ALTITUDINAL ZONATION OF FOREST COMMUNITIES IN SELANGOR, PENINSULAR MALAYSIA

T. Nakashizuka,

Forestry and Forest Products Research Institue, Tsukuba, Ibaraki, 305 Japan

Zulkifli Yusop & Abdul Rahim Nik

Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur, Malaysia

Received March 1991

NAKASHIZUKA, T., ZULKIFLI YUSOP & ABDUL RAHIM NIK. 1992. Altitudinal zonation of forest communities in Selangor, Peninsular Malaysia. Composition and structure of forest communities along altitudinal gradient were studied in relation to some climatic factors in Selangor, Malaysia. Lapse rates estimated from a two-year observation were 0.44 and 0.43°C per 100 *m* for maximum and minimum temperature, respectively. Altitudinal change in radiation reflected the frequent cloudy weather in the area at elevation higher than 800 *m* above sea level. Higher tree density and lower maximum tree height were observed at higher altitude. The number of family, genus and species per 500 m^2 were higher, while those per 50 individuals were lower in higher altitude. Diversity index (H') decreased linearly with altitude, while equitability (J') was almost uniform. Cluster analysis based on genus and family level similarity suggested the altitudinal classification as follows: lowland (0-700 *m* above sea level), transition (700-1100 *m* above sea level), lower montane (1100-1500 *m* above sea level), upper montane (1500-1700 *m* above sea level).

Key words: Altitudinal zonation - cluster analysis - diversity - floristic composition - forest community - minimum temperature - cloud line

Introduction

In tropical region, empirical classifications of forest vegetation have been prevailing because of high species diversity and difficulty in identification. Also on altitudinal zonation, only a few quantitative analyses have been made in tropical forests (Forest Department Sarawak 1977, Yamada 1977, Osawa *et al.* 1985, Kochummen 1982).

Several factors affecting the altitudinal distributions of tree species in tropical forests have been analysed (Grubb *et al.* 1963, Grubb & Whitmore 1966, 1967, Burgess 1969). Among them, temperature and cloud-relating climate have been considered as primarily important (Grubb & Whitmore 1967, Burgess 1969). The importance of minimum temperature on tree growth has been reported on several species (Roberts 1973, Sasaki 1979, Whitmore 1984). Clouds in the mountains of the tropical region affect the radiation, temperature and also air humidity. Grubb and Whitmore (1967) have suggested the importance of cloud on vegetation structure through the comparative analysis of lowland and montane forests and climatic factors. However, Burgess (1969) suggested that cloud was less important in Peninsular Malaysia.

This paper reports the altitudinal change in both climatic condition and forest structure. Floristic composition is analysed quantitatively, and the altitudinal zonations are classified. Some environmental factors along altitude are also analysed and their effects on vegetation are discussed.

Study area

The forests in Selangor, Peninsular Malaysia, were studied both by actual enumeration and by literature surveys. Field studies were carried out in the forests of Gombak [180-650 *m* above sea level (a.s.l.)] and Genting Highlands (780-1650 *m* a.s.l.). The data on forest composition in other parts of study sites were obtained from literature. At Kepong (70 *m* a.s.l.) in Kuala Lumpur, mean annual temperature and precipitation are 27.4°*C* and 2400 *mm*, without any marked dry season.

Granite is prevailing in the area (Whitmore & Burnham 1969). In the area higher than 1400 *m* above sea level, peat is accumulated on soil surface. Strongly weathered ferrallitic soils are prevailing in lowland, while yellow podozolic soils, acid brown forest soils or podozols are found in the mountain area (Whitmore & Burnham 1969). Nutrient supply from leaf litter is less in mountain area, and thus the nutrient level in the soil of montane forests is lower than that in the soil of lowland forests (Noraini & Salleh 1985). Montane forests have rather closed canopy with less frequent and smaller canopy gaps than lowland forests (Noraini 1990).

Method

Climatic condition along altitude

Continuous observations were carried out at two points of different altitude. The Forest Research Institute Malaysia (FRIM) at Kepong (70 *m* a.s.l.) maintains a climatic station. An auto-recording climatic station was set at the Hydroponic Station, Agricultural University of Malaysia, in Genting Highlands (1170 *m* a.s.l.). Air temperature, humidity, rainfall and radiation were monitored from February 1987 to March 1989.

The weekly maximum-minimum temperatures in forests were also monitored at 11 other points along an altitudinal transact. The maximum-minimum thermometers were hanged on tree trunks at 1.5 *m* high to avoid direct sunlight. Readings were done weekly from February to June 1987.

Cumulative radiation at open sites was measured at 13 points along altitude. A cumulative radiometer (Sun-station, Sun Systems Inc.), which has a sensitivity range of 300 to 1100 *nm* in wave length, was set at every point. Readings were taken weekly, from 12 to 27 February, 1987.

Tree enumeration in the field

Fifteen belts (10 *m* wide, 40-300 *m* long) were set up at about 100 *m* interval in altitude (Table 1). The belts were set up along the contour line from the ridge to the bottom to avoid any compositional bias due to topography. All trees above 10 *cm* in dbh (diameter at 1.3 *m* high) were identified and their dbh were measured. Leaf samples were taken from all trees and were identified with the assistance of FRIM staff. Out of total 1288 trees, 96% were identified at species level.

Table 1. Outline of the plots studied

Plot number	Altitude (*m*)	Study area (m^2)	Slope direction	Inclination (degree)
15a	180	1000	S80E	32
b	180	1000	S85W	25
c	180	1000	S45W	20
14a	350	1000	N55E	26
b	350	1000	S85E	30
13a	430	1000	N55E	26
b	430	1000	S70E	34
11a	510	1000	S20E	16
b	510	1000	S10E	16
10a	780	500	N60E	8
b	780	500	N60E	8
7a	920	500	N50E	33
b	910	500	S43E	30
6	1045	1000	S28W	18
2a	1140	600	N85W	36
b	1130	400	S70W	30
3a	1220	600	N85W	36
b	1200	400	S70W	30
5a	1310	500	S	26
b	1300	400	S	26
1a	1400	500	N10W	23
b	1400	500	N10W	23
8	1550	500	S85W	20
9a	1650	250	N65W	33
b	1650	150	S76E	28

Literature data

Data given in literature were also included in the analysis. The 1960s reconnaissance surveys in Ulu Selangor (Hock 1967) and in Kuala Lumpur and Klang (Cheah 1968) provided a large amount of data. However, there were some problems with regard to the tree identification and minimum size enumerated. The non-commecial trees were not identified to species level. Only the family names are shown for some trees.

Another data set used was from the report on the flora in Ulu Kali (Stone 1981). Detailed enumerations [trees higher than 0.9 *m* (3 *ft.*)] and identification at species level were carried out in that study. Only the tree genera that contain the species which have the potential to grow above 10 *cm* in dbh were selected as reported in Tree Flora of Malaya (Forest Department Malaysia 1972a, 1972b, 1978, FRIM 1989).

These secondary data, together with the present ones, were used to classify altitudinal forest types by the cluster analysis. To unify the quality of data, all data were converted to the exist or non-exist data at genus level. The trees belonging to the families of Anacardiaceae, Annonaceae, Burseraceae, Lauraceae, Myristicaceae and Sapotaceae were recorded at family level. Data in all plots in every 100 *m* altitudinal class (as 0-100 *m*, 100-200 *m*, *etc.*) were summed together, and were treated as one plot (represented as plots at the median of each altitudinal class, as 50, 150, 250 *m*, *etc.*)

Cluster analysis

Exist (1) or non-exist (0) coded data of genera and families in all 100 *m* altitudinal classes (17 classes, up to 1600-1700 *m* class) were used for the cluster analysis. The group average method was performed for the eucridean distance matrix among altitudinal classes. The computer programme developed by Tanaka *et al.* (1984) was applied.

Results

Climatic conditions along altitude

Altitudinal change in temperature showed a different pattern between maximum and minimum (Figure 1). Means of weekly maximum were rather constant in the altitude 70 to 690 *m* above sea level and decreased gradually in higher elevation. Minimum temperature, however, decreased linearly with altitude. The lapse rates estimated by the regression were 0.71 and 0.51°*C* per 100 *m* for maximum and minimum temperature, respectively.

The lapse rate calculated from the seven-day running average of two years data obtained from two climatic stations (70 and 1160 *m* a.s.l.) showed some variation. The lapse rate for the maximum temperature showed a greater variation than that of the minimum temperature. The lapse rate during the two-year period were 0.44 and 0.43°*C* per 100 *m* for the maximum and minimum temperature. The above rates were rather small compared to those reported by Whitmore (1984) (0.67°*C* per 100 *m*) or by Burgess (1969) (0.55 and 0.61°*C* per 100 *m*). However, they are comparable to the rate reported in Equador (0.43°*C* per 100 *m*) by Grubb and Whitmore (1967).

Radiation showed an almost similar pattern as by the maximum temperature along altitude (Figure 1). Radiation was comparable among the observation points lower than 800 *m* altitude, and decreased in higher altitude. This radiation pattern suggests the occurence of frequent clouds in the area higher than 800 *m* above sea level in this region.

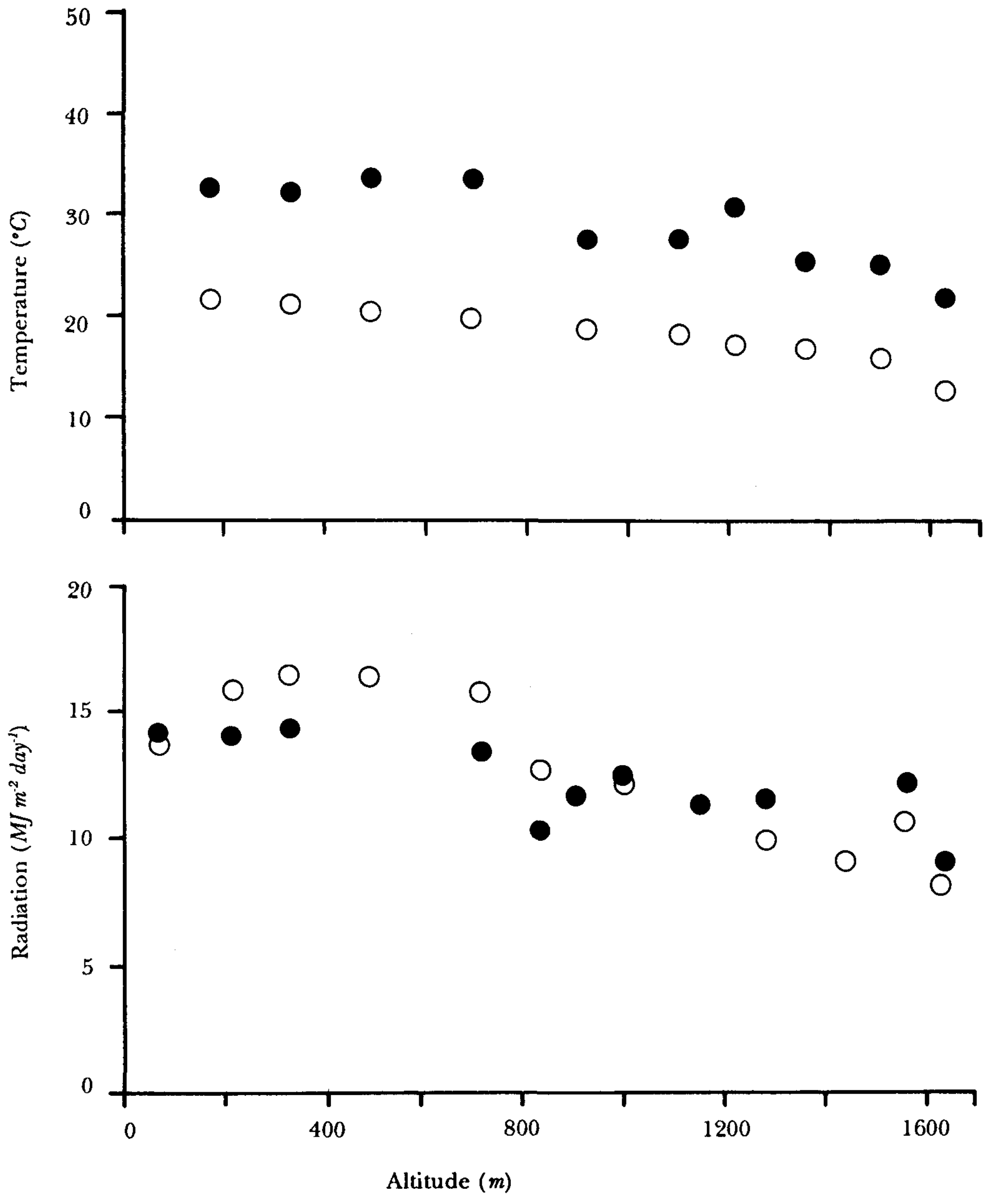

Figure 1. Altitudinal change of air temperature (Figure 1 a) and radiation (Figure 1 b); solid and open circless in Figure 1a show the mean weekly maximum and minimum temperatures respectively; ● and ○ in Figure 1b show the radiation during February 12 to 21, and during February 22 to 27, respectively

Altitudinal change in vegetation structure

With increasing altitude, the maximum height of trees became lower and the density of trees became higher (Figure 2), but there was no significant change in basal area (not significant at 5% level). Decrease in maximum height was not obvious in the plots lower than 800 *m* a.s.l. The change in density showed the reverse pattern; the density values in the plots lower than 800 *m* a.s.l. were comparable and became higher in higher elevation.

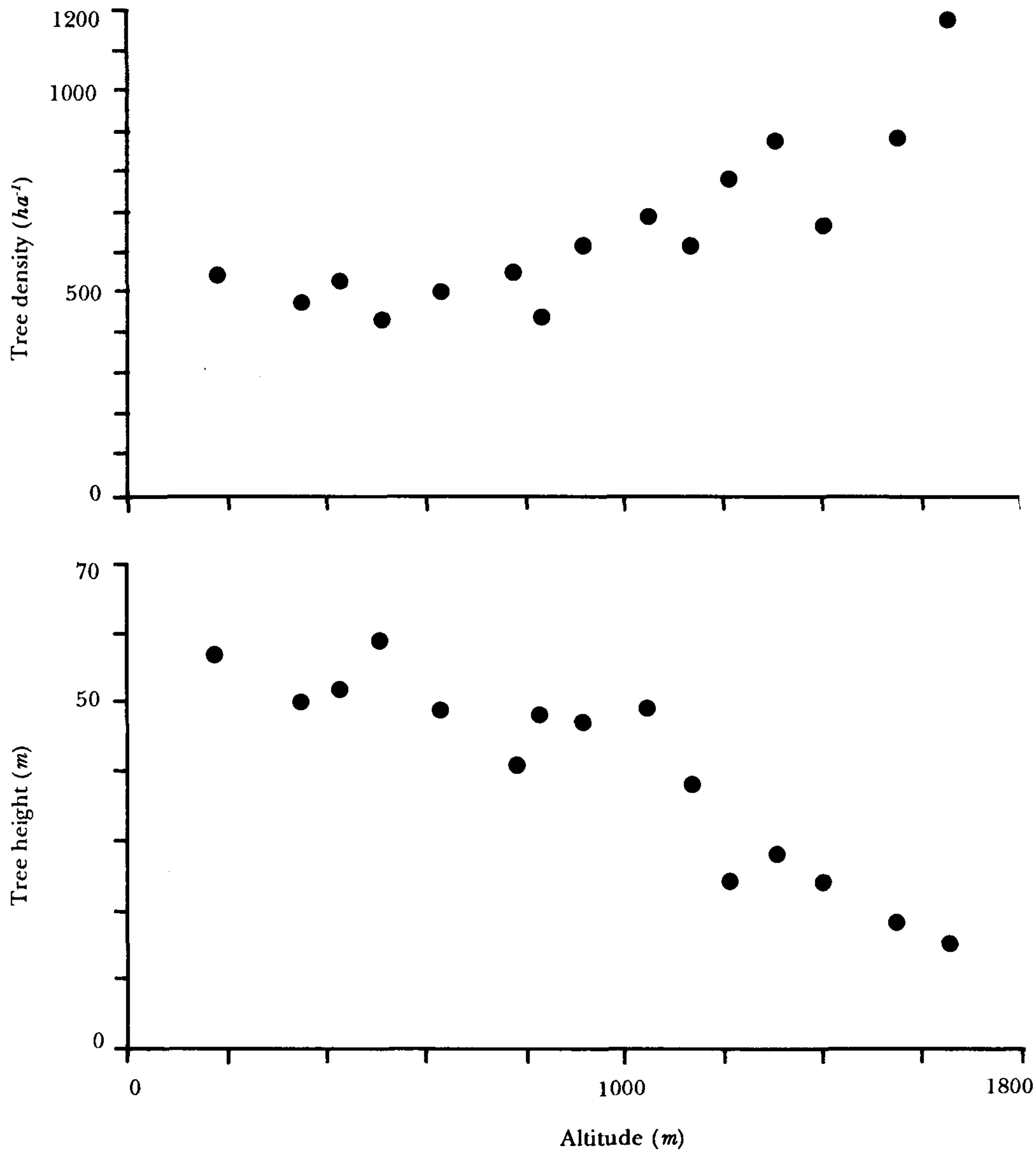

Figure 2. Altitudinal change of tree (dbh > 10 *cm*) density (Figure 2 a) and maximum tree height (Figure 2 b)

The number of species per unit area (500 m^2) increased with increasing altitude, while the number of species per unit number of tree (50 individuals > 10 *cm* in dbh) decreased with increasing altitude (Figure 3). Similar results were obtained for genera and families (Figure 3). Because of the high tree density in high altitude, the number of species recorded per 500 m^2 increased with altitude. A similar pattern of change in density and maximum temperature, that is, the change in the plot higher than 800 *m* a.s.l. was conspicuous.

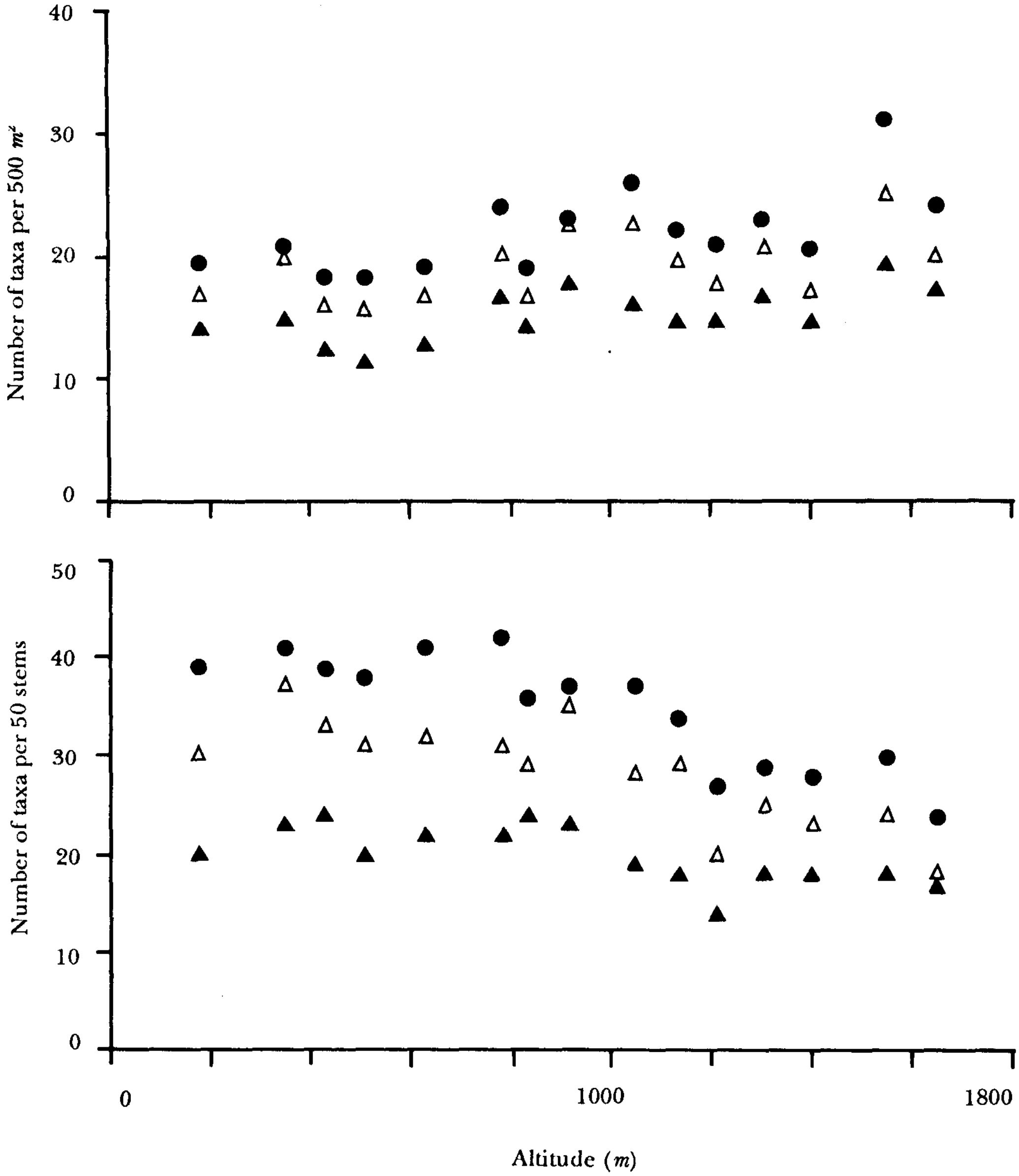

Figure 3. Altitudinal change of the number of taxa per 500 m^2 (Figure 3a) and per 50 stems (Figure 3b); solid and open circles and triangles show the number of species, genera, and families, respectively

Species diversity measured by H' (Shannon-Wiever's index calculated from the number of individuals of each species) showed a negative linear relationship with altitude, while equitability (Pielou 1975) remained constant with altitude (Figure 4). The number of species per 50 individuals (suggesting the potential floristic richness) decreased along altitude, but the equitability did not. This fact suggests that the basic organisation of the forest tree communities does not change with altitude.

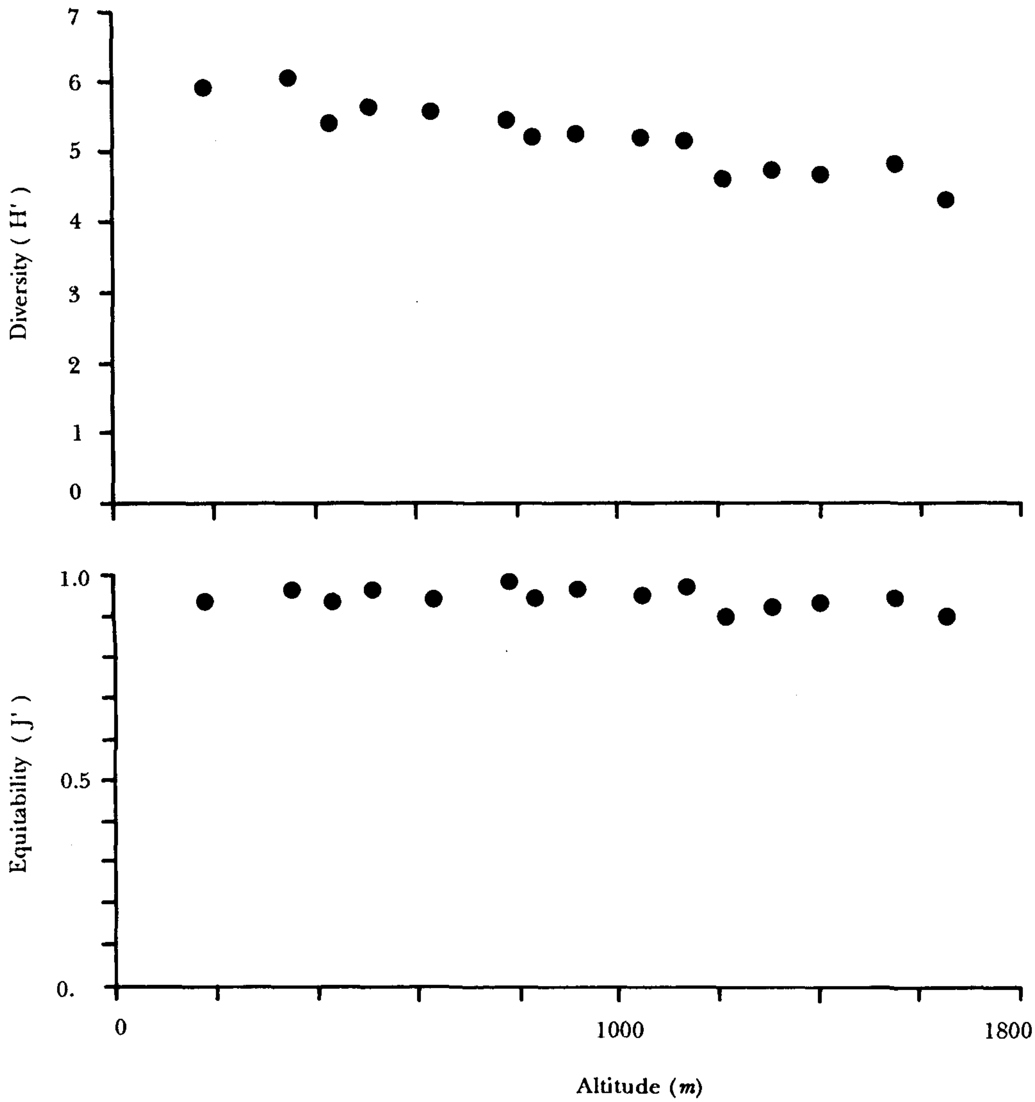

Figure 4. Altitudinal change of species diversity (H', Figure 4 a) and equitability (J', Figure 4 b)

Altitudinal zonation

Two kinds of cluster analyses showed consistent results. Both the data, based on genus and family level dissimilarities, suggested that there were two major clusters and a transition between them (Figure 5). The two compact groups consisted of plots in 0 to 700 and 1100 to 1700 *m* a.s.l. corresponding to the lowland and montane forests. The forests between 700 and 1100 *m* a.s.l. were classified as a transition zone.

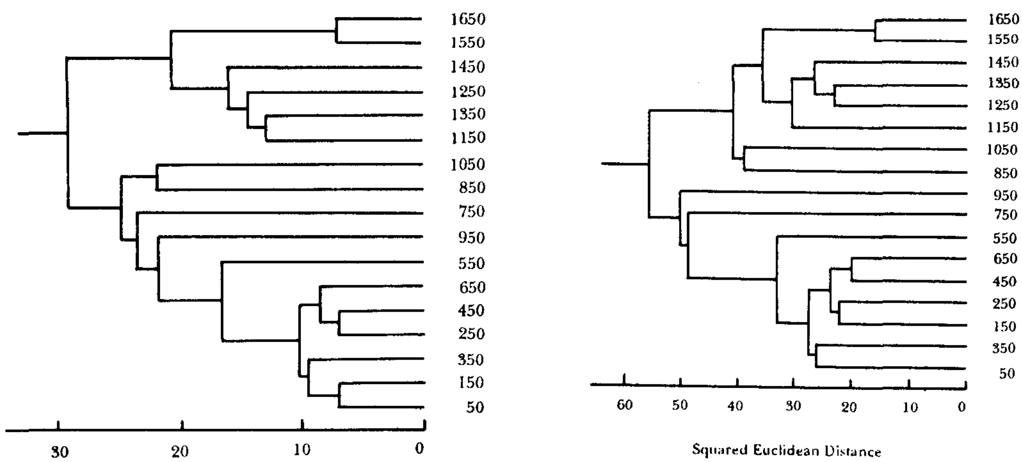

Figure 5. Dendrograms by cluster analysis based on dissimilarities of genus (Figure 5 a) and family level (Figure 5 b)

Among the forests higher than 1100 *m*, a cluster of the forests higher than 1500 *m* a.s.l. showed a sub-clustering, suggesting upper montane forests (Symington 1943). However, among the forests below 700 *m* a.s.l. no marked sub-clusters were recognised.

Distributions of the upper and lower limits of genera and families also showed that the forests between 700 and 1100 *m* a.s.l. are transitional (Figure 6). Many genera and families had their lower limits in distribution at 700 to 800 *m* a.s.l.; such genera as *Aporusa, Ardisia, Glochidion, Ilex* and *Mastixia*, and families as Cornaceae, Rosaceae, Rutaceae and Theaceae showed such a pattern. Many taxa had their upper limits in 1000 to 1100 *m* a.s.l. These facts showed that of the two groups of taxa, one should be called lowland taxa and another, montane taxa, which overlap in the zone between 700 and 1100 *m*.

Discussion

The present results suggest that the altitudinal zonation in Selangor could be classified as lowland (0-700 *m* a.s.l.), transition (700-1100 *m* a.s.l.), and montane forests (1100 *m* a.s.l. and higher). Forests higher than 1500 *m* a.s.l. could be classified as upper montane forests. Both classifications based on the formation (Burt Davy 1938, Whitmore & Burnham 1969) and on the floristic characteristics of the forests in Peninsular Malaysia (Symington 1943) have shown a consistent boundary at 750 and 1500 *m* a.s.l. The present results are fundamentally consistent with those classifications. Similar classifications were also found for Gunong Hulu, Sarawak (Forestry Department Sarawak 1977). However, the upper dipterocarp forests (Symington 1943), which were classified as lower part of montane forests (Burt Davy 1938, Whitmore & Burnham 1969) should be re-classified as a transition zone between lowland and montane forests from the present results. From his observa-

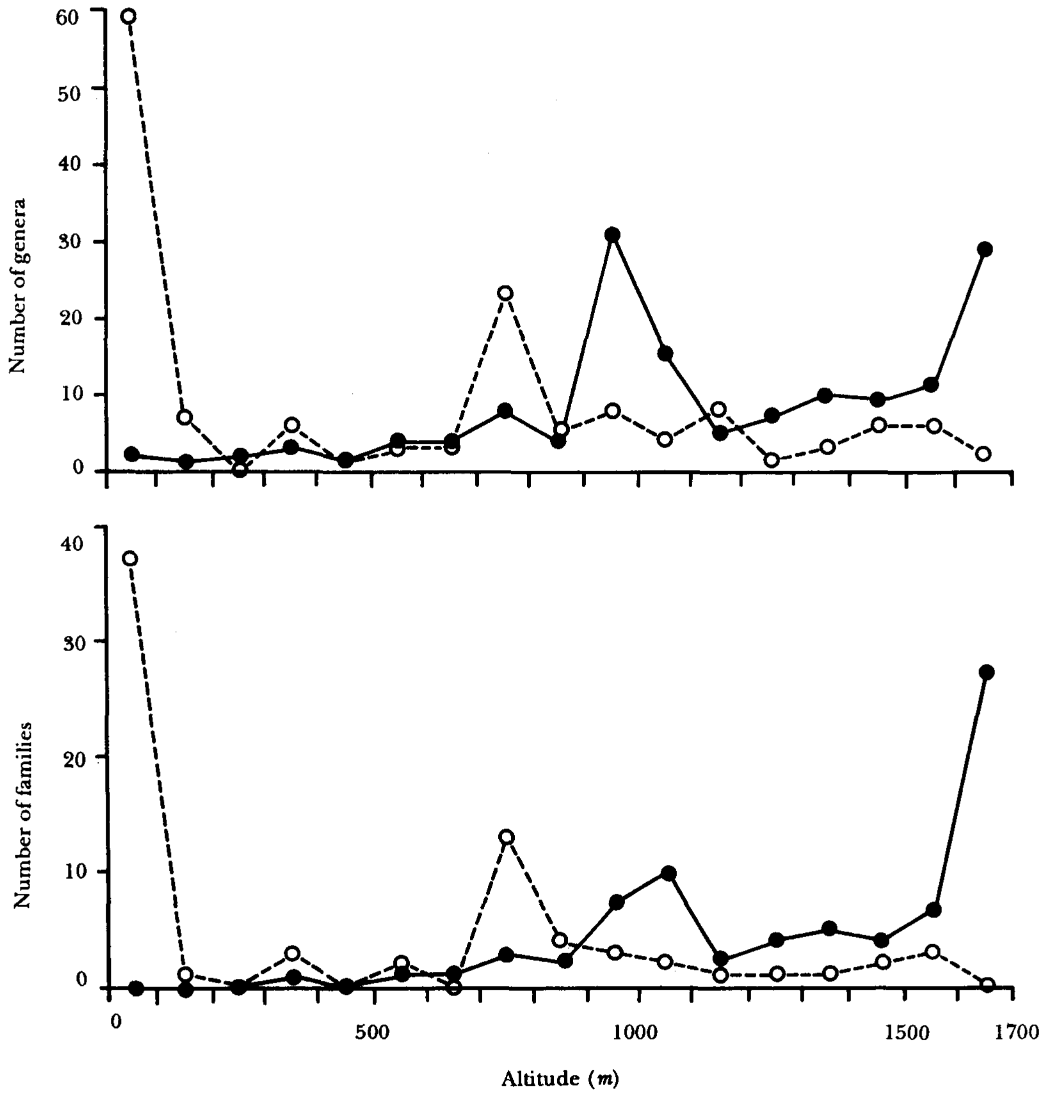

Figure 6. Altitudinal distributions of lower and upper limits of genera (Figure 6a) and families (Figure 6b); solid and open circles show the number of taxa which have their upper and lower limits in each interval (100 *m*) of altitude

tions of Dipterocarpaceae, Whitmore (1984) considered the boundary between these forests as abrupt. The present results, however, suggest that the transition zone is rather wide, ranging from 700 to 1100 *m* a.s.l.

Hill dipterocarp forests (Symington 1943) were not recognised as a marked group. Burgess (1969) suggested little floristic difference between them. The present results support this. Several features of forest community structure, maximum height and density of trees and number of species per 50 individuals showed no marked difference among forests lower than 800 *m* a.s.l. This fact suggests that the lowland and hill dipterocarp forests are very similar in structure. However, as the classification was made based on the data at genus and family levels, the difference between them could be recognised at species level.

The upper limit of lowland forests (700 *m* a.s.l.) is consistent with the lower limit of frequent cloud formation. The maximum temperature and radiation also remained constant below this altitude. Grubb and Whitmore (1968) also recognized the lower limit of montane forest in the Andes as being related to the lower level of constant cloud occurence. The factors that determine the upper limits of the lowland forests could not be identified by those data, since the change of both the factors along altitude showed a similar pattern. They may also effect vegetation in a complex way.

Burgess (1969) suggested the important effect of low temperature. Sasaki (1979) suggested the chill damage on tropical lowland tree species occurring at 15°*C*. Chilling injuries were also reported by Roberts (1973) at around 10 to 15°*C* in some seeds of tropical lowland species and by Mori *et al.* (1990) at below 15°*C* in seeds and seedlings of tropical tree species in Malaysia. These observations indicate a narrow plasticity of Dipterocarpaceae to changing temperature in the environment.

If lowland species have such a response to temperature, the minimum temperature could primarily determine the distribution of such a species. Minimum temperature showed a continous decrease with altitude. The annual mean minimum temperatures at 800, 1100 and 1500 *m* a.s.l. are 19.4, 18.2 and 16.5°*C*, respectively. Within the two years, the lowest temperature observed at the station at 1160 *m* a.s.l. was 16.1°*C*. It may go lower episodically. The minimum temperature could greatly affect the tree distribution in such an episodic climate. Ecophysiological analysis in detail could give the answer.

Acknowledgements

The senior author thanks Wan Razali Wan Mohd, Forest Research Institute Malaysia (FRIM) for providing him the facilities to conduct the research, and S.K. Yap, FRIM, for giving him useful suggestions. We are grateful to Y.C. Chan, FRIM and K.M. Kochummen, the former senior botanist at FRIM, for their help in tree identification, and to Raja Mohd. Raja Harun, Manager of Hydroponic Station, Agricultural University of Malaysia, for allowing the installation of the climatic station. This study forms a part of the joint research between FRIM and the Forestry and Forest Products Research Institute, Japan, funded by the Science and Technology Agency, Japan.

References

BURGESS, P.F. 1969. Ecological factors in hill and mountain forests of the states of Malaya. *Malayan Nature Journal* 22:119-128.

BURT DAVY, J. 1938. The Classification of Tropical Woody Vegetation Types. *Imperial Forestry Institute Paper 13.*

CHEAH, L.C. 1968. Kuala Lumpur and Klang Districts, Selangor. *Forest Resources Reconnaissance Survey of Malaya No. 18.* Forest Research Institute & Forest Department, Malaya.

FOREST DEPARTMENT MALAYSIA. 1972a. *Tree Flora of Malaya, Vol. 1* Longman, Kuala Lumpur.

FOREST DEPARTMENT MALAYSIA. 1972b. *Tree Flora of Malaya, Vol. 2.* Longman, Kuala Lumpur.

FOREST DEPARTMENT MALAYSIA. 1978. *Tree Flora of Malaya, Vol. 3.* Longman, Kuala Lumpur.

FOREST DEPARTMENT SARAWAK. 1977. *The Altitudinal Zonation of Forests Along the West Ridge of Gunong Mulu. 77 pp.*

FOREST RESEARCH INSTITUTE MALAYSIA. 1989. *Tree Flora of Malaya, Vol. 4.* Longman, Kuala Lumpur.

GRUBB, P.J., LLOYD, J.R. PENNINGTON, T.D. & WHITMORE, T.C. 1963. A comparison of montane and lowland rain forests in Equador. I. The forest structure, physiognomy, and floristic. *Journal of Ecology* 51:567-601.

GRUBB, P.J. & WHITMORE, T.C. 1966. A comparison of montane and lowland rain forests in Equador. II. The climate and its effects on the distribution and physiognomy of the forests. *Journal of Ecology* 54: 303-333.

GRUBB, P.J. & WHITMORE, T.C. 1967. A comparison of montane and lowland rain forests in Equador. III. The light reaching the ground vegetation. *Journal of Ecology* 55: 33-57.

HOCK, L.B. 1967. Ulu Selangor District, Selangor. *Forest Resources Reconnaissance Survey of Malaya No. 13.* Forest Research Institute and Forest Department, Malaysia.

KOCHUMMEN, K.M. 1982. Effects of Elevation on Vegetation on Gunung Jerai, Kedah. *Research Pamphlet No. 87.* Forest Research Institute, Kepong.

MORI, T., NAKASHIZUKA, T., SUMIZONO, T. & YAP, S.K. 1990. Growth and photosynthetic responses to temperature in several Malaysian tree species. *Journal of Tropical Forest Science* 3(1): 44-57.

NORAINI, M.T. 1990. Gap formation, viable seeds and species diversity in lowland dipterocarp and montane rain forests of Peninsular Malaysia. *Malaysian Applied Biology* 19: 57-71.

NORAINI, M.T. & SALLEH, A. 1985. Assessment of mineral nutrients in rainfall, throughfall and litter- fall in montane forests in Peninsular Malaysia. *Sains Malaysiana* 14: 303-314.

OSAWA, M., NAINGGOLAN, P.H.J., TANAKA, N. & ANWAR, C. 1985. Altitudinal zonation of forest vegetation on Mount Kerinci, Sumatra: with comparisons to zonation in temperate region of east Asia. *Journal of Tropical Ecology* 1: 193-216.

PIELOU, E.C. 1975. *Ecological Diversity.* John Wiley & Sons, New York.

ROBERTS, E.H. 1973. Predicting the storage life of seeds. *Seed Science and Technology* 1: 499-514.

SASAKI, S. 1979. Physiological study on Malaysian tropical tree species. Studies of storage and germination of Leguminosae and Dipterocarpaceae seed. *Tropical Agriculture Research* 12: 75-87.

STONE B.C. 1981. The summit flora of Gunung Ulu Kali (Pahang, Malaysia). *Federation Museums Journal* 26: 1-157.

SYMINGTON C.F. 1943. Forester's Manual of Dipterocarps. *Malayan Forest Records 16.* University of Malaya Press.

TANAKA, Y., TARUMI, T. & WAKIMOTO, K. 1984. *Handbook for Statistical Analysis by Personal Computer. II. Multivariate analysis.* Kyoritsu Suppan, Tokyo (In Japanese).

WHITMORE, T.C. 1984. *Tropical Rain Forests of the Far East.* Second Ed. Clarendon Press, Oxford.

WHITMORE, T.C. & BURNHAM, C.P. 1969. The altitudinal sequence of forests and soils on granite near Kuala Lumpur. *Malayan Nature Journal* 22: 99-118.

YAMADA, I. 1977. Forest ecological studies of the montane forest of Mt. Pangrango, West Java. *South East Asian Studies* 15: 226-254.