# SPECIES ASSEMBLY AND SITE PREFERENCE OF TREE SPECIES IN A PRIMARY SERAYA-RIDGE FOREST OF PENINSULAR MALAYSIA

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**ABD. RAHMAN, K., NIIYAMA, K., AZIZI, R., APPANAH, S. & IIDA, S. 2002. Species assembly and site preference of tree species in a primary seraya-ridge forest of Peninsular Malaysia.** The paper describes the use of main species as the criteria to classify forest sites using multivariate methods. The main objective is to clarify indicator species and its site preferences in a typical primary seraya-ridge forest. The sample is based on 150 subplots (20 × 20 m), from a six-hectare plot (200 × 300 m). Groups of sites were differentiated using hierarchical clustering analysis and ranked using ordination methods. Indicator species analysis determined the characteristic species of particular site group. Eight site groups were identified. The ordination results showed a strong correlation with elevation gradient. Most of the characteristic species showed strong association with elevation gradient and topographic positions, while generalist species showed weak correlation. The indicator values of 39 characteristic species at each step of hierarchical structure were computed and tested with the mean indicator value obtained from a Monte Carlo randomisation procedure at $p = 0.01$. The characteristic species which had broad niche breadths in the higher elevation included *Shorea curtisii, Lithocarpus wallichianus* and *Eurycoma longifolia* while in the lower elevation, the characteristics species included *Pimelodendron griffithianum, Antidesma cuspidatum* and *Artocarpus lanceifolius.* Several species such as *Drypetes polyneura* and

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*Gironniera parvifolia* had been identified as requiring narrower site preferences. The diagram of hierarchical cluster and associated indicator species provides a simple and intuitive way to describe species assemblages, while the ordination helps in explaining their site preferences.

Key words: Cluster analysis - ordination - indicator species - seraya-ridge forest - Malaysia

**ABD. RAHMAN, K., NIIYAMA, K., AZIZI, R., APPANAH, S. & IIDA, S. 2002. Pengumpulan spesies dan kecenderungan pokok memilih kawasan tertentu di hutan permatang-seraya Semenanjung Malaysia.** Kertas kerja ini menerangkan penggunaan spesies utama sebagai kriteria pengelasan hutan menggunakan kaedah multivariat. Objektif utama ialah untuk mengenal pasti spesies penunjuk dan kecenderungannya memilih kawasan tertentu di hutan permatang-seraya. Sampel penganalisisan adalah berasaskan 150 petak bersaiz 20 × 20 m dari plot enam hektar (200 × 300 m). Kumpulan-kumpulan kawasan tertentu dibeza menggunakan analisis tingkatan bergabung dan dikelas menggunakan kaedah ordinasi. Analisis spesies penunjuk menentukan spesies utama dalam kumpulan kawasan tertentu. Lapan kumpulan kawasan telah dikenal pasti. Keputusan ordinasi menunjukkan korelasi yang kuat dengan aras tanah. Hampir semua spesies penunjuk menunjukkan korelasi kuat dengan kecerunan aras tanah dan kedudukan-kedudukan topografi, manakala spesies yang berupaya tumbuh di pelbagai jenis kawasan menunjukkan korelasi yang lemah. Nilai penunjuk bagi 39 spesies utama pada setiap tingkat struktur tingkatan dikira dan dibandingkan dengan nilai purata yang terhasil daripada prosedur rawakan Monte Carlo pada p = 0.01. Antara spesies utama yang mempunyai kecenderungan yang kuat di aras tanah tinggi ialah *Shorea curtisii, Lithocarpus wallichianus* dan *Eurycoma longifolia,* manakala *Pimelodendron griffithianum, Antidesma cuspidatum* dan *Artocarpus lanceifolius* pula lebih cenderung di aras tanah lebih rendah. Beberapa spesies seperti *Drypetes polyneura* dan *Gironniera parvifolia* dikenal pasti lebih cenderung di kawasan yang lebih khusus. Rajah tingkatan bergabung dan perkaitan spesies penunjuk memberi cara mudah dan berkesan bagi menerangkan pengumpulan spesies, manakala kaedah ordinasi pula menerangkan kecenderungan spesies terhadap sesuatu kawasan.

## Introduction

The primary dipterocarp forests of Peninsular Malaysia are some of the most complex and species-rich forests in the world. In a lowland dipterocarp forest at Pasoh Forest Reserve, a 50-ha ecological plot was reported to contain 802 species of trees and shrubs > 1 cm diameter at breast height (dbh) (Kochummen *et al.* 1990). This species richness represents approximately 25% of the recorded tree flora of Peninsular Malaysia. The Semangkok Forest Reserve, Selangor contained 455 tree species ≥ 5 cm dbh in a 6-ha plot (Niiyama *et al.* 1999). Due to this complexity and high species diversity, classification of species by site has always been a challenging task to foresters and ecologists.

In the tropics, several attempts have been made to clarify species and site environment relationship. Symington (1943) suggested that hill dipterocarp forest and lowland dipterocarp forest can be differentiated from its specific composition of the dominant species of upper strata vegetation. The proportion of number of trees for several species in a hill dipterocarp forest gradually decreases from ridges to slopes and valley bottoms (Wan Razali & Roslan 1983). Niiyama *et al.* (1999) conducted an intensive study in a hill dipterocarp forest on the spatial patterns of common tree species relating to topography, canopy gaps and understorey vegetation. Most species showed significant aggregated patterns, except for two species, which were randomly distributed. Thirteen species were associated with specific type of topography. In a lowland dipterocarp forest, however, no association between spatial patterns of common canopy trees and topographical or other factors were found (Poore 1968). Spatial pattern, namely, random against clumping pattern of forest trees, could be related to different history of disturbance (Armesto *et al.* 1986). The presence of bertam (*Eugeissona tristis*), a stemless palms, has often been associated with the spatial distribution of certain common trees in hill dipterocarp forests (Wyatt-Smith 1968, Whitmore 1984). Physical and chemical soil properties are the major factors that control species richness at the pristine kerangas forest in Borneo and the montane forests in China (Bruenig & Huang 1990). Species-environment associations may reflect the conservation value of the site. Various techniques have been developed to quantify the conservation value of a site. Dufrene and Legendre (1997) discussed the advantages and disadvantages of these techniques and introduced a new method of assessing conservation value of a site using indicator species.

We assess species assemblages and their site preferences using clustering analysis, site ordination and indicator species analysis. The main objective is to clarify indicator species at each hierarchical level of cluster and its site preferences. Clustering analysis was used to detect group of sites, and ordination technique to rank the sites at each hierarchical clustering. The characteristic species of each site group and the associated hierarchical cluster level were determined using indicator species analysis.

## Materials and methods

### *Description of the study area*

The study site is located in Compartment 30, Semangkok Forest Reserve, a virgin jungle reserve (VJR), about 60 km north of Kuala Lumpur. The VJR is surrounded by second growth forest, mostly selectively logged in the 1980's (Niiyama *et al.* 1999). The typical hill dipterocarp forest occurred on the narrow ridge and steep slope and is categorised as the seraya-ridge forest. This forest type is characterised by large trees of *Shorea curtisii*, which is semi-gregarious, and the stemless palm, *E. tristis*, which frequently form a dense thicket. It is the most common type of hill forest in Peninsular Malaysia (Wyatt-Smith 1965).

A detailed study on the soil properties of the different topographic positions in this forest has been reported by Tange *et al.* (1998). They found that the surface soil chemical properties are influenced by topography and soil moisture regimes. The ridges and convex slopes have thin surface soil with low pH, high carbon, nitrogen and available phosphoric acid contents and high C/N ratios. The average annual rainfall is 2414 mm and the average annual minimum and maximum temperatures range between 21.9 and 33 °C (Saifuddin *et al.* 1991).

### *Study plot*

The data used in this study were taken from a 6-ha ecological plot established and measured in 1992. The plot dimensions are 200 × 300 m. The plot was subdivided into 150 quadrats of 20 × 20 m, 600 quadrats of 10 × 10 m, and 2400 quadrats of 5 × 5 m. For the multivariate analysis, we used 20 × 20 m quadrant as the basic sampling unit. Niiyama *et al.* (1999) used similar plot size in their spatial pattern analysis. The plot size resembled the approximate size of a large tree fall gap in the forest, which is an important contributing factor to community dynamics within the forest. Five most common trees observed were *Shorea curtisii, Lithocarpus wallichianus, Teijsmanniodendron coriace, Scaphium macropodum* and *Antidesma cuspidatum.* The plot design and layout are shown in Figure 1. The elevation is between 300 to 450 m asl with a ridge in the north-south direction, with aspects facing east and west slopes.

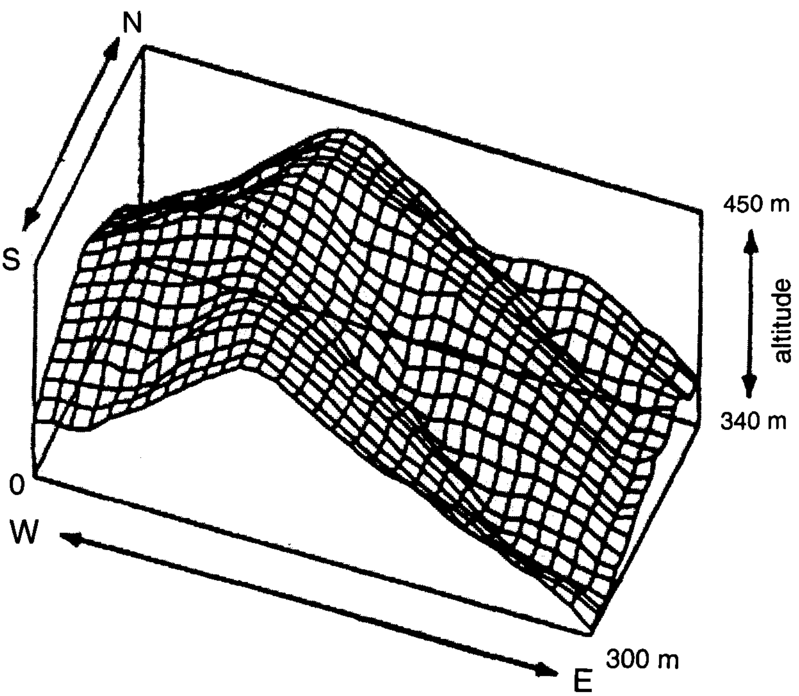



**Figure 1** Topography of the 6-ha ecological plot at Semangkok Forest Reserve

### *Data format*

Data analysis was done using PC-ORD Multivariate Analysis for Ecological Data Versions 3.20 and 4.0. The count data by species and quadrats were arranged in matrix or spreadsheet data format. Two data matrices were created. The number of rows and their names (quadrats) were the same for both matrices. The first matrix consisted of the quadrats against species data, and second matrix of quadrats against topographical parameters. The topographical parameters were slope, aspects, topographic position and elevation. Details of the category and coding of topographical parameters are shown in Table 1.

**Table 1** Description of the topographical parameters and coding used in the analysis

| Environmental variable | Category | Code | Description |
|---|---|---|---|
| Slope | Categorical | 1–8 | Classified based on percentage of slope |
| Aspect | Categorical | 1 | East facing slope |
| | | 2 | North-east and south-east |
| | | 3 | North or south |
| | | 4 | North-west or south-west |
| | | 5 | West |
| Topography | Categorical | 1 | Ridge |
| | | 2 | Slope |
| | | 3 | Valley |
| Elevation | Quantitative | | Unit in meters. Value is between the minimum (0) and the maximum (55) |

### *Data screening and transformation*

The data were screened to determine the need for data adjustments prior to the cluster analysis and site ordination analysis. The parameters evaluated were beta diversity and average skewness and coefficient of variation for rows and columns (Table 2). Beta diversity is a measure of the data heterogeneity among plots. It is the ratio of the total number of species to the average number of species. The first step taken was to delete rare species, which occurred in less than five per cent of the sampling units, which resulted in 292 species being deleted from the data set. The species data was transformed to presence/absence data due to high beta diversity. Beals smoothing technique was applied to relieve the zero truncation problems (Beals 1984, McCune 1994). This technique tends to reduce noise by enhancing the strongest patterns in the data (McCune 1994). The value of skewness and coefficient of variation decreased with each step of data transformation and both were significantly reduced after Beals smoothing transformation (Table 2). The transformed data were used for clustering analysis and site ordination while the untransformed data were used for indicator species analysis.

**Table 2** Details of the steps taken at each data screening and transformation

| Parameter | Before | Transformation 1 | 2 | 3 |
|---|---|---|---|---|
| Beta diversity* | 47.7 | 8.9 | 8.9 | 1.0 |
| Rows | | | | |
| Average skewness | 6.632 | 4.36 | 2.15 | 2.063 |
| CV of sums | 39.27 | 40.74 | 29.28 | 3.25 |
| Columns | | | | |
| Average skewness | 6.549 | 3.54 | 2.51 | 1.251 |
| CV of sums | 200.20 | 129.58 | 76.78 | 75.25 |
| Number of species | 487 | 190 | 190 | 190 |

* Beta diversity is the ratio of the total number of species to the average number of species

## *Data analysis*

The purpose of the cluster analysis was to define groups of sites based on similarities in community structure. Sites were clustered based on the hierarchical clustering method using Euclidean distance matrix and Ward's linkage method. Ward's linkage method was used to determine the minimum variance spherical clusters. Euclidean distance (ED) between the sample units *i* and *h* was calculated based on the following formula:

$$ED_{i,h} = \sqrt{\sum_{j=1}^{p}\left(a_{i,j} - a_{h,j}\right)^2}$$

where,

$a_{i,j}$ and $a_{h,j}$ = abundance of species *j* in sample units *i* and *h*.

Non-metric multidimensional scaling (NMS) ordination was used to determine the patterns of species distribution and their relationships to environmental gradients. NMS has the advantage in linearising the relation between environmental distance and phyto-sociological distance as it is based on ranked distance and, therefore, able to relieve the "zero truncation problem" (Beals 1984). It is an ordination method that is well-suited to data that are non-normal or are arbitrary, discontinuous, or have otherwise questionable scales. Sorensen's distance was used as the distance measure. In the preliminary run, we used six-dimensional solutions with 100 iterations. In PC-ORD, the program steps down from six-dimensional to one-dimensional ordination space. The final stress and number of iteration were plotted to choose the appropriate number of dimensions for the final runs. Stress is a measure of departure from monotonicity. The stress stabilised after the second dimension. A randomised version of the data set was used as null model to compare the correlation structure with the observed data set. Results indicated that the observed data descends more steeply than the usual curved descent for the randomised data. In the final solution, 70 iterations were used based on the plot of stress versus iteration number. The curve stabilised after 55 iterations.

The characteristic species of that particular site group and hierarchical cluster level were determined using indicator species analysis (Dufrene & Legendre 1997). The indicator species analysis helps to detect and describe the value of different species for indicating environmental conditions. The method assumes that two or more a priori groups of sample units exist. It combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a group. An indicator value for each species in each site group is produced. The indicator values range from zero (no indication) to 100% (perfect indication). Perfect indication occurs when an individual species is observed in all sites within one site group. These results were tested for statistical significance using the Monte Carlo randomisation technique. We used 1000 permutations, i.e. the sample units were reassigned to groups 1000 times. Each time a maximum indicator value was calculated. The probability of type 1 error was the proportion of times that the maximum indicator value from the randomised data set equalled or exceeded the maximum indicator value from the actual data set. The null hypothesis was that maximum indicator value was no larger than would be expected by chance, i.e. the species had no indicator value. The indicator value for each level of the hierarchy was plotted for the species with maximum indicator value greater than 25% in order to choose the most informative clustering level having the largest indicator value. According to Dufrene and Legendre (1997), the 25% threshold level assumes that a characteristic species is present in at least 50% of each site group and that its relative abundance in that group reaches at least 50%.

## Results

### *Site cluster*

In the clustering analysis, hierarchical classifications of sites were constructed by sequential merging of the sites or groups of sites with other sites or groups of sites. The hierarchical cluster dendrogram is shown in Figure 2. The percentage of chaining was relatively low at 0.65. We classified the sample units into eight site groups, which seemed fairly interpretable. At this level, 68% information remained and produced a manageable number of sample units ranging from 11 to 25 within each site group. In PC-ORD the eight site groups were identified by the following site group code: 1, 3, 4, 6, 11, 104, 107 and 116.

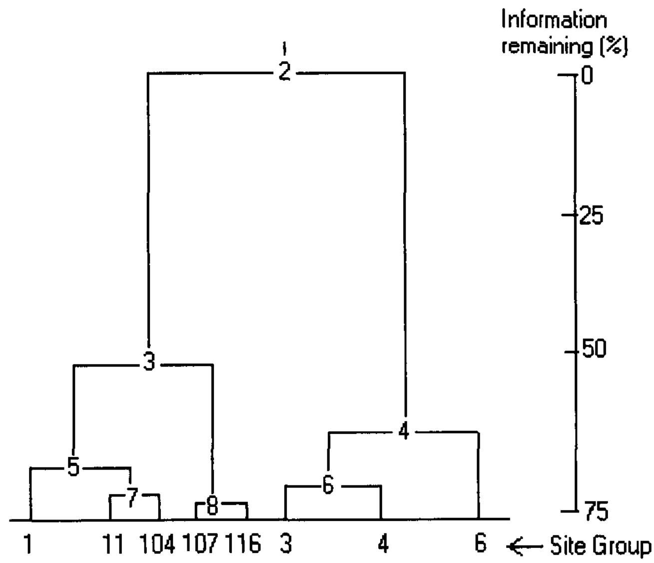



**Figure 2** Hierarchical dendrogram based on the Euclidean distance and Wards minimum variance method. Number within the hierarchical dendrogram indicates the cluster level.

### *Environment and species ordination*

A scatter plot of the NMS ordination with elevation gradient and topographic position class is shown in Figure 3. The ordination showed a strong correlation with elevation gradient. The ordination distances and distances in the original n-dimensional species space is highly correlated with Axis-1 but very poorly with Axis-2. Axis-1 explained 95.6% of the species data set variation, which is outstandingly high considering a complex and species-rich forest. We ran the NMS ordination using the same procedure mentioned earlier to validate the variation explained by Axis-1 (which is unexpectedly high) and similar results were generated.

Overlays of categorical parameter, i.e. by topography, aspects and slope in ordination space were compared. Results indicated that only topography showed a distinct relationship with Axis-1. This is expected, since topography is closely related to elevation, i.e. highest elevation gradient is generally found on a ridge. Details of the site group description and its site ranking from NMS results are shown in Table 3.

Based on the site ranking from ordination results and the cluster analysis, the site groups could be generalised to sites found on the upper elevation gradient (site groups 3, 4, 6) and lower elevation gradient (site groups 1, 11, 116, 104 and 107). The site groups can be arranged in accordance with their correlation to topographical gradient. Site group 6 represented the upper most elevation and was mostly found on the ridge and site group 107 was on the lower extreme of the elevation gradient and mostly located on the valley, based on the topography position overlaying the ordination space. Combination of both site clustering and site ranking by ordination method provided more information on the characteristics of the site group at each level of cluster.

Many species had the same ecological amplitude in relation to the elevation gradient. This is shown by the strong negative or positive correlation (r) of species with Axis-1 in ordination space. Species with weak correlation with Axis-1 indicated that they were not specific to elevation gradient.

Species with positive r were those that favoured the higher elevation gradient and those with negative r favoured the lower elevation. Species with extreme values of r (i.e. approaching to -1 or 1) were considered to be site specific, while species with r approaching 0 are generalists (i.e. their distribution was not restricted to the elevation gradient). Figures 4(a)–(c) show the ordination space for species that preferred either higher or lower elevation and for species that were not related to elevation gradient.

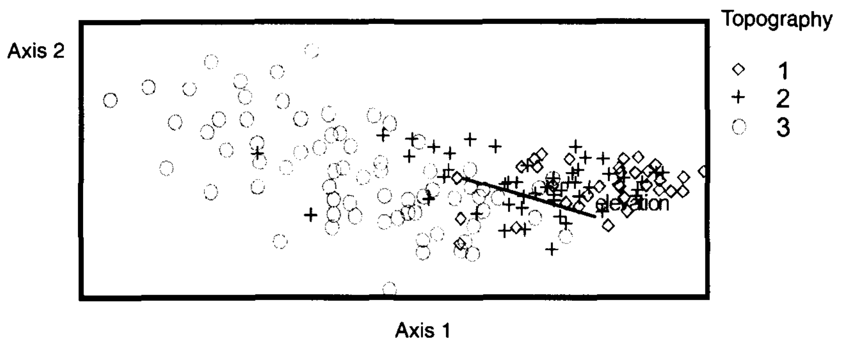
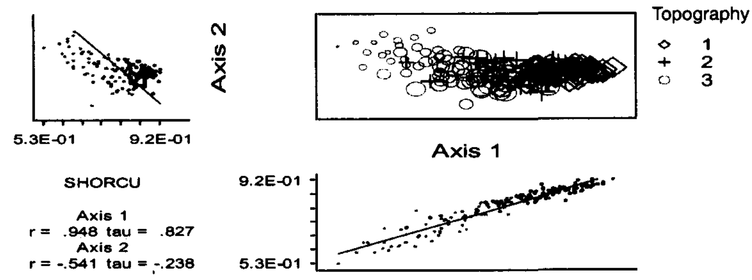


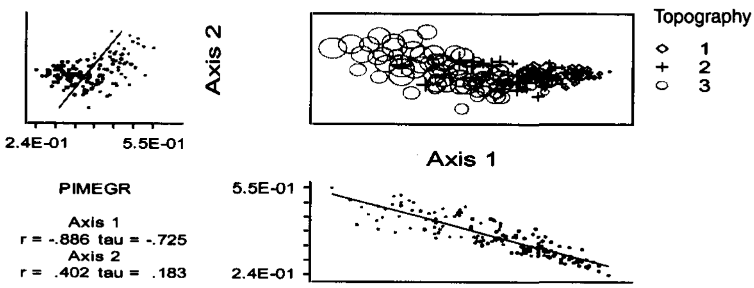

**Figure 3** A joint scatter plot and overlays of elevation gradient and topography position in ordination space. The line indicates elevation gradient. Topography code 1, 2 and 3 represent ridge, slope and valley respectively.

**Table 3** Description of site group based on the hierarchical dendrogram and site ranking from NMS ordination results of elevation gradient and topography

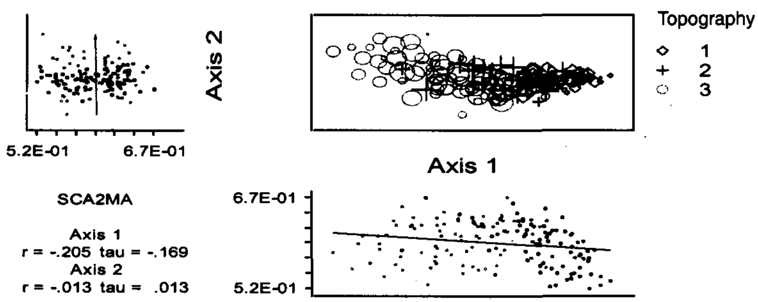
| Site group code | Description of the site group |
|---|---|
| 107 | Lower extreme of elevation gradient and mostly valley |
| 116 | Lower elevation and valley |
| 11 & 104 | Middle elevation and mixed of slope and valley |
| 1 | Upper middle elevation and mixed of slope and valley |
| 3 & 4 | Upper elevation and mixed of ridge and slope |
| 6 | Upper extreme of elevation gradient and mostly ridge |




(a) *Shorea curtisii*




(b) *Pimelodendron griffithianum*




(c) *Scaphium macropodum*

**Figure 4** Scatter plot of three groups of species in ordination space: (a) prefer higher elevation (b) prefer lower elevation, and (c) weak correlation with elevation gradient. (Species codes are listed in Appendix 1.)

## *Indicator species*

As mentioned earlier, we classified the two major site groups into sites that were confined to either lower or higher elevation based on the site ranking using the NMS ordination. Using species overlays and correlation coefficients, the site preferences of each species were evaluated. Since the ordination results showed a strong single environmental correlation with Axis-1, correlation coefficients provided a simple means to evaluate site preference of species. However, this preference at each site cluster from ordination was not clearly shown as we moved to each step of the hierarchy level (i.e. indicator species for that particular cluster level could not be ascertained quantitatively). A promising alternative is the indicator species analysis method. This method provides a constructive measure of site preference of a species and could be statistically tested. Using this information, the hierarchical cluster diagram was drawn with indicator species at each level of site cluster (Figure 5). The indicator value of each species determined the degree of site preference of the species.

In the indicator species analysis, we computed the indicator value for each step of hierarchical structure shown in Figure 2. A total of 39 species with maximum indicator values greater or equal to 25% (i.e. the characteristic species) at either one of the cluster levels were identified (Figure 5). The characteristic species decreased as the number of cluster level increased.

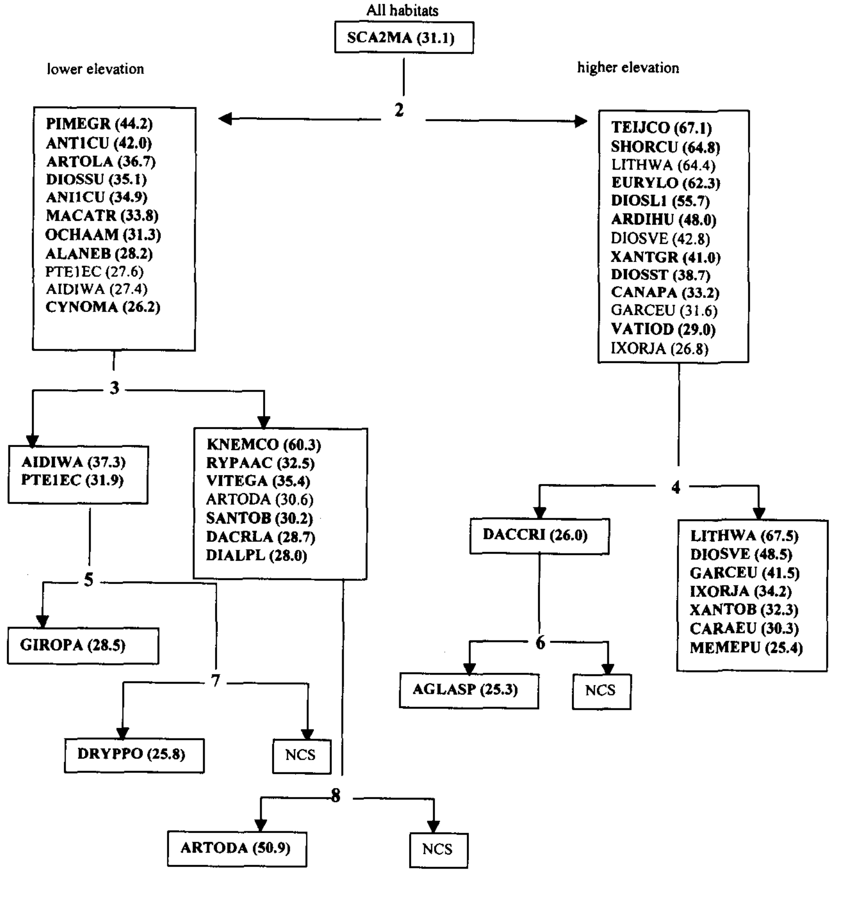



**Figure 5** Site clusters obtained from the hierarchical clustering methods (Figure 2) but with associated indicator species and indicator values in parentheses. All species indicator value > 25% are mentioned for each cluster where they are found, until they have reached the maximum indicator value. The maximum is indicated in bold. NCS indicates no characteristic species with indicator value > 25%. (Species codes are listed in Appendix 1.)

All characteristic species are significantly different from the mean indicator value obtained from the Monte Carlo randomisation procedure at p = 0.01, except for *Scaphium macropodum.* Its maximum value is 31.1% at cluster level two (p = 0.5). We considered this species as a generalist as it was not significantly confined to a particular site group (Figure 6). A similar finding was also observed in ordination space (Figure 4) where *S. macropodum* had a weak correlation with Axis-1.

Figure 6 demonstrates an example of the indicator values of species at each level of cluster. There are several types of distribution patterns observed from the graph. For several species, the indicator value was maximum at the highest hierarchy, decreasing gradually with the increase in cluster. These species have a broad niche breadth. Species with indicator values found at the higher level of the hierarchy were found on most sites of that group. Twelve indicator species

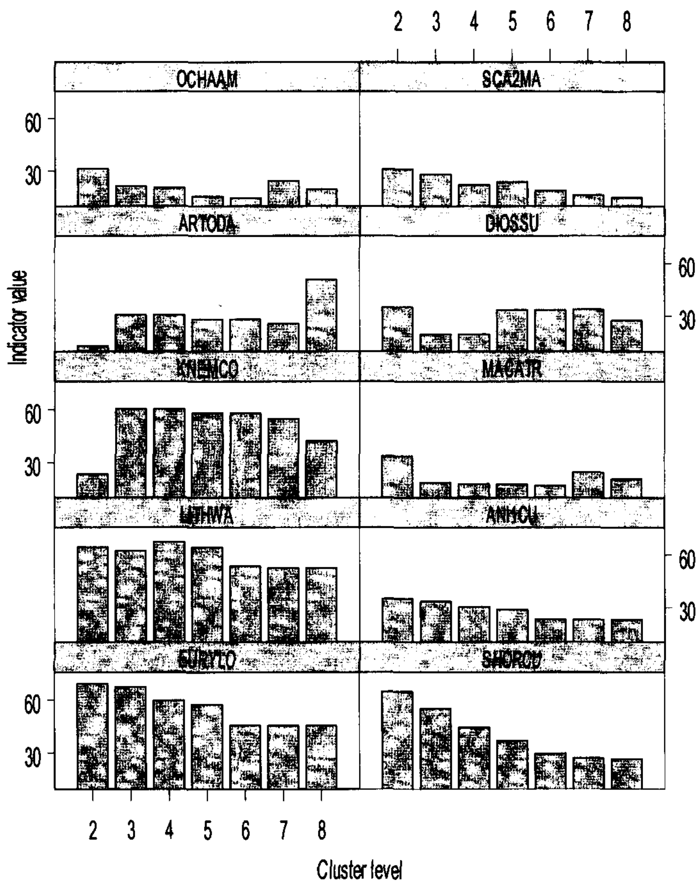



**Figure 6** Plots of the species indicator values obtained for the successive hierarchical clustering levels for selected species. (Species codes are listed in Appendix 1.)

were identified at cluster level 2 in the higher elevation site. The species were *Teijsmanniodendron coriaceum, Shorea curtisii, Lithocarpus wallichiinus, Eurycoma longifolia, Diospyros latisepala, Ardisia hulletii, D. venosa, Xantophyllum grifithii, D. styraciformis, Canarium patentinervium, Garcinia eugeniaefolia* and *Vatica odorata.* Three of these species were recorded at the lower hierarchical cluster. In the lower elevation, 11 characteristic species were identified. The species were *Pimelodendron griffithianum, Antidesma cuspidatum, Artocarpus lanceifolius, D. sumatrana, Anisoptera curtisii, Macaranga triloba, Ochanostachys amentacea, Alangium ebenaceum, Ptenandra echinata, Aidia wallichiana* and *Cynometra malaccensis.* Two of these species were identified at the lower hierarchical cluster.

The indicator value distribution of *Drypetes polyneura* and *Gironniera parvifolia* are good examples of species with maximum indicator values at lower hierarchy.

## Discussion

Similar findings in other studies have shown that certain species are generalists, while others are specialist. Masaki *et al.* (1992) conducted a cluster analysis in a mixed temperate forest based on inter-specific spatial correlation. They recognised three habitat guilds. Species in two groups were site specialists while the third one was a generalist. The site-specialist species occurred along ridges and bottom of the valley, while the generalist was not restricted to any of these sites. Niiyama *et al.* (1999) found that 13 species showed significant positive association with topography in the same study plot (Semangkok 6-ha ecological plot). The ridge species were also positively associated with ridge site and/or the distribution of the palms.

In this study, we identified the preferential sites of common species at different level of site clusters (Appendix 1). Out of eight site groups, three site groups fall under higher elevation (site codes 3, 4 and 6), while five sites (site codes 1, 11, 104, 107, 106) were categorised under lower elevation site. The higher elevation sites had three levels of hierarchical site clusters (2, 4 and 6), while the lower elevation has four levels of clusters (2, 3, 5 and 7). The hierarchical cluster level indicated the niche breadth of the indicator species. The niche breadth became narrower in the lowest hierarchical cluster level. Species with broad niche has maximum indicator value at the higher level of hierarchy. These species are classified as "eurotrophic" (Dufrene & Legendre 1997). On the other hand, species with maximum indicator at lower hierarchy are classified as "stenotophic", i.e. they require small niche breadth. It is an indicator of one or two small habitat. The eurotophic species are responsible for similarities between habitat and for the nested hierarchical structure in the site typology. Without them, no hierarchical structure should emerge among the site group (Dufrene & Legendre 1997). The number of indicator species decreased with decrease in the hierarchical cluster level. For example, there were 12 species identified at cluster level 2 in the higher elevation site, such as *Shorea curtisii, Teijsmanniodendron coriaceum* and *Eurycoma longifolia,* but this number decreased to one tree species (*Aglaia splendens*) at level

6 of site group code 3. At the extreme lower hierarchical cluster level, three site groups (site codes = 4, 16 and 104) was not represented by any indicator species. One characteristic species, *Scaphium macropodum*, was not restricted to any specific site. Niiyama *et al.* (1999) indicated similar findings for two species, *S. macropodum* and *Payena lucida*. We observed similar characteristics for *P. lucida* using species ordination but did not include it as characteristic species because the indicator value was less than 25%.

The combination of clustering analysis, ordination and species indicator analysis allowed us to determine species with large niche breadths or that occupied a wider range of site conditions and species that were restricted to certain site only. *Shorea curtisii*, for example, was mostly found on the higher elevation but gradually became less towards lower elevation. The preferences of a species to certain type of site may be associated with environmental factors. Tange *et al.* (1998) indicated that *S. curtisii* was absent in the valleys and suggested that the presence of seasonal anaerobic soil condition may be the limiting factor for its establishment. Several soil chemistry properties, particularly in the surface soil, have shown marked variation by topography. The proportion of the number of trees for several species gradually decreases from ridges to slope and valley bottoms in a hill dipterocarp forest at Tekam Forest Reserve (Wan Razali & Roslan 1983). For example, *S. curtisii*, based on proportion in relative density by tree numbers, decreased from 9 to 5 and 2%, for ridge, slope and valley bottom respectively. Niiyama *et al.* (1999) separated three groups of tree species in this study area. Species Group A comprised randomly distributed and valley species, Group B ridge species and Group C, slope and gap-associated species.

Our findings should be accepted with caution. The results are specific to the study site and blanket generalisation to other areas may not be appropriate. For example, the distribution and abundance of *Macaranga triloba*, a pioneer species commonly found in forest gaps, is presumably not restricted by the elevation gradient. Other interesting examples are *E. longifolia* and *Lithocarpus wallichianus*, which have been grouped as higher elevation species, but are commonly found in the lowland dipterocarp forest at the 50-ha plot in Pasoh (Manokaran *et al.* 1992). There seem to be other confounding factors that restrict the distribution of the species in this community. Addition of other important variables such as presence of other indicator plants, soil chemistry, gap sizes (vertical and horizontal) and population structure, to name a few, will provide a more informative interpretation of the underlying factors that control the community structure of the seraya-ridge forest.

## Conclusions

The diagram of hierarchical cluster and associated indicator species provide a simple and intuitive way to express species assembly of the indicator species and their site preference. For this analysis, we used only the topographical parameters of the study site. Ordination results showed that elevation and overlay of topographic position have strong correlations with species site preference. We were able to identify the indicator species at different levels of site clusters, which also indicate the niche breadth of the species. Characteristics species that were not restricted by the cluster level were regarded as generalists. Further research is recommended to examine the underlying factors that contribute to the species assembly and site preferences of tree community in the seraya-ridge forest.

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**Appendix 1** List of characteristic species code, scientific names, family, ecological functional group and its site preferences

| No. | SPCode | Species | Family | EC* | Site preferences |
|---|---|---|---|---|---|
| 1 | SCA2MA | *Scaphium macropodum* | Sterculiaceae | C | All habitats |
| 2 | PIMEGR | *Pimelodendron griffithianum* | Euphorbiaceae | C | 1, 11, 104, 107, 116 |
| 3 | ANT1CU | *Antidesma cuspidatum* | Euphorbiaceae | C | 1, 11, 104, 107, 116 |
| 4 | ARTOLA | *Artocarpus lanceifolius* | Moraceae | E | 1, 11, 104, 107, 116 |
| 5 | DIOSSU | *Diospyros sumatrana* | Ebenaceae | U | 1, 11, 104, 107, 116 |
| 6 | ANI1CU | *Anisoptera curtisii* | Dipterocarpaceae | E | 1, 11, 104, 107, 116 |
| 7 | MACATR | *Macaranga triloba* | Euphorbiaceae | P | 1, 11, 104, 107, 116 |
| 8 | OCHAAM | *Ochanostachys amentacea* | Olacaceae | C | 1, 11, 104, 107, 116 |
| 9 | ALANEB | *Alangium ebenaceum* | Alangiaceae | U | 1, 11, 104, 107, 116 |
| 10 | CYNOMA | *Cynometra malaccensis* | Leguminosae | E | 1, 11, 104, 107, 116 |
| 11 | AIDIWA | *Aidia wallichiana* | Rubiaceae | U | 1, 11, 104 |
| 12 | PTE1EC | *Pternandra echinata* | Melastomataceae | U | 1, 11, 104 |
| 13 | ARTODA | *Artocarpus dadah* | Moraceae | U | 11, 104 |
| 14 | KNEMCO | *Knema conferta* | Myristicaceae | C | 107, 116 |
| 15 | RYPAAC | *Ryparosa acuminata* | Flacourtiaceae | C | 107, 116 |
| 16 | VITEGA | *Vitex gamesepala* | Verbenaceae | U | 107, 116 |
| 17 | SANTOB | *Santiria oblongifolia* | Burseraceae | C | 107, 116 |
| 18 | DACRLA | *Dacryodes laxa* | Burseraceae | C | 107, 116 |
| 19 | DIALPL | *Dialium platysepalum* | Leguminosae | E | 107, 116 |
| 20 | GIROPA | *Gironniera parvifolia* | Ulmaceae | U | 1 |
| 21 | DRYPPO | *Drypetes polyneura* | Euphorbiaceae | C | 11 |
| 22 | TEIJCO | *Teijsmanniodendron coriace* | Verbenaceae | C | 3, 4, 6 |
| 23 | SHORCU | *Shorea curtisii* | Dipterocarpaceae | E | 3, 4, 6 |
| 24 | EURYLO | *Eurycoma longifolia* | Simarubiaceae | U | 3, 4, 6 |
| 25 | DIOSL1 | *Diospyros latisepala* | Ebenaceae | U | 3, 4, 6 |
| 26 | ARDIHU | *Ardisia hullettii* | Myrsinaceae | U | 3, 4, 6 |
| 27 | XANTGR | *Xantophyllum griffithianum* | Polygalaceae | C | 3, 4, 6 |
| 28 | DIOSST | *Diospyros styraciformis* | Ebenaceae | U | 3, 4, 6 |
| 29 | CANAPA | *Canarium patentinervium* | Burseraceae | U | 3, 4, 6 |
| 30 | VATIOD | *Vatica odorata* | Dipterocarpaceae | C | 3, 4, 6 |
| 31 | LITHWA | *Lithocarpus wallichianus* | Fagaceae | C | 3, 4, 6 |
| 32 | DIOSVE | *Diospyros venosa* | Ebenaceae | U | 3, 4, 6 |
| 33 | GARCEU | *Garcinia eugeniaefolia* | Guttiferae | C | 3, 4, 6 |
| 34 | DACRR1 | *Dacryodes rugosa* | Burseraceae | C | 3, 4 |
| 35 | IXORJA | *Ixora javanica* | Rubiaceae | U | 6 |
| 36 | XANTOB | *Xanthophyllum obscurum* | Polygalaceae | C | 6 |
| 37 | CARAEU | *Carallia eugenioidea* | Rhizophoraceae | C | 6 |
| 38 | MEMEPU | *Memecylon pubescens* | Melastomataceae | U | 6 |
| 39 | AGLASP | *Aglaia splendens* | Meliaceae | C | 3 |

*Ecological grouping code: E: Emergent C: Canopy U: Understorey
Site preferences refers to the site group code mentioned in Figure 3