SOIL FERTILITY AND TREE SPECIES DIVERSITY IN TWO MALAYSIAN FORESTS

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AMIR HUSNI MOHD. SHARIFF, MILLER, H.G. & APPANAH, S. 1991. Soil fertility and tree species diversity in two Malaysian forests. The influence of soil fertility on species diversity between Tekam Forest Reserve (TFR) and Pasoh Forest Reserve (PFR) is discussed. TFR has mainly volcanic derived soil while PFR soil comprises shale and alluvial deposits. The former is species poor compared to PFR. The difference is rather a function of geological formation than soil series *per se.* A Competition-Domination-Suppression hypothesis is advanced to explain for the difference in species diversity in the two reserves.

Key words: Tropical rain forests - species diversity - soil nutrients - competition - domination

Introduction

In the tropics, various factors have been attributed to plant species distribution and diversity. One school favours edaphic and climatic variations, and another stochastic events. Edaphic influence on floristic composition and structural pattern of Malaysian rain forests has been touched upon in the pioneering work of Foxworthy (1927) and Wyatt-Smith (1963). The dominant role of edaphic factors was strongly argued by Ashton (1965, 1973, 1977) and subsequent re-examination of Ashton's data by Austin *et al* (1972) confirmed Ashton's claim. Further support was given by Baillie (1978), Baillie and Ashton (1983) and elsewhere by Huston (1980).

Symington (1943) first alluded that chance and opportunity may be the main determining factors influencing the distribution of species, but he admitted that "obscure local climate and edaphic variations" have a lesser role. Many later authors have championed chance and opportunity to be the main controlling factors of species diversity. They include Poore (1968), Whitmore (1974) and Hubbell and Foster (1983).

Without experimentation, it is difficult to tease out which of the above two factors plays the dominant role in plant species distribution and diversity. However, in the course of our study on why some species are present in large numbers in some areas and less in others, we reflected on the factors that may have contributed to species distribution and diversity.

The studies were carried out by comparing the soil fertility and species occurrence in two lowland dipterocarp forests in Peninsular Malaysia. Tekam Forest Reserve (TFR), located in Pahang, and Pasoh Forest Reserve (PFR), in Negri Sembilan were chosen for the study. They were chosen on the basis of their strong differences in soils, and vegetation. Geological formations and fertility status of the two reserves vary conspicuously, one being mainly volcanic and the other sedimentary and alluvial derived.

Site description

Pasoh Forest Reserve (PFR)

PFR, which is approximately 83 *km* south of Kuala Lumpur, covers an area of592 ha and is surrounded by 1360 *ha* of buffer zone. The annual temperature is between 24.5 to 27.2°C with precipitation of 1800 *mm* y^{1} (Dale 1959). It has among the lowest mean annual rainfalls in Peninsular Malaysia.

Elevation is 75 to 100 *m*, rising to 600 *m* in the eastern boundary. Topography is slightly undulating. Underlying are sedimentary rocks in the east and igneous in the west (Loganathan 1980). PFR is rich in dipterocarps with a high representation of the red meranti group (Wyatt-Smith 1961, Wong & Whitmore 1970).

Tekam Forest Reserve (TFR)

TFR, which is about 170 *km* east of Kuala Lumpur, covers a large and until recently, undisturbed area of 12400 *ha*. The north, east and west are bounded by steepland rising over 300 *m* in elevation (FELDA 1967) with slope extremes of 35° and 2°. The elevation of the study area is mainly between 80 to 300 *m*, except a small portion of the northern section being 320 *m*. Average precipitation is between 2765 and 2980 *mm* y^{1} (Abdul Rahim 1983) with air temperature of between 24 and 29°C (Dale 1959). This study was conducted at the 56.6 *ha* Tekam hydrological basin.

The geology of TFR is associated with volcanism (Khoo 1977) and abundant in tuffaceous materials (Ibrahim, A. unpublished). The red meranti group of *Dipterocarpus* and *Shorea* are widespread (Poore 1964) while the seraya type dominates higher elevations (FELDA 1967).

Materials and methods

Field sampling

Detailed and semi-detailed soil surveys were conducted. The manual for soil surveyors in Malaysia (Paramananthan 1986) was used for identification of soil series. The five dominant soils in each reserve are Padang Besar (PBR) (Orthoxic Tropudult), Bukit Tuku (BTU) (Aquic Paleudult), Awang (AWG) (Aquic Paleudult), Ulu Dong (UDG) (Typic Paleudult) and Chat series (Typic Paleudult) for PFR; Jengka (JKA) (Rhodic Paleudult), Tajau (TJU) (Typic Paleudult), Jeram (JRM) (Typic Paleudult), Jempol series (JPL) (Typic Paleudult) and Bungor (BGR) (Typic Paleudult) for TFR.

On each soil type, a *2-ha* plot (100 x 200 *m)* was laid in the north-south direction. Ten sub-plots of 10 x 10 m were chosen from every 2-*ha* plot for soil sampling. Ten bulk samples (one bulk sample being taken from five sampling points) were collected to represent depths of 0 to 15 *cm* and 15 to 30 *cm.* Samples from each sub-plot were thoroughly mixed to ensure uniformity.

Floristic survey

All trees 10 *cm* dbh or more were enumerated and identified at species level on every *2-ha* plot belonging to ten different soil types. Species which could not be identified are classified as 'UNKNOWN'.

Laboratory procedure

Soil samples were oven dried for 48 to 72 *h* at 60" *C.* The samples were crushed through a roller mill and passed through a 2 *mm* sieve. For determination of N, total nutrients and micronutrients, samples were sieved through 60 mesh size.

The ratio of 1:2.5 (soil:water) was used for pH measurement. Kjedahl digestion procedure was adopted for total N (%) determination (USDA1972). Available P was determined by Bray and Kurtz's Method No. 2 (1945), measured colorimetrically in the presence of ammonium molybdate with stannous chloride acting as reductant (Watanabe & Olsen 1965). Leaching with IN ammonium acetate buffered at pH 7 was adopted for extraction of available cations. For total cations and total P, Cu and Zn, the perchloric : sulphuric acid mixture (1:1) digestion procedure was adopted (Lim 1975). Subsequent determination procedures were as outlined by Jackson (1958). Exchangeable and total Kwere determined with Corning 410 flame photometer, and Ca, Mg, Cu and Zn by Hitachi 170-30 atomic absorption spectrophotometer.

Data analysis

Analysis of variance (ANOVA) was used to compare the soil chemical data for bulk samples between the reserves, in both soil depths (n = 50). F test was adopted with least significant difference (LSD) set at 5% level.

The vegetation data were sorted into species, family, frequency and girth class intervals (10 *cm* dbh), using Structured Fortran 77 (Ellis 1980).

Results and discussion

Floristic diversity between PFR and TFR

Fifty six families were identified in PFR compared to 52 in TFR (Appendix 1). The dominant families in both forest reserves are shown in Table 1. Dipterocarpaceae (13%) and Burseraceae (9%) are prevalent in PFR, while Euphorbiaceae (19%) and Sapindaceae (14%) are in TFR. The most dominant species in PFR, *Xerospermum intermedium constituted* only 2.6% of the total species (> 10 cm dbh), while *Elateriospermum tapos* dominated the TFR at 9.1% of the total tree species (Appendix 1). There is less tendency for an individual species to dominate in PFR, and it is species rich compared to TFR (Table 2). The distribution of dipterocarp species varied considerably between the two reserves as well (Table 3).

Table 1. The most dominant families and number of individuals (of trees > 10 *cm* dbh) found in Pasoh and Tekam Forest Reserves based on 10 *ha* enumeration on each site

Family	PFR	%*	TFR	%*
Annonaceae	240	4.5	158	3.1
Burseraceae	462	8.6	241	4.7
Dipterocarpaceae	698	13.0	139	2.7
Euphorbiaceae	426	7.9	986	19.2
Fagaceae	192	3.7	35	0.7
Flacourtiaceae	73	1.4	203	4.0
Lauraceae	97	1.8	231	4.5
Leguminosae	285	5.3	246	4.8
Myristicaceae	206	3.8	243	4.7
Polygalaceae	99	1.8	109	2.1
Sapindaceae	217	4.0	728	14.2
Sapotaceae	139	2.6	100	1.9
Sterculiaceae	114	2.1	131	2.5

Note : * - Number of individual trees / total number of trees X 100%

Table 2. Ten most common species in Pasoh and Tekam Forest Reserves based on 10 *ha* plot for each reserve, expressed as percentage of total number of trees

Dominant species in PFR	Dominant species in TFR
Alangium ridleyi (1.0%)	*Canarium littomlef. rufum* (0.5%)
Barringtonia maingayi (1.1%)	*Canarium pseudosumatranum* (1.6%)
Dacryodes rugosa (1.3%)	*Elateriospermum tapos* (9.1%)
Ganuasp. A (1.1%)	*Gymnacranthera bancana* (1.9%)
Ixonanthes icosandra (1.1%)	*Hydnocarpus wrayi* (2.5%)
Ochanostachys amentaceae (1.2%)	*Litsea erectinervia* (2.6%)
Shorea leprosula (1.9%)	*Mallotus philippensis* (4.9%)
Sharea ovalis (1.7%)	*Nephelium lappaceum* (5%)
Shorea parvifolia (1.4%)	*Pometia pinnata* (7.7%)
Xerospermum intermedium (2.6%)	*Pseudovaria macrophylla* (2%)

Source : Amir, H.M.S. & Miller, H.G. (unpublished)

Table 3. Distribution of dipterocarp species in Pasoh and Tekam Forest Reserves

Species common to PFR and TFR	Species exclusive to PFR	
S. parvifolia	*S. kunstleri*	*A. laevis*
S. bracteolata	*S. dasyphylla*	*A. megistocarpa*
S. teprosula	*S. macroptera*	*A. costata*
S. avalis	*S. lepidota*	*D. mnitus*
S. guiso	*S. materialist*	*N. heimii*
S. multiflora	*S. maxwelliana*	*P. densijlora*
H. dryobalanoides	*S. laevis*	*H. nervosa*
D. comutus	*S. maxima*	*H. dyeri*
D. custulatus	*S. paucijlora*	*H. mengarawan*
D. baudii	*S. accuminata*	*V. bella*
D. gracilis	*S. hnpeifolia*	
D. sublamellatus	*A. scapula*	
V. paucijlora	*A. curtisii*	

Species exclusive to TFR
S. curtisi
S. assamica
S. eurynchus
H. sulcata

Note: S - *Shorea,* D - *Dipteromrfnis,* P - *Parasharea,* V - *Vatita,* A - *Anisoptera,* N - *Neobalanocarpus,* H - *Hopea*

Source : Amir, H.M.S. & Miller, H.G. (unpublished)

Ashton (1973, 1977) and Baillie (1978) identified total P, K and Mg as limiting nutrients that correlate with species diversity in tropical rain forest ecosystem. Exchangeable and total Mg were the underlying factors suggested by Baillie and Ashton (1983). Threshold values for total P, total Mg and exchangeable K were suggested to be at 40 to 150 ppm, 1200 ppm (9.87 *meq* 100 g^1 soil) and 1000 to 2500 ppm (2.56-6.40 *meq* 100 g^l soils), respectively.

The present study indicates that Mg (<400 ppm) and exchangeable K (<100 ppm) are below the threshold value in both reserves. For total P, diversity is greatest between the suggested limits but declines below or above the limits. Interestingly, all soils in this study are within the range of P where species diversity is greatest and least. Average total P in the topsoil and subsoil of PFR is 143 and 122, respectively (Table 6). This association of high P with low diversity was also highlighted by Goodland (1971), and Riswan (1982). In this study, TFR had low species diversity with mean total P in the topsoil and subsoil at 294 and 207 ppm, respectively (Table 6). This accords with the suggestion by Ashton (1977) that species diversity is correlated with total P availability.

In TFR no pronounced differences in the number and range of species were observed between the five soils (Table 4). This holds for the volcanic influenced soils (TJU, JPL, JKA and JRM) and the sandstone-shale derived BGR series. This is because the latter coexists in the volcanic belt and its fertility status within the top 30 *cm* is comparable to the others. Low species count in AWG series (Table 4) is accentuated by unidentified trees totalling 183.

Table 4. Selected forest characteristics in terms of frequency and topsoil fertility level of Tekam and Pasoh Forest Reserves by soil series

	Tekam Forest Reserve				
Forest characteristics	TJU	JPL	BGR	JKA	JRM*
Trees *ha'*	479	535	524	568	463
Basal area *ha' (m2 ha*^{1}*)*	33	37	28	32	25
Families *ha'*^{1}	18	19	18	21	20
Species *ha'*^{1}	64	78	83	90	69
Number of dipterocarps *ha*^{1}	4.5	16	15	25	9
Number of dipterocarp species *ha'*	1	3.5	3.5	6.6	2.5
Altitude *(m)*	220	220	180	80	325
Topsoil fertility levels:					
Base saturation	14.9	16.7	13.2	14.3	12.8
CEC/soil *	10.7	7.2	8.3	9.1	8.6
Total cations *	19.1	18.3	8.7	14.2	12.7
Total exchangeable bases *	1.6	1.2	1.1	1.3	1.1
Available P (ppm)	8.9	4.9	6.4	6.4	7.1
Total P (ppm)	238	261	240	257	475

	Pasoh Forest Reserve				
Forest characteristics	PER	BTU	UDG	AWG	Chat*
Trees *ha'*	498	635	506	496	560
Basal area *ha' (m*^{2} *ha')*	28	21	26	26	27
Families fa^{1}	22.2	21.5	21.5	19.0	24.0
Species *ha'*	126	108	134	82	153
Number of dipterocarps *ha'*	79	128	34	56	51
Number of dipterocarp species *ha'*	10	13	9	10	10
Altitude *(m)*	150	75	100	75	85
Topsoil fertility levels:					
Base saturation	9.7	14.0	13.7	20.7	12.7
CEC/soil *	9.3	5.0	5.1	8.7	7.9
Total cations *	10.2	3.6	7.9	3.7	10.1
Total exchangeable bases *	0.9	0.7	0.7	1.8	1.0
Available P (ppm)	4.5	5.9	7.0	5.8	3.3
Total P (ppm)	231	72	153	134	126

Note: All fertility levels were taken from soil profile readings except available and total from composite samples. * *meq/100* gsoil; * soil series (refer p. 320: *Field sampling,* series follow for all tables)

Based on the above observation, it is postulated that species dominance and diversity are less an expression of soil series, but more of the geological body. Baillie and Ashton (1983) finally concluded that species differences are rather a function of geological formation than soil series *per se.* In this context it must be observed that soil series are based on soil profile characteristics. The issue then must be, do series consistently differ in nutrient concentration within one forest reserve? This may be the issue that needs further investigation.

The low diversity but high count of individual species in TFR compared to PFR may be explained by 'Competition-Domination-Suppression phenomenon.' The dominance of *Pometia pinnata, Elateriospermum tapos, Nephelium lappaceum* and *Mallotus philippensis* in TFR is conspicuous in terms of species density based on 10 *ha* plot. The ratios between the reserves for these species are 11:1 (393 to 35), 17:1 (469 to 28), 23:1 (255 to 11) and 84:1 (254 to 3), respectively. *P. pinnata* can grow into large canopy trees and respond well to gaps (Whitmore 1974). Similarly, *E. taposcan* grow up to 39 TO (Shaw 1975), and is a long lived pioneer that shows clumping characteristics (Ho *et al.* 1987). *N. lappaceum* is a medium sized tree (height of 9-15 m), and it requires shade initially (Whitehead 1959). The genus *Mallotus* has pioneering properties (Wyatt-Smith 1966, Whitmore 1973); *M. philippensis* is capable of reaching 21 TO in height. The true light requirement of this species is not known.

The four dominant species are successional in nature, and establish rapidly in gap conditions. They require more light than the majority of dipterocarps. Where these four species flourish, they will have a head start following the creation of gaps and eventually suppress the dipterocarps. This is well supported by distribution patterns of dipterocarps between the two reserves. While there are as many as 23 species of dipterocarps exclusive to PFR, there are only four in TFR, with 13 common to both reserves (Table 3).

Table 5. Dominant families and species by soil series of Tekam and Pasoh Forest Reserves

	Tekam Forest Reserve				
	TJU	JPL	BGR	JKA	JRM
Dominant families (%):					
Sapindaceae	20.8	9.5	10.7	11.5	19.9
Euphorbiaceae	9.8	28.7	25.8	14.7	16.0
Lauraceae	6.3	4.5	2.5	4.0	5.5
Myristicaceae	5.4	5.2	-	4.6	4.8
Burseraceae	4.6	4.2	5.0	6.5	2.8
Leguminosae	6.3	5.6	4.4	5.0	6.9
Flacourtiaceae	4.5	-	2.8	5.5	5.3
Rhizophoraceae	-	-	4.0	-	-
Polygalaceae	-	2.7	-	4.7	-
Dominant species (%):					
Pometia pinnata	13.7	4.3	5.6	3.7	12.4
Elateriospermum tapos	-	20.1	10.6	6.3	6.4
Mallotus philippensis	4.2	3.6	12.1	-	-
Litsea erectinervia	4.2	2.9	-	-	3.1
Nephelium lappaceum	3.9	3.9	3.4	6.2	6.4
Hydnorarpus wrayi	-	-	-	4.1	2.8
Pellacalyx axillaris	-	-	5.6	-	-
Pseudovaria macrophylla	3.5	-	-	-	-
Canarium pseudosumatranum	-	-	-	3.3	-
Saraca thaipingensis	3.5	-	-	-	-
Gymnacranthera bancana	-	-	-	-	2.8
	Pasoh Forest Reserve				
	PBR	BTU	UDG	AWG	Chat
Dominant families (%):					
Euphorbiaceae	16.6	2.7	8.7	3.9	8.7
Dipterocarpaceae	15.8	20.1	6.8	11.4	9.1
Burseraceae	8.0	10.1	5.8	9.6	8.9
Fagaceae	-	8.1	3.1	3.6	-

Table 5. Continued.

	Pasoh Forest Reserve				
	PBR	BTU	UDG	AWG	Chat
Dominant families (%):					
Leguminosae	2.8	5.1	6.0	6.8	1.5
Myrtaceae	3.5	6.0	4.1	9.1	4.8
Sapotaceae	5.0	2.8	-	-	-
Myristicaceae	3.5	4.1	4.1	-	5.8
Annonaceae	4.1	4.7	5.8	3.1	4.6
Sapindaceae	2.3	5.0	4.1	6.8	2.1
Dominant species (%):					
Ganua species A	4.4	-	-	-	-
Shorea avails	-	5.1	-	-	-
Xerospermum intermedium	-	3.5	3.1	4.9	-
Canarium pseudosumatranum	-	-	-	5.2	-
Koompassia malaccensis	-	-	-	-	2.3
Dipterocarpus sublamellatus	3.3	-	-	-	-
Canarium littorals rufum	-	3.9	-	-	-
Ixonanthus icosandra	-	-	2.3	-	-
Gironiera nervosa	-	-	-	-	2.0
Shorea multiflora	2.8	-	-	-	-
Dacryodes rugosa	2.6	-	2.0	-	-
Shorea leprosula	-	3.2	-	3.4	-
Ochanostachys amentaceae	-	-	-	-	1.9
Scaphium macropodium	-	-	1.7	-	1.8
Eugenia spicaia	-	-	-	2.6	-
Mallotus griffithianus	2.3	-	-	-	-
Eugenia griffithii	-	3.1	-	-	-
Alangium ridleyi	-	-	1.7	-	-
Baningtonia macroslachya	-	-	-	2.4	-
Shorea parvifolia	-	-	-	-	1.5

Note: The symbol "-" denotes that the percentage is too small for presentation

The crown development in the two sites may also play an additional role in the dominance of some species. The less fertile soils of PFR (Table 6) are associated with low basal area (Amir & Miller 1989) and sparse crown density (personal observations). In contrast TFR which is extremely fertile supports higher timber volume (Amir & Miller 1989). The more sparse crown density of PFR will therefore permit more light to infiltrate and promote germination of many species compared to the closed canopy of TFR.

The highly fertile soils of TFR may give a significant advantage to the four dominant species, enabling them to dominate the reserve. This results in suppression of other species. Soil fertility of PFR is not sufficiently high for any individual species to completely dominate the reserve. Thus the level of competition is kept at minimum, leading to high species diversity.

Actually, an equally plausible alternative explanation may exist why TFR is poorer in species. The dominant species in TFR are successional. This could mean the area was under disturbance, and hence the lower diversity. Further analysis on this point is needed.

Table 6. Analysis of variance (ANOVA) of means of chemical soil properties of topsoil and subsoil bulk samples from Pasoh and Tekam Forest Reserves (where n=50 for each reserve. Means are compared using F test)

Site	Soils	Available and exchangeable nutrient plus pH				
		Av.P (ppm)	Ex. K	Ex. Ca	Ex. Mg	pH (H_2O)
			meq/100 *g* soils			
PFR	Topsoil	5.29	0.097	0.344	0.261	4.24
TFR	Topsoil	6.73	0.179	0.337	0.380	4.40
Sig. levels		***	***	NS	***	*
PFR	Subsoil	3.17	0.070	0.231	0.137	4.39
TFR	Subsoil	4.34	0.137	0.170	0.329	4.57
Sig. levels		***	***	***	***	*

Site	Soils	Total soil nutrients							
		N (%)	P (ppm)	K	Ca	Mg	Fe_2O_3 (%)	Cu	Zn
				— meq/ 1 00 *g* soils —				(ppm)	
PFR	Topsoil	0.077	143	2.47	2.68	1.84	0.97	7.42	33.20
TFR	Topsoil	0.094	294	5.05	3.03	3.08	2.07	12.17	28.70
Sig. levels		***	***	***	NS	***	***	***	NS
PFR	Subsoil	0.047	122	2.29	1.63	1.91	1.54	5.85	23.50
TFR	Subsoil	0.056	207	8.41	1.70	4.55	2.79	9.83	13.80
Sig. levels		**	***	***	NS	***	***	***	***

Note: *, **, *** and NS are significant at 5, 1, 0.1% and non- significant, respectively
Source: Amir & Mona (1990)

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Appendix 1. Number of families and trees >10 *cm* dbh on soil types in Tekam and Pasoh Forest Reserves in a 2 *ha* plot each (values in parentheses indicate descending order of the ten most frequent and abundant families)

	Tekam Forest Reserve						
Family	TJU	JPL	JKA	BGR	JRM[+]		Total
Alangiaceae	16	13	15	26	17	=	87
Anarcadiaceae	14	12	27	15	1	=	69
Annonaceae	46	38	30	24	20	=	158(8)
Apocynaceae	6	3	11	5	3	=	28
Araliaceae	9	*	6	1	1	=	17
Bignoniaceae	*	*	*	*	*	=	-
Bombaceae	*	2	4	5	*	=	11
Bunonaceae	1	*	*	*	*	=	1
Burseraceae	44	45	74	52	26	=	241(5)
Combretaceae	1	*	2	1	2	=	6
Compositae	*	*	*	*	4	=	4
Celastraceae	*	*	*	1	*	=	1
Crypteroniaceae	*	*	*	*	*	=	-
Dilleniaceae	1	4	6	12	4	=	27
Dipterocarpaceae	9	32	50	30	18	=	139(9)
Ebenaceae	25	17	16	15	24	=	97
Elaeocarpaceae	*	*	*	*	2	=	2
Erythroxylaceae	#	*	1	*	*	=	1
Euphorbiaceae	94	307	167	270	148	=	986(1)
Fagaceae	1	9	15	6	4	=	35
Flacourtiaceae	43	14	57	40	49	=	203(7)
Guttiferae	2	10	19	7	6	=	44
Hypericaceae	*	*	2	*	*	=	2
Icacinaceae	*	1	4	*	*	=	5
Irvingiaceae	*	2	2	*	2	=	6
Ixonanthaceae	*	3	2	4	*	=	9
Juglandaceae	#	*	*	*	*	=	-
Lauraceae	60	48	46	26	51	=	231(6)
Lecythidaceae	4	6	4	4	11	=	29
Leguminosae	60	41	35	46	64	=	246(3)
Loganiaceae	*	*	*	*	*	=	-
Linaceae	*	*	*	*	*	=	-
Malvaceae	1	*	*	*	*	=	1
Melastomaceae	*	7	6	23	3	=	39
Meliaceae	15	16	22	18	17	=	88
Moraceae	27	16	14	14	7	=	78
Myristicaceae	52	56	52	39	44	=	243(4)
Myrsinaceae	*	*	*	*	*	=	-
Myrtaceae	16	24	43	26	14	=	123
Ochanaceae	*	*	*	*	*	=	-
Olacaceae	13	20	22	12	5	=	72
Oleaceae	*	*	*	*	*	=	-
Oxalidaceae	*	2	*	*	*	=	2
Polygalaceae	3	29	54	16	7	=	109
Proteaceae	*	*	*	*	*	=	-
Rhizophoraceae	1	16	13	42	3	=	75
Rosaceae	5	7	10	5	7	=	34
Rubiaceae	11	19	17	10	8	=	65
Rutaceae	*	1	*	*	2	=	3
Santalaceae	*	*	*	*	*	=	-
Sapindaceae	199	102	131	112	184	=	728(2)
Sapotaceae	22	23	33	11	11	=	100
Simaroubiaceae	*	1	2	*	*	=	3
Sterculiaceae	35	23	18	28	27	=	131(10)

Appendix 1. Continued.

	Tekam Forest Reserve						
Family	TJU	JPL	JKA	BGR	JRM		Total
Styracaceae	*	1	2	*	2	=	5
Symplocaceae	*	*	*	*	*	=	-
Theaceae	*	*	*	*	*	=	-
Thymeleaceae	4	20	21	9	11	=	65
Tiliaceae	7	8	14	5	9	=	43
Trigoniaceae	*	*	*	*	*	=	-
Ulmaceae	*	1	1	*	1	=	3
UNKNOWN	101	67	48	74	92	=	382
Urticaceae	2	*	*	*	1	=	3
Verbenaceae	6	4	11	14	14	=	49
Violaceae	2	*	8	*	*	=	10
Total	958	1070	1137	1048	926	=	5139

	Pasoh Forest Reserve						
Family	AWG	BTU	Chat	PBR	UDG		Total
Alangiaceae	11	5	10	16	18	=	60
Anacardiaceae	15	27	40	18	26	=	126
Annonaceae	31	58	51	41	59	=	240 (7)
Apocynaceae	*	1	5	9	10	=	25
Araliaceae	*	*	*	*	*	=	-
Bignoniaceae	*	*	1	*	*	=	1
Bombaceae	4	4	21	11	7	=	47
Bunonaceae	*	*	*	*	*	=	-
Burseraceae	95	128	100	80	59	=	462 (2)
Combretaceae	1	6	*	*	*	=	7
Compositae	5	*	*	*	*	=	5
Celastraceae	*	*	3	7	2	=	12
Crypteroniaceae	*	*	10	1	3	=	14
Dilleniaceae	1	6	8	8	4	=	27
Dipterocarpaceae	113	256	102	158	69	=	698 (1)
Ebenaceae	11	16	13	19	17	=	76
Elaeocarpaceae	2	1	11	8	1	=	23
Erythroxylaceae	*	*	*	*	*	=	-
Euphorbiaceae	39	34	97	165	91	=	426 (3)
Fagaceae	36	103	16	6	31	=	192 (9)
Flacourtiaceae	6	4	22	13	28	=	73
Guttiferae	2	46	21	21	23	=	113
Hypericaceae	5	6	2	*	5	=	18
Icacinaceae	*	*	*	*	*	=	-
Irvingiaceae	*	*	4	2	*	=	6
Ixonanthaceae	8	9	12	8	23	=	60
Juglandaceae	*	*	1	*	*	=	1
Lauraceae	16	19	31	17	14	=	97
Lecythidaceae	24	16	7	9	17	=	73
Leguminosae	67	65	64	28	61	=	285 (5)
Loganiaceae	*	2	*	*	*	=	2
Linaceae	*	*	1	4	*	=	5
Malvaceae	*	*	*	*	*	=	-
Melastomaceae	17	9	20	3	18	=	67
Meliaceae	21	3	27	23	20	=	94
Moraceae	16	15	16	8	13	=	68
Myristicaceae	12	52	65	35	42	=	206 (8)
Myrsinaceae	*	*	*	2	*	=	2

Appendix 1. Continued

	Pasoh Forest Reserve						
Family	AWG	BTU	Chat	PBR	UDG		Total
Myrtaceae	90	76	54	35	46	=	301 (4)
Ochanaceae	*	*	*	*	2	=	2
Olacaceae	17	5	21	13	14	=	70
Oleaceae	*	*	1	*	*	=	1
Oxalidaceae	1	2	10	1	7	=	21
Polygalaceae	6	23	22	16	32	=	99
Proteaceae	*	*	1	*	1	=	2
Rhizophoraceae	3	7	24	11	15	=	60
Rosaceae	3	2	12	*	2	=	19
Rubiaceae	11	14	24	12	34	=	95
Rutaceae	*	2	4	8	*	=	14
Santalaceae	*	*	*	4	1	=	5
Sapindaceae	67	64	24	23	39	=	217 (6)
Sapotaceae	18	36	20	50	15	=	139 (10)
Simaroubiaceae	*	*	*	*	*	=	-
Sterculiaceae	7	26	37	14	30	=	114
Styracaceae	4	12	*	1	1	=	18
Symplocaceae	*	*	1	*	*	=	1
Theaceae	*	*	*	2	*	–	2
Thymeleaceae	*	6	5	2	*	–	13
Tiliaceae	5	3	7	4	8	=	27
Trigoniaceae	*	*	1	1	3	=	5
Ulmaceae	18	6	39	9	19	=	91
UNKNOWN	183	95	31	65	82	=	456
Urticaceae	*	*	*	*	*	=	-
Verbenaceae	*1	1	1	5	1	=	9
Violaceae		*	*	*	*	=	-
Total	992	1271	1120	996	1013	=	5392

Notes: * denotes absent families and UNKNOWN is unidentified family composition; ' soil series (refer p. 320: *Field sampling)*