% (7 trees) belonged to big DBHC that is DBHC6. These trees were represented by *Trigonobalanus verticillata* (dbh = 98.5 cm), *Vatica umbonata* (dbh = 80 cm), *Lithocarpus wrayi* (dbh = 66 cm), *Quercus gaharuensis* (dbh = 60 cm), *Quercus gemellifolia* (dbh

= 54 cm), The total DBH and BA of all trees recorded in this FA2 were 2717 cm and 59862.22 cm², giving us the mean DBH and mean BA area of 16.45 cm and 362.80 cm², respectively.

The importance values of 18 species, excluding 60 species with I_v from 1.43 to 4.89% in FZ2P2 is tabulated in Table 5. The dominant species having the highest I_v was *Trigonobalanus verticillata* (Fagaceae) with I_v of 13.97%. The first and second co-dominant species having the second and third highest I_v were *Syzygium stapfianum* (Myrtaceae) and *Syzygium subdecussatum* with I_v of 13.13 and 12.68%. Species with I_v greater than 8% includes *Decaspermum parviflorum*, *Quercus gemelliflora*, *Paranephelium*, *Vatica umbonata* and *Wikstroemia polyantha*. In term of family, Myrtaceae was the most dominant family having the I_v of 79.49% (Table 1). The first and second co-dominant families were Fagaceae and Thymelaeaceae with I_v of 51.86 and 21.18%. Analysis on the distribution of species in different I_v C was shown in Table 3 above. The table indicated that 76.8% of the total 78 species recorded fall into I_v C2 and 17.92% fall into I_v C3. The percentage of the species belonged to I_v C4 is 5.12% or represented by 4 species; these species belong to the 4 largest I_v recorded that is *Trigonobalanus verticillata*, *Syzygium stapfianum*, *Syzygium subdecussatum* and *Wikstroemia polyantha* (Table 5).

Table 5. Percentage of R_f , R_d , R_D and I_v of all tree species with dbh of ≥ 5 cm in FZ2P2 at 1050 m in FHRC, UKM in Raub, Pahang*.

Species	Family	RD	R_d	R_f	I_v
1 <i>Trigonobalanus verticillata</i>	Fagaceae	12.58	0.59	0.8	13.97
2 <i>Syzygium stapfianum</i>	Myrtaceae	3.42	6.51	3.2	13.13
3 <i>Syzygium subdecussatum</i>	Myrtaceae	5.35	4.13	3.2	12.68
4 <i>Wikstroemia polyantha</i>	Thymelaeaceae	6.02	3.54	2.4	11.96
5 <i>Vatica umbonata</i>	Dipterocarpaceae	8.3	0.59	0.8	9.69
6 <i>Paranephelium</i>	Sapindaceae	2.53	2.95	3.2	8.68
7 <i>Quercus gemelliflora</i>	Fagaceae	5.17	1.77	1.6	8.54
8 <i>Decaspermum parviflorum</i>	Myrtaceae	0.91	3.54	4	8.45
9 <i>Tristanopsis merguensis</i>	Myrtaceae	3.16	2.36	2.4	7.92
10 <i>Quercus gaharuensis</i>	Fagaceae	5.04	1.18	1.6	7.82
11 <i>Lithocarpus wrayi</i>	Fagaceae	5.65	0.59	0.8	7.04
12 <i>Syzygium claviflorum</i>	Myrtaceae	1.9	3.54	1.6	7.04
13 <i>Lithocarpus scortechnii</i>	Fagaceae	3.49	1.77	1.6	6.86
14 <i>Calophyllum wallichianum</i>	Guttiferae	1.61	3.54	1.6	6.75
15 <i>Aquilaria malaccensis</i>	Thymelaeaceae	1.35	2.95	2.4	6.7
16 <i>Syzygium curtisii</i>	Myrtaceae	2.31	2.36	1.6	6.27
17 <i>Melia</i>	Meliaceae	0.61	2.36	3.2	6.17
18 <i>Syzygium garcinifolium</i>	Myrtaceae	0.94	2.36	2.4	5.7

*60 species with I_v between 1.43 and 4.89% were excluded from the table.

III. *Syzygium leptostemon*, *Wikstroemia poyantha* - *Syzygium napifome* Zone: A total of 455 trees or estimated 2750/ha with a DBH of ≥ 5 cm was recorded. They were represented by 144 species belonging to 95 genus and 47 families. Myrtaceae were the most diverse family containing 16 species, followed by Guttiferae with 12 species and Fagaceae with 11 species. Families with 6-7 species include Sapotaceae, Lauraceae and Theaceae. 21 of the total 47 families

recorded were found to contain 1 species each, 7, 5 and 5 families, respectively contained 2, 3 and 4 species. However, in term of density, Myrtaceae is the most dominant contributing 26.84% of the total trees recorded; other dominant families contributing between 5.5 and 10.54% of the total trees includes Rutaceae (10.54%), Guttiferae (7.28%), Fagaceae (5.94%) and Theaceae (5.5%). Families contributing between 3 and 4.4% include Flacourtiaceae, Sapotaceae, Lauraceae and Thymelaeaceae. A total of 23 families were found to contribute less than 1% of the total trees recorded each. The species diversity indices obtained in this FZ3 is shown in Table 1. The R, H' and E values obtained were 6.75, 4.62 and 0.93, respectively.

This study also showed that 92.43% of the trees inventoried fall into two small DBHC that is 39.02% fall into DBHC1, 38.15% fall into DBHC2 and 15.26% fall into DBHC3 (Table 2). The table also indicated that only 7.64% of tree inventoried belonged to DBHC4-7. Of these 1.75% (8 trees) were belong to DBHC6 and DBHC7. These trees were represented by *Syzygium leptostemon* (Myrtaceae) with a DBH of 100.5 cm, *Aquilaria malaccensis* with DBH of 70 cm, *Wikstroemia polyantha* with DBH of 65 cm and 50 cm, *Santiria rubiginosa* (Burseraceae) with a DBH of 64.5 cm, *Perrottetia alpestris* (Celastraceae) with DBH of 57.5 cm, *Hydnocarpus wrayi* (Lauraceae) with DBH of 57 cm and *Lindera pipericarpa* (Lauraceae) with DBH of 53 cm. The total DBH and BA of all trees recorded in this FA were 5352 cm and 122121 cm², giving us the mean DBH and mean BA area of 18.03 cm and 417.92 cm², respectively.

The importance values of species, excluding 136 species with I_v from 0.57 to 4.88% in FZ3P3P4 (Table 6). The dominant species having the highest I_v was *Syzygium leptostemon* (Myrtaceae) with I_v of 11.96%. The first and second co-dominant species having the second and third highest I_v were *Wikstroemia polyantha* (Thymelaeaceae) and *Syzygium napiforme* (Myrtaceae) with I_v of 11.33 and 10.24%. Species with I_v greater than 10% is *Decaspermum parviflorum*. In term of family, Myrtaceae was the most dominant family having the I_v of 72.01% (Table 1). The first and second co-dominant families were Fagaceae and Guttiferae with I_v of 20.91 and 20.62%. Analysis on the distribution of species in different I_v class was shown in Table 3. The table indicated that 63.89% of the total 144 species recorded fall into I_v C2 and 29.86% fall into I_v C1. The percentage of the species belonged to I_v C3 is 2.78 and 3.47% fall into I_v C4.

Table 6. Percentage of R_f , R_d , R_D and I_v of all tree species with a DBH of ≥ 5 cm in FZ3P3P4 at 1100 - 1150 m in FHRC, UKM in Raub District of Pahang*.

Species	Family	R_d	R_f	R_D	I_v
1 <i>Syzygium leptostemon</i>	Myrtaceae	2.42	1.62	7.92	11.96
2 <i>Wikstroemia polyantha</i>	Thymelaeaceae	2.2	1.89	7.24	11.33
3 <i>Syzygium napiforme</i>	Myrtaceae	4.84	2.43	2.97	10.24
4 <i>Decaspermum parviflorum</i>	Myrtaceae	3.74	2.97	3.44	10.15
5 <i>Aquilaria malaccensis</i>	Thymelaeaceae	1.54	1.08	4.14	6.76
6 <i>Syzygium cerinum</i>	Myrtaceae	2.42	1.89	2.15	6.46
7 <i>Prunus arborea</i>	Rosaceae	1.76	2.16	2.28	6.2
8 <i>Gordonia taipengensis</i>	Theaceae	1.98	2.43	0.85	5.26

*136 species with I_v between 0.57 - 4.88% were excluded from the table.

IV. *Syzygium filiforme* - *Decaspermum parviflorum* - *Litsea machilifolia* Zone: A total of 198 trees or estimated 1980 ha⁻¹ with a DBH of ≥ 5 cm was recorded. They were represented by 83 species belonging to 54 genus and 30 families. Myrtaceae were the most diverse family containing 10 species, followed by Guttiferae and Lauraceae with 8 species each and Fagaceae and Theaceae with 7 species each. Families with 3 species include Burseraceae, Elaeocarpaceae,

Euphorbiaceae and Rubiaceae. 13 and 9 of the total 47 families recorded were found to contain 1 and 2 species each, respectively. However, in term of density, Myrtaceae is the most dominant contributing 25.29% of the total trees recorded; the first and second co-dominant families contribution 10.63 and 7.60% of the total trees were Lauraceae and Guttiferae; Theaceae too contribute 7.10% of the total trees; families contributing between 3 and 7% of the total trees include Fagaceae (6.08%), Flacourtiaceae (4.57%), Melastomataceae (4.05%) and Polygalaceae (3.54%), 8 families were found to contribute less than 1% and 15 families contributing 1-3% of the total trees recorded each. The species diversity indices obtained in FA4 is shown in Table 1. The R, H' and E values obtained were 5.88, 4.12 and 0.93, respectively.

This study showed that 88.17% of the trees inventoried fall into two small DBHC that is 44.31% fall into DBHC2 and 43.86% fall into DBHC1 (Table 2). The table also showed that 6.12 and 5.10% of the trees inventoried belonged to DBHC3 and DBHC4. It was also found that 1.02% of these trees fall into DBHC5; these trees were represented by *Dacrydium elatum* (Podocarpaceae) with a DBH of 43 cm, *Aquilaria malaccensis* with DBH of 70 cm, *Wikstroemia polyantha* with DBH of 65 cm and 50 cm and *Litsea machilifolia* (Lauraceae) with a DBH of 40 cm, The total DBH and BA of all trees recorded in FA4 were 2307 cm and 37145.83 cm², giving us the mean DBH and mean BA area of 11.65 cm and 187.60 cm², respectively.

The importance values of 17 species, excluding 66 species with I_v from 1.25 to 4.67% in FZ4P5 is given in Table 7. The dominant species having the highest I_v was *Syzygium filiforme* (Myrtaceae) with I_v of 13.02%. The first and second co-dominant species having the second and third highest I_v were *Decaspermum parviflorum* (Myrtaceae) and *Litsea machilifolia* (Lauraceae)

Table 7. Percentage of R_f, R_d, R_D and I_v of all tree species with a DBH of ≥ 5 cm in FZ4P5 at 1200 m in FHRC, UKM in Raub, Pahang*.

Species	Family	R _f	R _d	R _D	I _v
1 <i>Syzygium filiforme</i>	Myrtaceae	2.68	6.57	3.76	13.02
2 <i>Decaspermum parviflorum</i>	Myrtaceae	4.7	5.05	3.03	12.78
3 <i>Litsea machilifolia</i>	Lauraceae	2.68	3.03	5.92	11.63
4 <i>Memecylon megacarpum</i>	Melastomataceae	2.68	2.53	5.05	10.26
5 <i>Xanthophyllum affine</i>	Polygalaceae	2.68	3.03	3.99	9.71
6 <i>Syzygium garcinifolium</i>	Myrtaceae	2.68	3.03	2.45	8.16
7 <i>Lindera lucida</i>	Lauraceae	2.68	2.53	2.51	7.72
8 <i>Lithocarpus elegans</i>	Fagaceae	2.01	1.52	3.75	7.28
9 <i>Melia</i> sp.	Meliaceae	2.68	2.53	1.54	6.75
10 <i>Ryparosa wallichii</i>	Flacourtiaceae	2.68	3.03	0.78	6.49
11 <i>Aglaia malaccensis</i>	Meliaceae	2.68	2.02	1.76	6.47
12 <i>Syzygium napiforme</i>	Myrtaceae	1.34	3.54	1.43	6.3
13 <i>Syzygium chloranthum</i>	Myrtaceae	0.67	1.52	3.86	6.05
14 <i>Tristaniopsis merguensis</i>	Myrtaceae	1.34	1.52	2.93	5.79
15 <i>Quercus elmeri</i>	Fagaceae	1.34	1.01	2.88	5.23
16 <i>Ixonanthes icosandra</i>	Ixonanthaceae	2.01	2.53	0.59	5.13
17 <i>Dacrydium elatum</i>	Coniferae	0.67	0.51	3.86	5.03

*66 species with I_v between 1.25 and 4.67% were excluded from the table.

with I_v of 12.78 and 11.64%. Species with I_v greater than 8% includes *Memecylon megacarpum*, *Xanthophyllum affine* and *Syzygium garcinifolium*. In term of family, Myrtaceae was the most dominant family having the I_v of 72.01% (Table 1). The first and second co-dominant families were Lauraceae and Fagaceae with I_v of 36.94 and 25.93%. Two other notable families with I_v of 24.07 and 18.67% were Theaceae and Guttiferae.

Analysis on the distribution of species in different I_v class was shown in Table 3. The table indicated that 79.2% of the total 83 species recorded fall into I_v C2 and 15.7% fall into I_v C3. The percentage of the species belonged to I_v C4 is 4.9%.

Influence of altitude on forest structures: Previous researchers have demonstrated a distinctive influence of altitude on changes in the forest structures on the vegetation of tropical rain forest (Adam *et al.* 2010, Adam and Enning 1996, Ohsawa *et al.* 1985, Kochummen 1982).

In this study, correlation analysis has been carried out in order to establish the effect of elevation on changes in forest structures of the study area. The analysis on 15 forest structures has carried out to determine the strength of their strength of correlation with increasing altitude. This analysis has obtained the negative r-values from 0.29 to 0.99 and a positive r-value of 0.96 (Table 8). The negative value showed a decrease in the value of forest structure with increasing altitude and vice versa. The r-value of greater than 70% obtained from this study indicated a strong correlation with increasing altitude and *vice versa*. Table 8 showed a strong negative correlation

Table 8. Correlation analysis of 16 forests attributes in descending order of important of four FZ along the western slope of FHRC, UKM in Raub District, Pahang.

Forest attributes	FZ1P1	FZ2P2	FZ3P3P4	FZ4P5	Correlation r
1 Mean BA (cm ²)	417.92	358.71	280.50	187.6	-0.99
2 Biggest DBH of tree (cm)	135	98.5	100.5	43	-0.97
3 % of trees with DBH >30 cm	14.96	13.26	7.42	6.16	-0.96
4 E	0.94	0.94	0.93	0.93	-0.85
5 Mean DBH cm	18.08	21.3	15.47	11.65	-0.84
6 Mean tree height (m)	12.5	12.4	12.95	8.6	-0.83
7 I_v of Dominant species (%)	19.71	13.97	11.96	13.02	-0.72
8 $R = S/\sqrt{N}$	6.97	6.01	6.75	5.88	-0.65
9 Number of family	46	34	47	30	-0.61
10 I_v of 1 st co-dominant species (%)	15.36	13.13	11.33	12.78	-0.60
11 Number of genus	89	58	95	54	-0.51
12 H'	4.55	4.1	4.62	4.12	-0.43
13 Estimated Density/ha	2970	1680	2750	1980	-0.42
14 I_v of 2 nd co-dominant species (%)	7.73	12.68	11.29	11.63	-0.42
15 Number of species	120	78	144	83	-0.29
16 % of trees with DBH 5 - 20 cm	14.96	13.26	7.42	6.12	0.96

of first 7 attributes as listed with r-values from 0.72 to 0.99; the next 9 attributes established a weak negative correlation, with r-values from 0.29 to 0.62. The results of this study conform to the finding of previous reports. On the other hand, percentage of small size trees with DBH of 5 - 20 cm with r-value of 0.96, decrease significantly with increasing altitude. This study also showed that number of trees with DBH > 50 cm is not recorded at 1200 m but 7, 7 and 4 trees respectively with DBH > 50 cm are recorded at 1000, 1050 and 1100 - 1150 m, respectively. Similar results have also been obtained by other past researchers (Adam *et al.* 2007, Adam and Enning 1996).

Previous studies showed that forest zonation is related with altitude in tropical mountains (Ohsawa *et al.* 1985, Adam and Enning 1996). Lowland rain forest having three canopy layers with distinct emergent is found at the foot of the mountain, changing into two canopies without emergent layer at mid-elevation and conspicuously change into gnarled forest made up of one tree layer toward the peak of the mountain. The changing structures of this forest is very obvious along the ridge in very high ((9 mountain such as Mt. Kinabalu (4101 m) and Mt Trusmadi (2642 m) in Sabah, Mt. Murud (2424 m) and Mt. Mulu in Sarawak and Mt. Brinchang in Peninsular Malaysia. Factors such as temperature, relative humidity, rainfall, wind velocity and light intensity do not vary or change uniformly with increasing altitude and the rate of change of climate with altitude differs from one area to the other depending on topography and other factors (Adam and Enning 1996). This variation thus determine the actual limit of vegetation on different mountain or hills of the tropic and on other section of the same mountain range. On coastal hill and isolated peak and ridges, the limit of vegetation are lower than those of inland mountain range (Adam and Enning 1996).

Clustering analysis using WLM has classified the forest of the study area into four forest zones. These forest zones are correlated with altitudes; FZ1 is found at 1000 m, FZ2 at 1050 m, FZ3 at 1100 - 1150 m and FZ4 at 1200. Similar results were demonstrated by other researchers (Adam & Enning 1996; Ohsawa *et al.* 1985). Adam and Enning (1996) divided the tropical rain forest at Danum Valley, Sabah State of Malaysia into FZ1 which occurs at 150 - 250 m, FZ2 at 350 - 500 m, FZ3 at 600 - 700 m, FZ4 at 820 m. Ohsawa *et al.* (1985) found out that the forest at Mount Kerinci, Sumatra into four zones that is FZ at 1750 - 2100 m, FZ2 at 2100 - 2400 m, FZ3 at 2400 - 2900 m and FZ4 at 2900 - 3200 m.

These forest zones are characterised by the dominant species and two co-dominant species having the highest, second and third highest I_v , respectively. The combination of these three species differs between FZ. In FZ1 these species were represented by *Dacrydium elatum*, *Prunus arborea* and *Adinandra dumosa*, FZ2 were represented by *Trigonobalanus verticillata*, *Syzygium stapfianum* and *Syzygium subdecussatum*, FZ3 were represented by *Syzygium leptostemon*, *Wikstroemia polyantha* and *Syzygium napiforme* and FZ4 were represented by *Syzygium napiforme*, *Decaspermum parviflorum* and *Litsea machilifolia*. Similarly for family, FZ1 were represented by Podocarpaceae, Guttiferae and Rosaceae, FZ2 by Myrtaceae, Fagaceae and Thymelaeaceae, FZ3 by Myrtaceae, Fagaceae and Guttiferae and FZ4 by Myrtaceae, Lauraceae and Fagaceae. The result clearly indicated that family Myrtaceae and Fagaceae dominated the forests at FZ2, FZ3 and FZ4. The result of the study showed a different set of species combination of dominant and co-dominant, there is no single species dominant and there between these FZ. In addition, the dominant and co-dominant of these four FZ are dominated by 6 species of the family Myrtaceae and the other six species from six different families.

FZ2, FZ3 and FZ3 shared the most common attributes. In these zones, Myrtaceae has the highest number of species, trees, DBH contribution and dominant family with the highest I_v . In FZ1, family with the highest number of species, trees, DBH contribution and dominant family with the highest I_v were Guttiferae and Myrtaceae, Theaceae, Podocarpaceae and Podocarpaceae.

The correlation analysis of the forest attributes in the four FZ of the study area showed the following general trend. Mean BA, biggest tree DBH, percentage of trees with DBH >30 cm, E, mean DBH, I_v of dominant species, R, number of family, I_v of first co-dominant species, number of species, H' , estimated density/ha, I_v of 2nd co-dominant species and number of species decrease with increasing altitude. On the other hand, the percentage of small trees with DBH between 10 and 20 cm decreases with increasing altitude. These results conformed to the finding of previous studies of tropical rain forest by plant ecologists (Adam *et al.* 2010, Adam *et al.* 2007, Adam and

Enning 1996, Mahmud *et al.* 1992, Adam and Affandi 1993, Soepadmo 1987, Ohsawa *et al.* 1985, Yamada 1975)

Comparative analysis showed differences in all forest attributes among four forest zones. Correlation analysis showed a distinct decrease of mean BA, biggest tree DBH percentage of trees with DBH >30 cm, E and I_v of dominant species with increasing altitude. On the other hand, there is a distinct increase in the percentage of small trees of DBH from 5 - 20 cm with increasing altitude.

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