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NATURAL FOREST DYNAMICS. I. HOMOGENEITY OF SPECIES DISTRIBUTION

Wan Mohd. Shukri Wan Ahmad, Wan Razali Wan Mohd.

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

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Ashari Muktar

Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

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WAN MOHD. SHUKRI, W.A., WAN RAZALI, W.M. & ASHARI, M. 1997. Natural forest dynamics. I. Homogeneity of species distribution. This study was carried out on a randomly chosen 10-ha (200 x 500 m) forest area within the 50-ha Demography Project area of the Forest Research Institute Malaysia (FRIM) in Pasoh Forest Reserve, Negri Sembilan, Malaysia. The 10-ha study area contained 13 950 trees of 5 cm dbh and larger with a total of 619 species. Of the total 619 species, 26 (4.2%) species were of dipterocarps, 525 (84.8%) non-dipterocarps and 68 (11.0%) miscellaneous species. The results indicate that there is a 95% chance of detecting trees belonging to either all dipterocarp, all non-dipterocarp, or miscellaneous species groups by using a contiguous area of 5 ha; a contiguous area of 2 ha is sufficient to detect trees of all diameter size classes from 5 cm dbh onwards. For practical purpose, a contiguous area of 5 ha is sufficiently large to sample and detect tree distribution by species group and size class simultaneously. The implications of the results of the present study are discussed in relation to the need of establishing larger plot size to enumerate tree parameters, especially in monitoring forest growth dynamics by major species grouping and size class.

Key words: Species distribution - species-area curve - homogeneity - heterogeneity - dipterocarp - non-dipterocarp

WAN MOHD. SHUKRI, W.A., WAN RAZALI, W.M. & ASHARI, M. 1997. Dinamik hutan semula jadi. I. Keseragaman taburan spesies. Kajian ini dijalankan di kawasan yang dipilih secara rawak seluas 10 ha (200 x 500 m) di dalam kawasan 50 ha Projek Demografi oleh Institut Penyelidikan Perhutanan Malaysia (FRIM), di Hutan Simpanan Pasoh, Negri Sembilan, Malaysia. Kawasan seluas 10 ha ini mengandungi 13 950 pokok yang berdiameter paras dada 5 cm ke atas dan 619 spesies. Dari jumlah 619 spesies, 26 (4.2%) spesies dari kumpulan dipterokap, 525 (84.8%) kumpulan bukan dipterokap dan 68 (11.0%) kumpulan spesies yang lain. Keputusan menunjukkan peluang untuk menemui pokok dari spesies kumpulan dipterokap, bukan dipterokap dan kumpulan spesies yang lain dengan menggunakan kawasan seluas 5 ha adalah 95%; kawasan seluas 2 ha mencukupi untuk menemui pokok-pokok bersaiz kelas 5 cm dpd dan ke atas. Untuk kegunaan praktik, satu kawasan seluas 5 ha mencukupi bagi persampelan taburan pokok dan

untuk mendapatkan pokok mengikut kumpulan spesies dan kelas diameter pada satu-satu masa. Implikasi keputusan kajian ini dibincangkan dengan keperluan penubuhan plot bersaiz besar bagi mengukur parameter pokok terutama dalam pemerhatian pertumbuhan dinamik hutan berdasarkan kumpulan utama spesies dan kelas diameter pokok.

Introduction

Organisations that depend on wood as a raw material often have large capital investments to manage the timber land. Periodic inventories of the resources are required for tax records, for justification of various forest management expenditures, and for determination of the quantity and quality of wood available for utilisation. Some inventories are concerned with plantation survival counts, some with stock piles and land appraisal, and still others with studies of tree growth or site evaluation (Avery & Burkhart 1983).

In studies of plant communities, it is a common practice to quantify and classify distributions of species (Mohler 1983). Wong (1976) and Wyatt-Smith (1966) have described the distribution of trees by family, genus and species in some lowland dipterocarp forests. Wyatt-Smith (1966) also described the nature of tree distribution in the hill forest of Bukit Lagong Forest Reserve. He found an aggregated distribution for those species with two, three and four individuals present per plot (5 acres) and as random distribution for those species with five individuals. Wan Razali and Roslan (1983), in an analysis of a 16-ha block of a hill dipterocarp forest, found that the probability of diameter distribution of all trees ≥ 10 cm dbh was statistically not significant (that is, equal distribution) when comparisons were made between plots (10 × 10 m) on ridge top vs. mid slope, ridge top vs. lower slope, and mid slope vs. lower slope.

The primary objective of this paper was to test the homogeneity of species distribution by diameter class and specific group. This is important as one would be able to make a better decision as to a more appropriate plot size when establishing a "large" plot size in long term studies of forest dynamics.

Methodology

Overview

This study was carried out on a randomly selected 10-ha (200 × 500 m) virgin forest area within the 50-ha Demography Project in the Pasoh Forest Reserve, Negri Sembilan, Malaysia, established by the Forest Research Institute Malaysia (FRIM).

The study area was divided into 1000 contiguous 10× 10 m quadrats or plots. One hundred percent enumeration data of all trees 1 cm diameter at breast height (dbh) and above were available from this Demography Project. However, this study used only trees of 5 cm dbh and above. The commercial species

classification currently employed by the Forestry Department Peninsular Malaysia (FDPM, 1986) was used in this study.

The detailed species classification, site description and plot design of the study area have been described in Wan Razali *et al.* (1997). In the case of the Demography Project in Pasoh, the plot size of 50-ha could be larger than measurement plots normally established for enumeration and growth studies. However, the choice of 50-ha plot may have been done without any statistical consideration but was more as a comparison with the ones already established at the Barro Colorado Island, Panama and elsewhere in the tropics.

Analysis of data

The original data for each tree were transferred from the field form to computer files in two steps. First, map co-ordinates were generated from the field map by digitising. A dBASE III program was then used to generate sequential tag numbers, and to direct the digitiser's output to the appropriate record. Second, the tag number, species code, and diameter were manually entered into a separate file. This system created a dBASE III file for each 20-m quadrat (Manokaran *et al.* 1990).

Construction of species-area curve

Data from dBASE III files were transferred into QUARTRO PRO in order to compute the total numbers of trees in each 1-ha unit. Cumulative number of species for the whole 10-ha study area according to the various species groups was used to develop Species-Area Curves – one curve for each of the following group in order to see a general trend of species distribution in the selected 10-ha plot:

- ALL DIPT. (all dipterocarps)
- ALL NON-DIPT. (all non-dipterocarps)
- MISC. (other species including conifers)
- ALL SPECIES (all species)

Test of homogeneity of species distribution

The 10-ha study area was divided into ten, five and two contiguous units of equal area such that each unit area would cover the range of topographic features. The actual number (density) of trees per species group and per diameter class was used for this homogeneity test, all with a chi-square statistic at 5% significance level.

Results and discussion

Number of trees and species-area curve

The 10-ha study area contained 13 950 trees of 5 cm dbh and above comprising dipterocarps, non-dipterocarps and miscellaneous species groups. Table 1 shows the number of trees and percentage by species groups in the study area. The complete numbers of trees by species groups in each 1-ha unit are shown in Table 2.

There were 619 species identified from the total number of trees in the 10-ha plot; 26 (4.2%) species were classified as dipterocarps (ALL DIPT.), 525 (84.81%) non-dipterocarps (ALL NON-DIPT.) and 68 (10.99%) miscellaneous (MISC) species. Table 3 shows the numbers of species and percentages by species groups in the study area.

Table 4 shows the species-area relationship by 1-ha unit for all species groups. Cumulative numbers of species-area are shown in Table 5. From the cumulative numbers of species, species-area curves were constructed for the whole 10-ha study area as shown in Figure 1.

Table 1. Number of trees ≥5 cm dbh in the 10-ha study area

Species group*	Number of trees	%
Dipterocarps	1 466	10.51
DM	791	5.67
DNM	675	4.84
Non-Dipterocarps	11 196	80.26
ND. LHW	2 723	19.52
ND. MHW	4 206	30.15
ND. HHW	4 267	30.59
Miscellaneous (MISC)	1 288	9.23

* DM = dipterocarp, meranti; DNM = dipterocarp, non-meranti; ND. LHW = non-dipterocarp, light hardwood; ND.MHW = non-dipterocarp, medium hardwoods; ND.HHW = non-dipterocarp, heavy hardwoods (Wan Razali *et al.* 1997).

More new species were recorded with increasing area sampled. This was to be expected. The first hectare shows a total (ALL SPECIES) of 381 species, increasing to 619 species in the tenth hectare with the number of different species entering each 1-ha unit ranging from 5 to 86 species. A similar situation was shown for ALL-NON DIPT. species group, ranging from 317 species in the first hectare to 525 species in the tenth hectare. For total dipterocarp (ALL DIPT.), a total of 26 different species were found in the 10-ha plot, ranging from 16 to 22 species per hectare.

Table 2. Tree number table for the 10-ha study area of Pasoh Forest Reserve

Species group Trees ≥ 5 cm dbh	Number of trees in each 1-ha unit										Total
	1	2	3	4	5	6	7	8	9	10	
DM	67	79	65	60	84	76	94	129	65	72	791
DNM	67	79	91	56	79	68	67	60	53	55	675
ALL DIPT.	134	158	156	116	163	144	161	189	118	127	1466
ND. LHW	264	269	254	257	256	291	262	283	293	294	2723
ND. MHW	445	454	458	415	422	405	404	415	402	386	4206
ND. HHW	446	405	454	424	437	432	416	404	420	429	4267
ALL NON-DIPT.	1155	1128	1166	1096	1115	1128	1082	1102	1115	1109	11196
MISC	135	129	124	130	105	131	130	105	155	144	1288
ALL SPECIES	1424	1415	1446	1342	1383	1403	1373	1396	1388	1380	13950

Table 3. Number of species in the 10-ha study area

Species group*	Number of species	%
Dipterocarps	26	4.20
DM	10	1.62
DNM	16	2.58
Non-Dipterocarps	525	84.81
ND. LHW	172	27.80
ND. MHW	205	33.10
ND. HHW	148	23.90
Miscellaneous	68	10.99

* All trees ≥ 5 cm dbh.

Homogeneity of tree species and size class distribution

Table 6 shows the results of chi-square test of homogeneity of species distribution. The distribution of the species in the study area was highly heterogeneous for most species groups. For example, the chi-square test of homogeneity for Dipterocarp, meranti (DM) is highly significant at 5% level in the ten, five and two contiguous units of equal area. This may have been due to the presence of large number of trees of one or two species within this species group in a very few contiguous unit areas. But the tree distribution of ALL DIPT., ALL NON-DIPT., and MISC species groups was only homogeneous in the 5-ha unit areas.

In this study area, the distribution of tree species by diameter classes was highly homogeneous when comparisons were made between 2-ha and 5-ha unit areas. Wan Razali (1980), in an analysis by species groups of a 16-ha block of a hill dipterocarp forest in Malaysia, found that all trees ≥ 10 cm dbh were homogeneously distributed only when two equal contiguous areas of 8 ha each were compared. However, he further found that tree distribution for various diameter size classes was homogeneous, except trees of 15 - 30 cm dbh, when 4-ha unit areas were compared.

Table 4. Species number table for the 10-ha study area of Pasoh Forest Reserve

Species group Trees ≥ 5 cm dbh	Number of species in each 1-ha unit									
	1	2	3	4	5	6	7	8	9	10
DM	10	8	9	8	9	10	9	10	9	8
DNM	12	9	8	10 (1)	11 (2)	12 (1)	10	11	11	8
ALL DIPT.	22	17	17	18 (1)	20 (2)	22 (1)	19	21	20	16
ND. LHW	86	92 (34)	93 (18)	83 (7)	83 (8)	95 (9)	86 (4)	100 (4)	84	86 (2)
ND. MHW	121	125 (33)	130 (20)	125 (8)	120 (3)	126 (5)	121 (5)	126 (4)	129 (4)	115 (2)
ND. HHW	110	91 (14)	88 (6)	86 (1)	89 (5)	90 (6)	98 (3)	95 (1)	92	97 (2)
ALL NON-DIPT.	317	308 (81)	311 (44)	294 (16)	292 (16)	311 (20)	305 (12)	321 (9)	305 (4)	298 (6)
MISC	42	32 (5)	38 (7)	32 (3)	27 (1)	38 (7)	30	30 (1)	32 (1)	29 (1)
ALL SPECIES	381	357 (86)	366 (51)	344 (20)	339 (19)	371 (28)	354 (12)	372 (10)	357 (5)	343 (7)

Figure in parenthesis indicates the number of new different species in each species group entering each 1-ha unit area.

Table 5. Cumulative species number table for the 10-ha study area of Pasoh Forest Reserve

Species group Trees ≥ 5 cm dbh	Number of species in each 1-ha unit									
	1	2	3	4	5	6	7	8	9	10
DM	10	10	10	10	10	10	10	10	10	10
DNM	12	12	12	13	15	16	16	16	16	16
ALL DIPT.	22	22	22	23	25	26	26	26	26	26
ND. LHW	86	120	138	145	153	162	166	170	170	172
ND. MHW	121	154	174	182	185	190	195	199	203	205
ND. HHW	110	124	130	131	136	142	145	146	146	148
ALL NON-DIPT.	317	398	442	458	474	494	506	515	519	525
MISC	42	47	54	57	58	65	65	66	67	68
ALL SPECIES	381	467	518	538	557	585	597	607	612	619

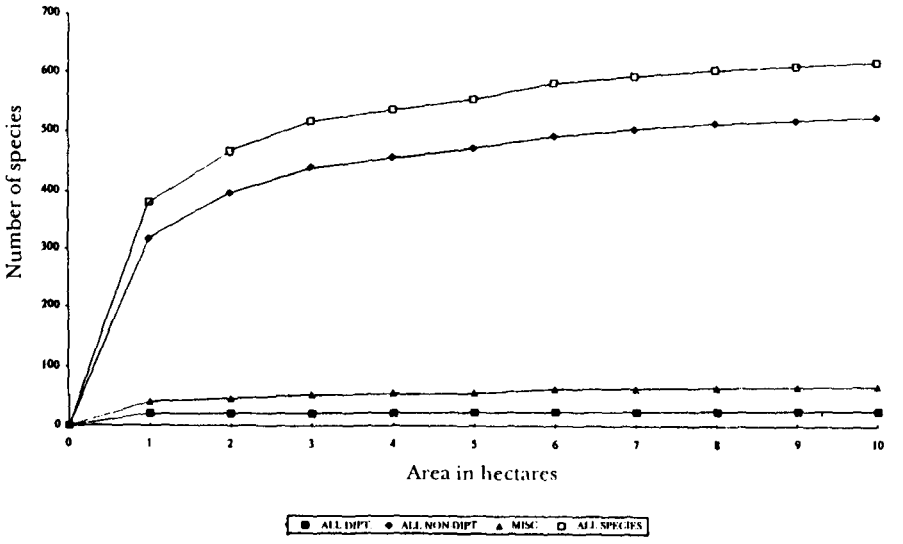

Figure 1. Species-area curves for the 10-ha study area. All trees ≥ 5 cm dbh

Table 6. Chi-square test of homogeneity of trees 5 cm dbh and larger by species group and size class distribution

	Θ Observed χ^2		
	By 10 equal unit areas (1 ha each)	By 5 equal unit areas (2 ha each)	By 2 equal unit areas (5 ha each)
Species group (≥ 5 cm dbh)			
DM	47.46***	38.62***	9.13***
DNM	17.32*	8.12	6.38**
ALL DIPT.	26.57***	18.92***	0.43
ND. LHW	10.19	6.93	6.86***
ND. MHW	7.68	6.51	6.15**
ND. HHW	4.71	2.29	0.44
ALL NON-DIPT.	3.48	2.48	0.06
MISC	17.43*	10.86*	1.82
Diameter classes, all species (dbh in cm)			
5 - < 10	4.01	0.49	0.22
10 - < 15	4.43	1.29	0.06
15 - < 30	9.61	1.83	0.94
30 - < 45	7.55	1.25	0.09
45 - < 60	20.20**	4.32	0.78
≥ 15	2.54	0.20	0.01
≥ 30	4.83	0.27	0.01
≥ 45	3.69	1.57	0.00
≥ 60	17.12*	7.80	0.34

Θ Reject the hypothesis of homogeneity at 0.05 level if observed χ^2 is greater than the table value (16.919, 9.488 and 3.841) with 9,4 and 1 degrees of freedom respectively.

Therefore, when sampling for tree density, an area of 5 ha is sufficiently large in order to detect the homogeneity of species distribution for ALL DIPT., ALL NON-DIPT. and MISC species in this type of natural forest. However, due to the richness of ALL NON-DIPT. species in this area, an area of 1 ha is already able to detect the homogeneity of species distribution. If one is interested in species distribution by size classes only, then a 2-ha area is sufficient to detect homogeneity of size class distribution of all trees ≥ 5 cm dbh, irrespective of species.

All in all one, can infer that there is a 95% probability (chance) of detecting trees belonging to the same species group (of ALL DIPT., ALL NON-DIPT. and MISC) by using a contiguous area of 5 ha each. Similarly, there is also a 95% probability of finding trees of all size classes (from 5 cm dbh onwards) in an area by using a contiguous area of 2 ha each only. However, for practical purpose an area of 5 ha is sufficiently large to sample if one is interested in the distribution of trees, simultaneously by species groups and size classes.

Conclusion

The shape of the species-area curve for ALL SPECIES in this study area was found to have a similar trend to that of a 16-ha (200 × 800 m - all trees ≥ 10 cm dbh) tropical hill forest at Sungai Tekam Forest Reserve, Pahang, Malaysia (Wan Razali 1980). Wyatt-Smith (1966) found a similar species-area relationship in Bukit Lagong hill forest on a 0.5-ha stand. The study by Lang *et al.* (1971) on a 1.5-ha stand of tropical moist forest on Barro Colorado Island, Panama also showed a similar shape of species-area curve for trees greater than 2.5 cm dbh. However, all the above areas showed different species distribution in terms of number and occurrence of a specific species. For example, in Sungai Tekam Forest Reserve (Wan Razali 1980), only a total of 133 species were found in the 16-ha area as compared to 619 species in the present study area of 10 ha. Several reasons could have caused the differences between the present study and the one in Sungai Tekam Forest Reserve. Firstly, the size of the study area; secondly, the location chosen; and finally the level of species identification which was more thoroughly done in Pasoh than in Sungai Tekam.

Distribution of trees in terms of size classes seems to be more homogeneous when compared to species groups. The present results do have some implications on long term ecological studies and/or demographic studies in terms of size of a study area. This implication can be seen in the light of the need to establish larger plot size in tree enumerations, especially if a project involves measuring tree diameters in order to monitor the dynamics of forest growth and analysing tree information by species groups. Specifically, the results of this study indicate that it is sufficient to establish at least two random replicates of a 5-ha plot and a statistically unbiased plot size compared to one 10-ha plot if we are interested to analyse tree information simultaneously by species groups and size classes.

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References

AVERY, T.E. & BUKHART, H. E. 1983. *Forest Measurements.* 3rd edition. McGraw-Hill, New York. 331 pp.

FDPM. 1986. *Panduan Kerja Luar Inventori sebelum Tebangan (Pengemaskinian I).* Unit Pengurusan Hutan, Ibu Pejabat Perhutanan Semenanjung Malaysia, Kuala Lumpur. 50 pp.

LANG, G.E., KNIGHT, D.H. & ANDERSON, D.A. 1971. Sampling the density of tree species with quadrats in a species-rich tropical forest. *Forest Science* 17 : 395 - 400.

MANOKARAN, N., LAFRANKIE, J.V., KOCHUMMEN, K.M., QUAH, E.S., KLAHN, J.E., ASHTON, P.S. & HUBBEL, S.P. 1990. *Methodology for the Fifty Hectare Research Plot at Pasoh Forest Reserve.* Forest Research Institute Malaysia, Kepong, Malaysia. 69 pp.

MOHLER, C.L. 1983. Effect of sampling pattern on estimation of species distribution along gradients. *Vegetatio* 54 : 97 - 102.

WAN RAZALI, W.M. 1980. Species distribution and sampling tree density: a preliminary investigation using quadrats in a tropical high forest. *Malaysian Forester* 43(4) : 452 - 468.

WAN RAZALI, W.M. & ROSLAN, I. 1983. Tree-diameter distribution pattern in three topographic positions in a hill forest of Peninsular Malaysia. Pp. 11 - 23 in *Mensurational Problems of Forest Inventory in Southeast Asia.* BIOTROP Special Publications No. 19. BIOTROP, Indonesia.

WAN RAZALI, W.M., WAN MOHD. SHUKRI, W.A. & ASHARI, M. 1997. Natural forest dynamics. II. Sampling of tree volume using quadrats in tropical forests of Peninsular Malaysia. *Journal of Tropical Forest Science.* (In press).

WONG, Y.K. 1976. *Some Indications of Total Volume of Wood Per Acre in Lowland Dipterocarp Forest.* Research Pamphlet No. 53. Forest Research Institute, Malaysia : 3 - 16.

WYATT-SMITH, J. 1966. *Ecological Studies on Malayan Forests.* Research Pamphlet No. 52. Forest Research Institute Malaysia, Kepong, Malaysia.