STRUCTURE AND FLORISTIC COMPOSITION OF THE BEECH FOREST IN TAIWAN

CHANG-FU HSIEH[(1)]

(Manuscript received 1 December 1988, revised version accepted 19 January 1989)

Abstract: In Taiwan, *Fagus hayatae* Palib. *ex* Hayata (Taiwan beech) is of particular interest because of its limited and relic-like distribution within the Lalashan Nature Reserve in northern Taiwan. It forms nearly pure stands extending about 18 km along the ridges at elevations of 1,300 to 2,000 m.

Three stands, representing northern, middle, and southern ranges of the beech forests, were sampled using thirty-two 10×10 m quadrats. They were surveyed for physiognomy, structure and floristic composition. About 172 species of vascular plants were encountered. Species richness per plot averaged 39. Diversity of trees with a DBH >1.0 cm was calculated as Shannon-Wiener index (2.34) and Simpson index (0.12). The density was 5700 stems with an average basal area of 56 m^2 per ha. The beech contributed more than 76% of the total basal area. Other important species were ***Rhododendron formosana*** and ***Enkianthus perulatus*** in the subcanopy layer. In the understory, *Yushanian niitakayamensis* (dwarf bamboo) usually formed extremely dense layers.

Sum of square agglomerative cluster analysis led to the recognition of 3 vegetation types. Reciprocal averaging ordination of the plots suggested a vegetational continuum in response to topographic gradient.

Size-class distribution of the beech indicated a unimodal pattern with underrepresentation exhibited in the smallest size-class; however, variation among sampling locations might be present. It also suggested that Taiwan beech was likely to be shade-intolerant.

In terms of physiognomy and generic composition, closest affinity appeared to be with the ***Fagus lucida*** forest of Mt. Fangchingshan in southeastern China.

INTRODUCTION

To the south of Taipei, and some 30 kilometers from the city limits, lies the tract of land known as the Lalashan Nature Reserve (Fig. 1). It contains 6390 hectares, and is roughly rectangular in shape (between 24°41′ and 24°50′ north latitude and 121°23′ and 121°30′ east longitude).

The Reserve was established in 1975 by the Forestry Bureau for two reasons, namely, because it contains many giant Taiwan red cypress (*Chamaecyparis formosensis* Matsum.), and also because the Taiwan beech (*Fagus hayatae* Palib. *ex* Hayata) is only confined to this area. As one of the major representative of the deciduous forests in Taiwan, the beech is particularly considered to be of ecological interest.

Very few works have been conducted for Taiwan beech. General description of the area, and of its vegetation, has been given by Tsoong and Chang (1954). Later. Severinghaus and DeVol (1974) pointed out the distribution of Taiwan

(1) 謝長富, Department of Botany, National Taiwan University, Taipei, Taiwan, ROC.

beech on Lalashan. Liu and Su (1972) presented some quantitative information on the beech forest of Takaishan. Shen and Boufford (1988) mentioned the similarities between *F. hayatae* and *F. lucida* of mainland China, and this new discovery represents a disjunction of about 1400 km between the two populations. No attempt has been made to compare the vegetation and ecology of these two disjunct areas.

The present paper will discuss the beech forest first in terms of flora or species composition, and second in terms of populations and vegetation structure, and will then seek to interpret the status of forest regeneration.

STUDY AREA

The study area is extremely rugged with steep slopes (Fig. 1). Elevations range from a low of approximately 300 m to 2129 m at the summit of Tamanshan. The main ridge runs in the north from Chulushan southwestward to Lupinshan, thence stretching in a northwest-southeast direction to the south limit of the reserve.

Within the reserve, *Fagus hayatae* occurs in relatively pure stands along ridges at elevations of ca. 1300 to 2000 m (Fig. 2). They extend about 18 km from Chulushan to Lalashan. The upper and lower portions of these stands are mingled with species of warm-temperate rain forest in the north and warm-temperate montane coniferous forest in the south respectively. Some plantations of Japanese fir (*Cryptomeria japonica*) approach the ridge in the northern part.

The climate is temperate, with a strong monsoon influence. Because the Snow Mountain Range blunts the impact of wind from the south-west, the force of the north-east monsoon is greater. The following meteorological records (1954–1983) are from the Fushan weather station, which is about 5 km east of and 1,322 m below Takaishan:

Mean annual temperature ....20.9°C
Mean January temperature...........................12.3°C
Mean July temperature...............................28.5°C
Mean maximum temperature (Aug.) ....39.5°C
Mean minimum temperature (Jan.)...................−2.0°C
Mean annual precipitation...........................2827 mm
Mean relative humidity...............................87%

There is no dry season, but the heavy rains are frequent from June to October. Temperatures and precipitation are somewhat lower in the higher part of the Reserve. The ridges and summits are always wrapped by clouds, even in rainless days. During winter months, light snowfalls are not common.

Most of the rocks within the range of beech forest belong to the Upper Wulai Group and the Lower Hsichih Group (Tang and Yang, 1976). They are sedimentary rocks, and can be separated from the base to top into Tsuku-Kankou Formation, Tatungshan Formation, Makang Formation, Mushan Formation, and Taliao-Kungkuan Formation (Fig. 3). The Upper Wulai Group is lithologically composed prevailingly of indurated shale with closely spaced interbeds of thin-bedded fine-grained sandstones. While the Lower Hsichih Group is represented chiefly by alternations of sandstone, shale, and claystone.

The soils at the study sites are well drained, and classified mainly as

Placoaquod and Dystrochrept (Hsieh and Chen, 1987). They are strongly acidic (pH 3.2–4.2). The depths of the soils vary from 50 to 80 cm. Organic matter contents are between 1 and 5%. Their textural composition can be classified as clay and silty clay.

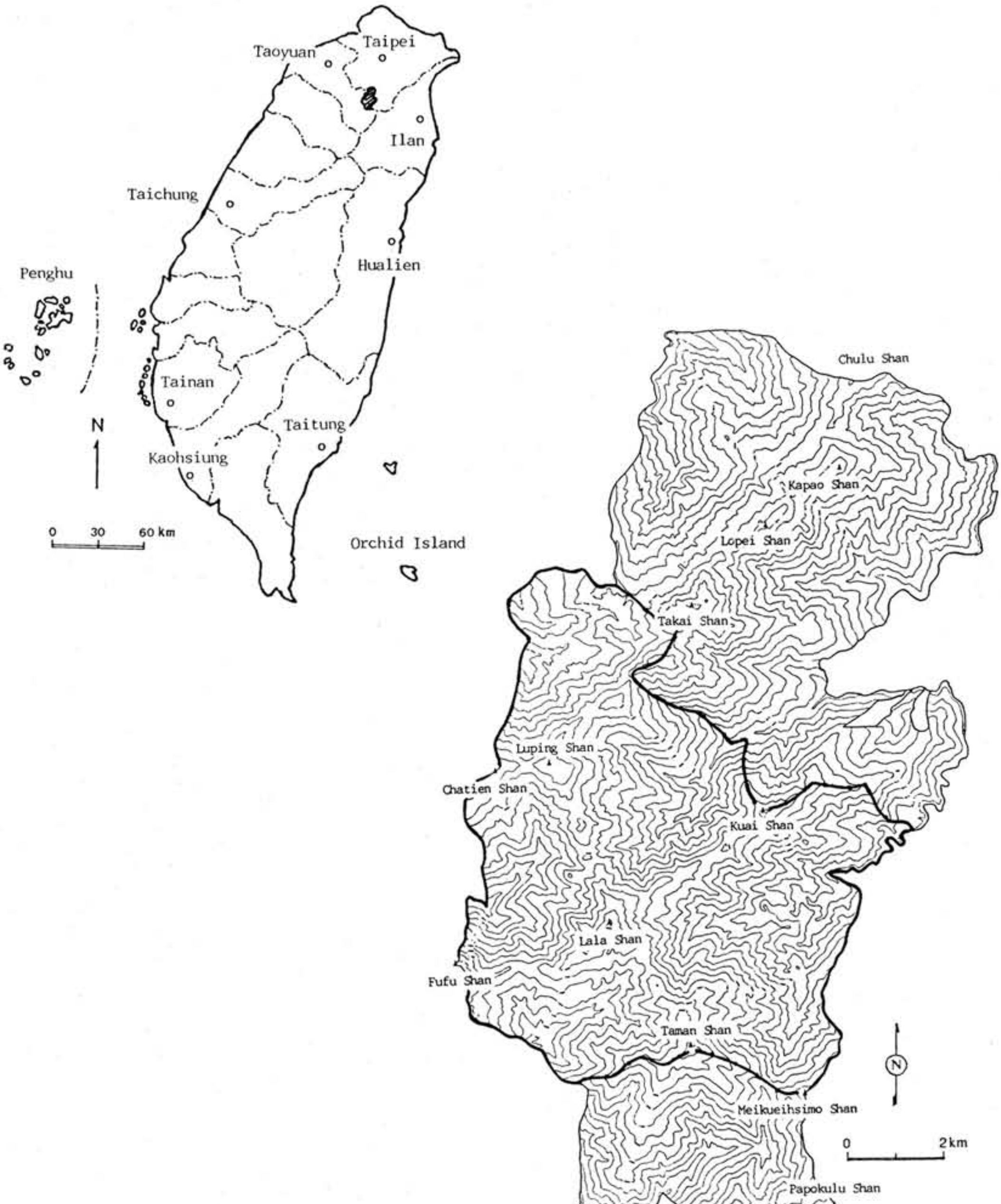


Fig. 1. Location of the study area. Enclosed area is Lalashan Nature Reserve.

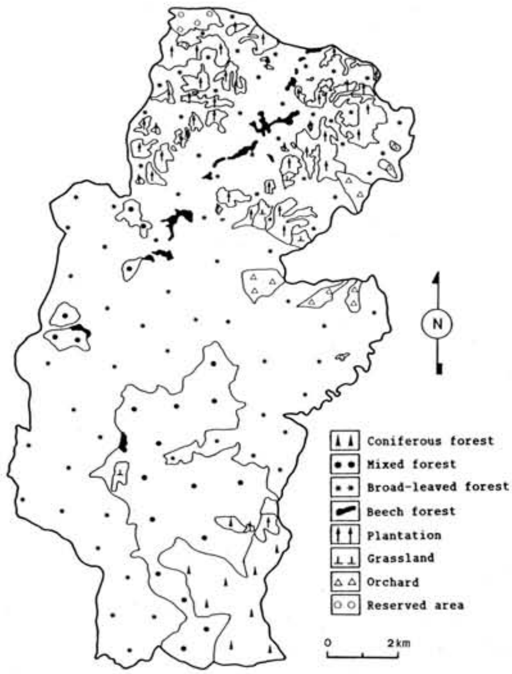


Fig. 2. Vegetation map showing the distribution of ***Fagus hayatae***.

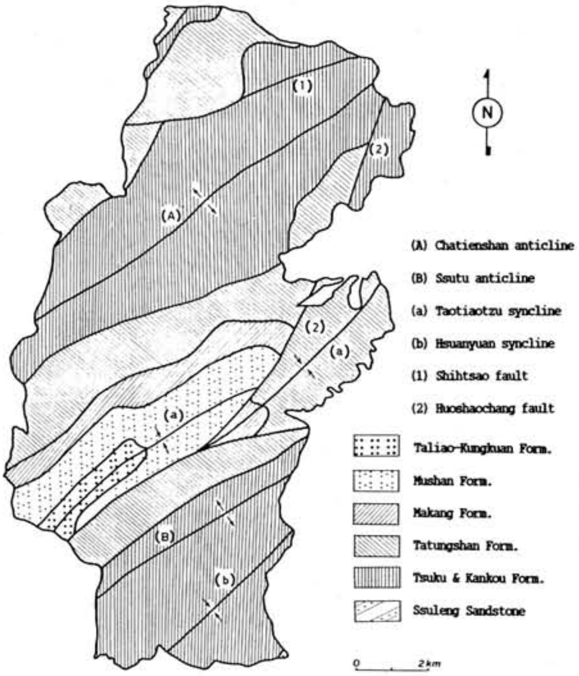


Fig. 3. Geological map of the study area.

METHODS

Field sampling

A total of 32 quadrats were studied during the July to October periods of 1986 and 1987. They were chosen to represent the north (Lopeishan), middle (Takaishan), and south (Lalashan) range of the beech forest (Fig. 4). Elevation ranges were 1400-1500, 1500-1700, and 1700-1950 m respectively. The quadrats were

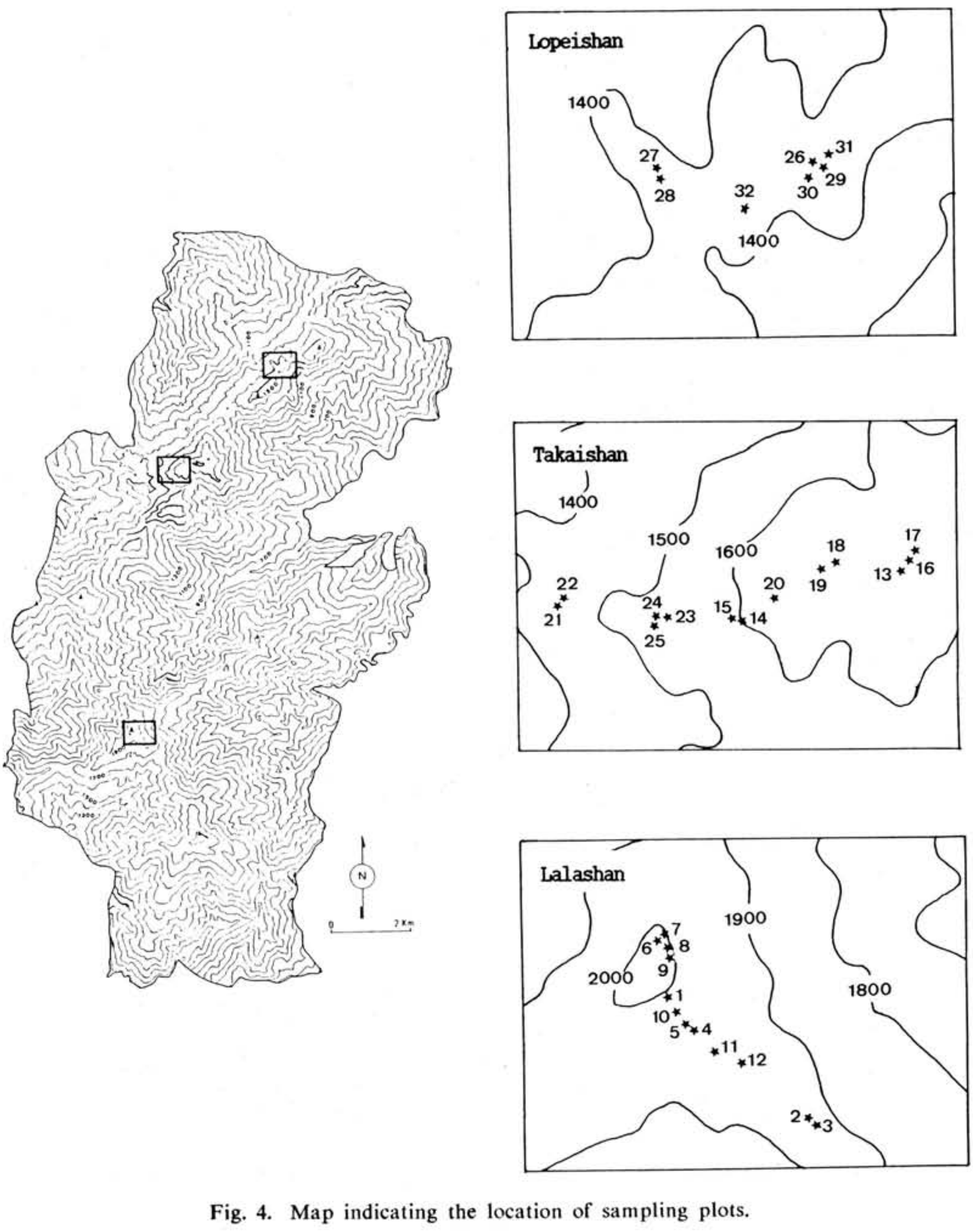


Fig. 4. Map indicating the location of sampling plots.

usually distributed evenly along the trails, and those of difficult access were excluded. Each quadrat is 10×10 m in size.

For the overstory, number of each tree species was recorded, and their height and diameter at breast height (DBH) were measured. Ages were estimated as the number of rings on cores. For the understory, percentage cover estimates were made for each species.

Data analyses

For ease of representation, the number of species considered in the classification and ordination process was reduced to a more manageable size. The reduction was made objective and quantitative through the use of the relative importance of each species. Those species of higher rank were used in subsequent analyses.

Important value was represented as overall basal area (in square meters per hectare) or cover value for species in understory. Species richness and two indices of diversity were calculated, the Shannon-Wiener index H (Margaleff, 1958) and the Simpson index C (Simpson, 1949). Size-class analysis of the beech was conducted using successive 5 cm increments beginning with the 0.5–5 cm size-class.

Classification and ordination of the common species were also undertaken, with the objective of recognizing trends of variation in the forest and examining groupings of interspecific relationships. For cluster analysis, sum of square agglomerative clustering (Ward, 1963; Orlo'ci, 1967) was performed on Euclidean distances. The advantages of this clustering algorithm are discussed by Goodall (1978) and Milligan (1980). After initial classification, the data were further examined with reciprocal averaging (Hill, 1973, 1974; Gauch *et al.*, 1977).

RESULTS

Floristics and diversity

A total of 172 species of vascular plants were found in the 32 quadrats. In terms of major growth forms, there were 57 trees, 26 shrubs, 17 scandent shrubs and vines, and 72 herbs and pteridophytes.

The total basal area of the trees recorded in the quadrats was 56.56 m^2/ha which corresponded with 0.57% of the quadrat area. The overstory was mainly composed of beech. It contributed more than 76% of the total basal area. Other trees whose basal area was more than 1% of the total were *Chamaecyparis formosensis*. *Tsuga chinensis* var. *formosana*, *Rhododendron formosanum*, *Enkianthus perulatus*, *Symplocos sumuntia*, and *Symplocos lancifolia* (Table 1). Species of high cover under the tree layer were *Yushania niitakayamensis* (dwarf bamboo), *Eurya crenatifolia*, *Berberis kawakamii*, *Plagiogyria glauca* var. *philippinensis*, *Liriope minor*, *Ardisia japonica*, and *Plagiogyria euphlebia*.

Twenty-six species, including 14 trees, 6 shrubs, 2 scandent shrubs, and 4 herbs and ferns, occurred in more than 50 percentage of the quadrats. *Chamaecyparis formosensis* and *Tsuga chinensis* var. *formosana* were only locally abundant, occurring in less than 10% of the quadrats (Table 1).

The mean number of species recorded per quadrat is 39, and ranges from 19 to 59 (Table 2). In the north, the beech forests average more species than those in the south. Tree densities range from 2100 to 11100 stems/ha (averages=5700), and is somewhat higher in Takaishan area. Diversity of trees with DBH>1 cm was calculated as Shannon-Wiener index (2.34) and Simpson index (0.12). These two measures vary in a somewhat parallel manner.

Table 1. Species with higher important value and frequency. Important value is defined as overall basal area for tree species and percentage cover for other species

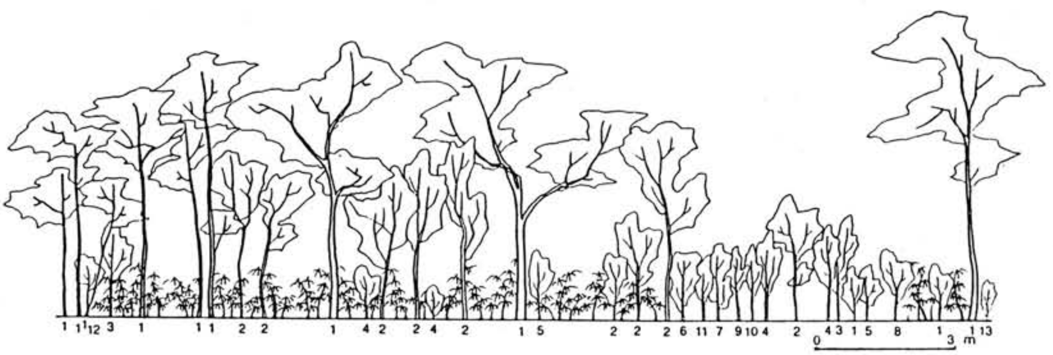
	Species	I. V.	Frequency (%)
Trees			
1	*Fagus hayatae*	43.46	100.0
2	*Chamaecyparis formosensis*	2.68	9.4
3	*Tsuga chinensis formosana*	2.16	6.3
4	*Rhododendron formosanum*	1.94	31.3
5	*Enkianthus perulatus*	0.88	46.9
6	*Symplocos sumuntia*	0.70	56.3
7	*Rhododendron hyperythrum*	0.55	31.3
8	*Cyclobalanopsis longinux*	0.51	34.4
9	*Osmanthus heterophyllus bibracteatus*	0.37	90.6
10	*Dendropanax pellucidopunctata*	0.30	71.9
11	*Cyclobalanopsis acuta paucidentata*	0.28	75.0
12	*Photinia parvifolia*	0.23	90.6
13	*Camellia tenuifolia*	0.20	78.1
14	*Ilex pedunculosa*	0.19	59.4
15	*Daphniphyllus glaucescens oldhamii*	0.19	68.8
16	*Persea thunbergii*	0.18	21.9
17	*Prunus takasagomontana*	0.15	15.6
18	*Neolitsea acuminatissima*	0.11	78.1
19	*Viburnum furcatum*	0.10	87.5
20	*Syzygium buxifolium*	0.08	3.1
21	*Symplocos lucida*	0.07	12.5
22	*Neolitsea acutotrinervia*	0.07	40.6
23	*Cleyera japonica*	0.06	59.4
24	*Illicium arborescens*	0.06	50.0
25	*Acer palmatum pubescens*	0.06	15.6
26	*Ternstroemia gymnanthera*	0.05	34.4
Shrubs			
27	*Yushania niitakayamensis*	2150.00	93.8
28	*Eurya crenatifolia*	52.20	87.5
29	*Berberis kawakamii*	37.00	37.5
30	*Viburnum taiwanianum*	22.00	75.0
31	*Pieris taiwanensis*	21.80	50.0
32	*Skimmia reevesiana*	21.20	68.8
33	*Damnacanthus indicus*	14.40	15.6
34	*Sarcandra glabra*	11.80	18.8
35	*Rubus shinkoensis*	8.10	56.3
36	*Blastus cochinchinensis*	6.80	25.0
37	*Damnacanthus angustifolius stenophyllus*	5.80	15.6
38	*Rhamnus crenata*	5.40	15.6
Scandent shrubs or vines			
39	*Stauntonia hexaphylla*	13.60	84.4
40	*Smilax arisanensis*	10.80	71.9
41	*Tripterospermum lanceolatum*	7.40	40.6
42	*Hydrangea anomala*	5.20	6.3
Herbs and ferns			
43	*Plagiogyria glauca philippinensis*	443.20	93.8
44	*Liriope minor*	97.80	46.9
45	*Ardisia japonica*	62.80	65.6
46	*Plagiogyria dunnii*	40.80	34.4
47	*Plagiogyria euphlebia*	23.00	53.1

Table 1. (Continued)

	Species	I. V.	Frequency (%)
48	*Coptis quinquefolia*	16.60	62.5
49	*Selaginella doederleinii*	15.60	21.9
50	*Pilea distachys*	13.00	21.9
51	*Carex filicina pseudo-filicine*	7.20	43.8
52	*Pellionia arisanensis*	7.00	6.3
53	*Asarum infrapurpureum*	6.60	28.1
54	*Lycopodium serratum*	5.60	12.5
55	*Calanthe reflexa*	5.60	12.5
56	*Sarcopyramis delicata*	5.40	40.6
57	*Alpinia intermedia*	5.40	9.4
58	*Christella acuminata*	5.00	3.1

Table 2. Measures of species number, density, Shannon-Wiener index (H), and Simpson index (C)

Quadrat	SP (Total)	SP (Tree)	Density (Stems/ha)	Diversity (H)	Diversity (C)
1	19	11	3200	2.17	0.11
2	31	15	2600	2.25	0.15
3	24	15	2100	2.47	0.08
4	24	15	3200	2.40	0.09
5	29	11	4100	2.18	0.11
6	26	8	2300	1.74	0.19
7	30	11	3400	1.97	0.16
8	34	16	4400	2.60	0.06
9	25	10	4600	1.92	0.17
10	25	14	3900	2.29	0.11
11	31	15	4300	2.40	0.09
12	23	12	2100	2.36	0.06
13	38	18	5500	1.93	0.28
14	44	17	7000	2.08	0.13
15	45	18	10000	1.92	0.13
16	31	12	4300	2.18	0.11
17	42	16	4300	2.52	0.08
18	37	14	10400	2.25	0.12
19	37	12	6400	2.09	0.15
20	43	19	7300	2.17	0.19
21	49	24	11000	2.80	0.07
22	44	22	8800	2.65	0.09
23	42	16	10300	2.13	0.16
24	43	22	7500	2.56	0.10
25	45	19	9100	2.56	0.08
26	53	18	7600	2.23	0.16
27	53	24	3100	3.00	0.04
28	59	24	7000	2.83	0.06
29	48	19	4300	2.37	0.14
30	48	18	4500	2.10	0.22
31	56	25	7100	2.93	0.05
32	59	23	6600	2.14	0.23
Average	39	17	5697	2.32	0.12



1. *Fagus hayatae*
2. *Enkianthus perulatus*
3. *Dendropanax pellucidopunctata*
4. *Illicium philippinense*
5. *Eurya crenatifolia*
6. *Eurya glaberrima*
7. *Daphniphyllus glaucescens oldhamii*
8. *Viburnum taiwanianum*
9. *Viburnum luzonicum*
10. *Neolitsea acutotrinervia*
11. *Camellia tenuifolia*
12. *Neolitsea acuminatissima*
13. *Photinia parvifolia*

Fig. 5. Profile diagram of selected sample of beech forest in Takaishan site.

In Fig. 5 is reproduced a profile diagram of a typical part of the beech forest in Takaishan site. *Fagus hayatae* forms a relatively even canopy at 6 m. The subcanopy layer is mainly occupied by *Enkianthus perulatus*. Dwarf bamboo is abundant in understory. Saplings of different tree species show higher density in canopy opening.

Classification and ordination

The cluster analysis dendrogram is given in Fig. 6. A plot of the fusion sum of squares versus the number of groups, together with ecological considerations, suggests the recognition of 3 vegetation types.

Type 1 consists of 10 Lalashan, 6 Takaishan, and 1 Lopeishan quadrats. Its subtree stratum is characterized by *Photinia parvifolia*, *Osmanthus heterophyllus* var. *bibracteatus*, *Camellia tenuifolia*, *Viburnum furcatum*, and *Neolitsea acutotrinervia*.

Type 2 consists of 7 Takaishan quadrats. The outstanding feature of this community is the relatively abundance of *Enkianthus perulatus* and *Rhododendron formosanum* in subcanopy layer.

The third type consists of 6 quadrats from Lopeishan area. *Berberis kawakamii* and *Damnacanthus indicus* are considered the characteristic shrubs for this community type, and *Plagiogyria glauca* var. *philippinensis* is frequently rich in herb layer.

The results of the ordination of the basal area and cover data are shown in Fig. 7. Only axes 1 and 3 are ecologically meaningful. The scattergram suggests, in general, the group structure imposed on the quadrat data by cluster analysis is reproduced well by the ordination. Along axis 1 from left to right, the quadrats tend away from higher altitude (ca. 2000 m) in the south into lower altitude (ca. 1400 m) in the north. Quadrats of the Takaishan (ca. 1600–1700 m) show their intermediate placement within the ordination. Species characteristic of warm-temperate montane coniferous forest (e. g. *Chamaecyparis formosensis*, *Tsuga chinensis* var. *formosana*, *Acer palmatum* var. *pubescens*, *Cyclobalanopsis longinux*, *Microtropis fokienensis*, etc.) are found at the right end of the first axis. On the other hand, species of the warm-temperate rain forest (e. g. *Persea thunbergii*,

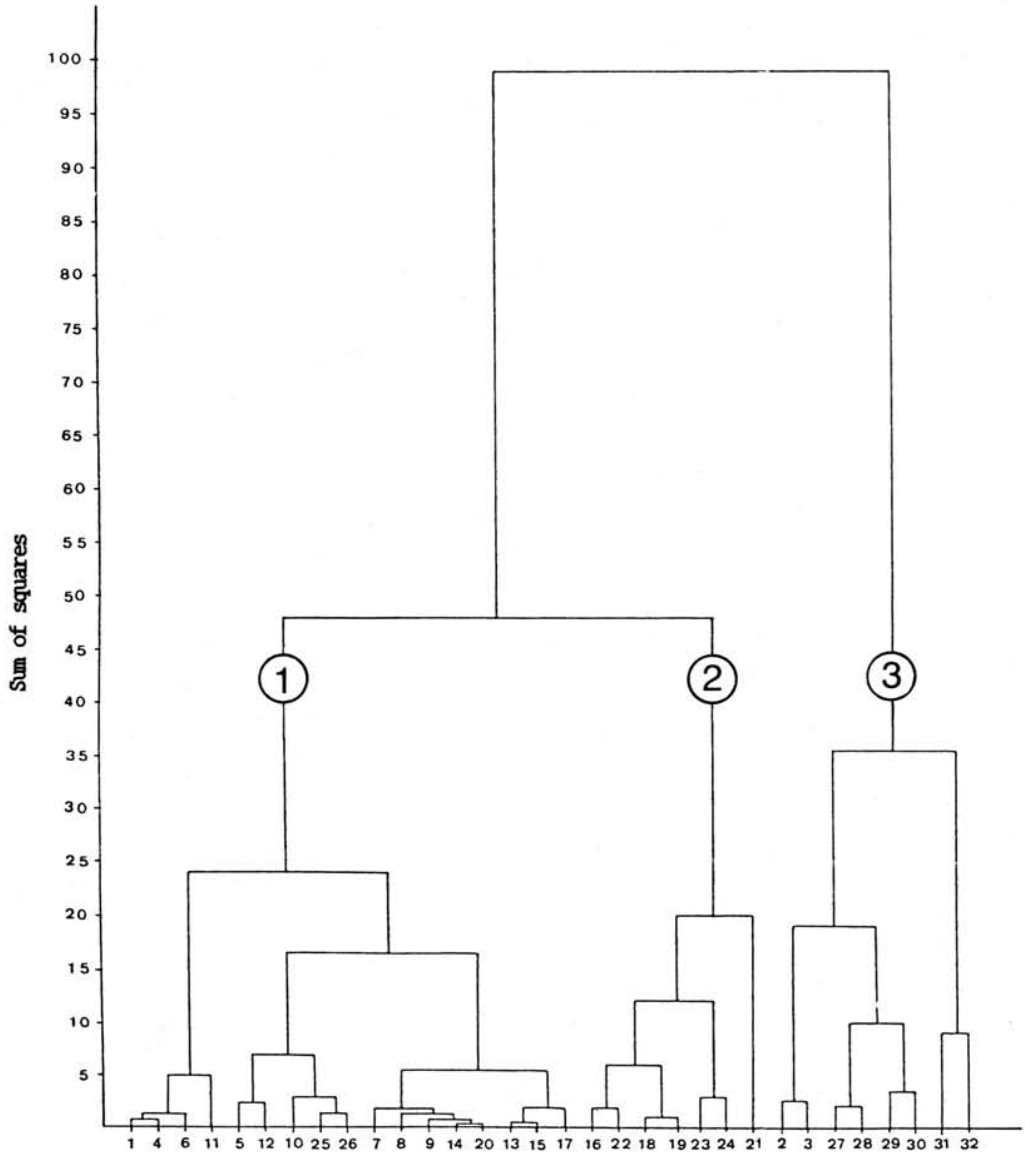


Fig. 6. Sum of squares agglomerative dendrogram of the 32 quadrats. The three vegetation types described in the text are indicated.

Symplocos lucida, Sarcandra glabra, Blastus cochinchinensis, Dendropanax pellucido-punctata, etc.) occur near the left of the scattergram. The third axis seems related to the degree of exposure. Quadrats from Takaishan (e. g. quadrat 16, 21, 22, 23, and 24) are located on the rocky summit, and are concentrated at the upper part of the scattergram. The occurrences of *Pieris taiwanensis, Syzygium buxifolium, Myrica rubra* var. *acuminata, Cleyera japonica,* and *Ternstroemia gymnanthera* contribute most of their distinctiveness.

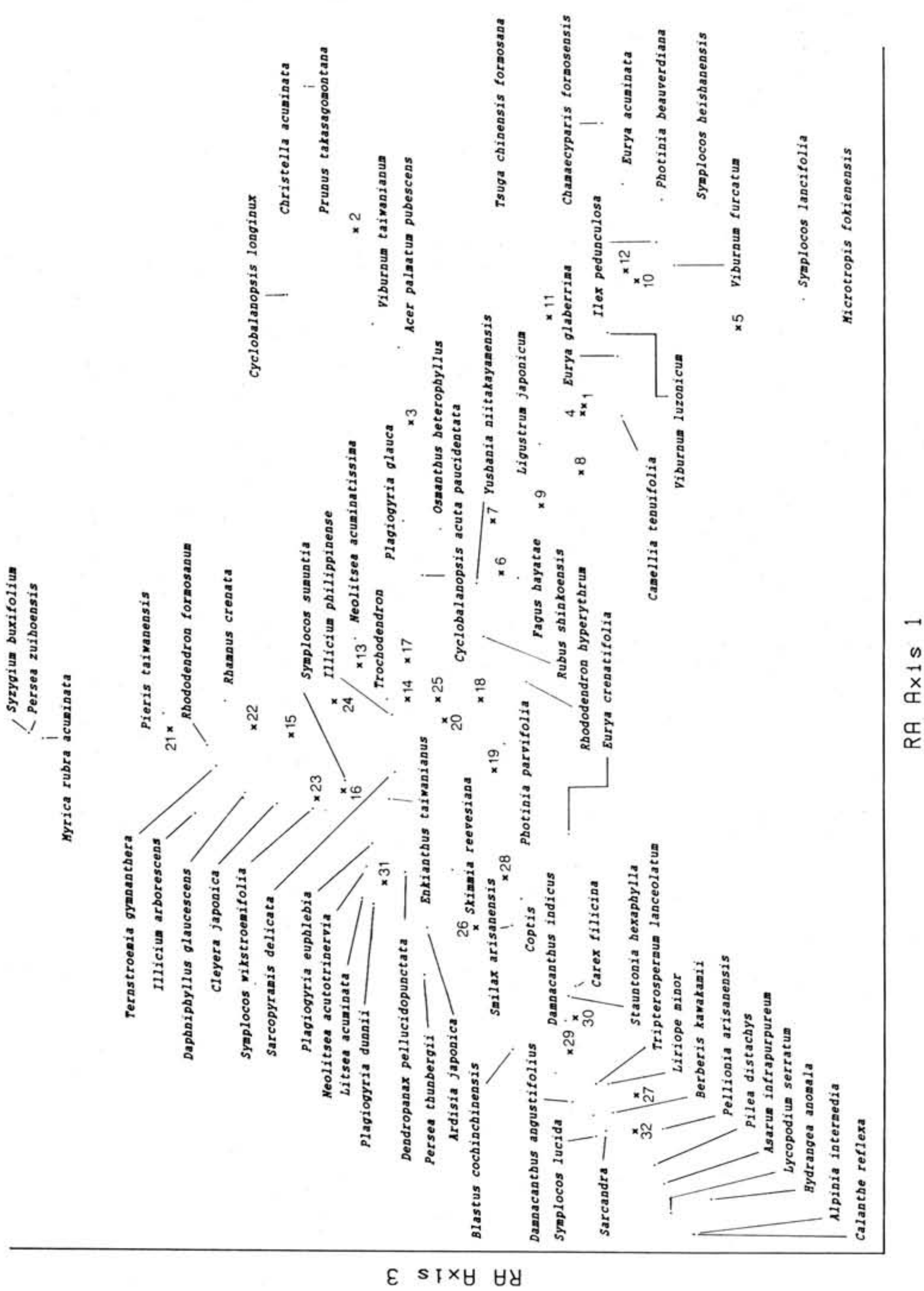


Fig. 7. Distributions of 32 quadrats and 72 species relative to the first and third axes of reciprocal averaging ordination.

Species population structure

The population structures of sufficiently abundance species (more than 50 stems) were analysed (Figs. 8 and 9). The beech sites are shown individually because it along showed significant within-species variation among sampling locations.

Size-class distribution of the beech from Takaishan (Fig. 8b) shows an unimodal pattern. The most abundantly represented size-class is not the smallest. Size-class structure is similar for the Lopeishan stand, however, the skewness of the distribution is slightly shifted to the right. By contrast, the size-class distribution of beech trees from Lalashan stand has two well-defined peaks with concentration of the greater part of the individuals (47%) in the last two size-class. The combined beech size-class at all sites is shown in Fig. 8d. In general, the pattern doesn't deviate very much from those of the Takaishan and Lopeishan stands. An underrepresentation in the smallest size-class is also remarkable.

Among other trees, two distribution patterns are evident (Fig. 9). The first pattern is well described by the negative exponential curve with considerably higher density in the lower size-class. *Enkianthus perulatus* typifies this distribution. The second shows trend similar in form to the beech. Only *Rhododendron formosanum* shows this kind of distribution.

Examination of the size-age scattergrams (Fig. 10) indicates that the variables are correlated (Lalashan: Age=7.60+2.80×DBH, R=0.91; Takaishan: Age=26.69+5.2×DBH, R=0.65), although there is considerable range in older trees. As compared to Lalashan population, the Takaishan population shows a narrow range in DBH.

Scattergrams of DBH vs. height are represented in Fig. 11. No apparent relationship exists in Takaishan population. Due to greater exposure, the trees are stunted by wind storms, and are mature at a relatively smaller height than

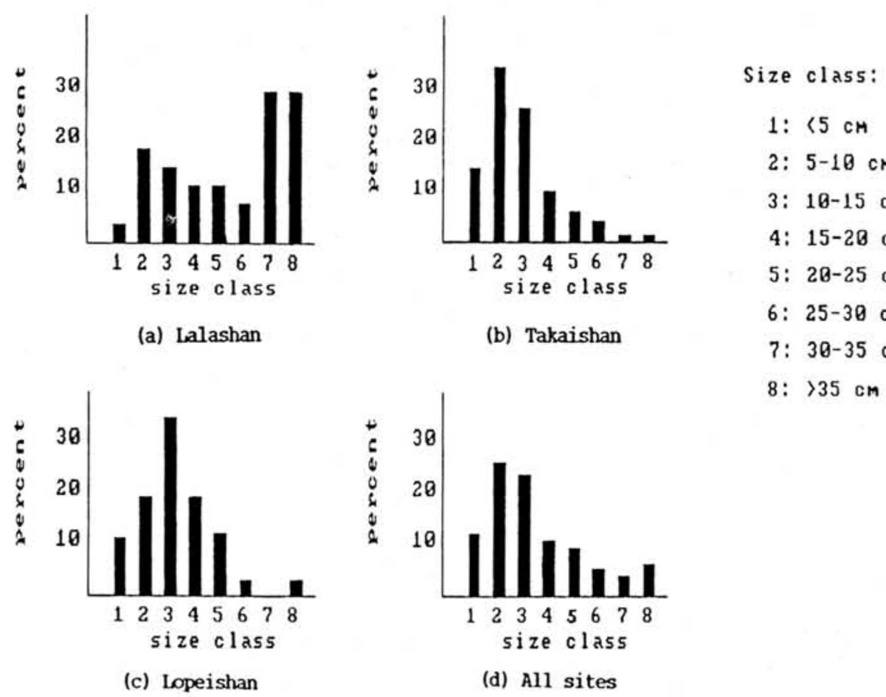


Fig. 8. Size-class distributions of the beech from three sites.

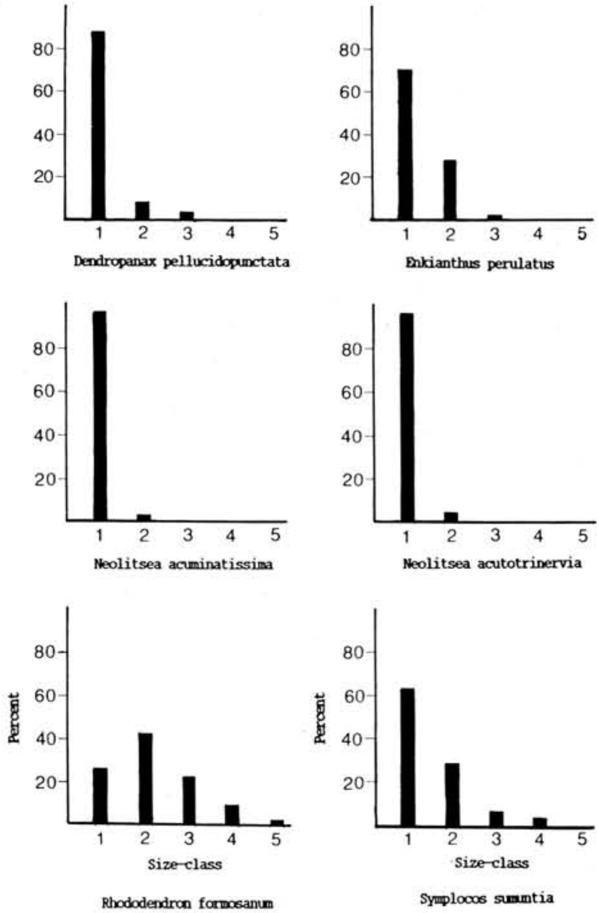


Fig. 9. Size-class distributions of selected tree species other than beech.

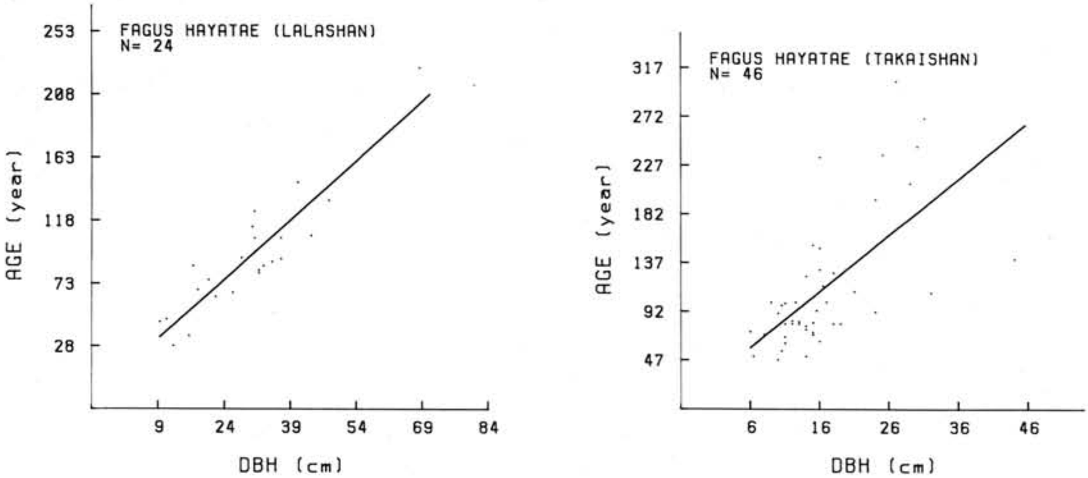


Fig. 10. Relationship of DBH to age for the beech.

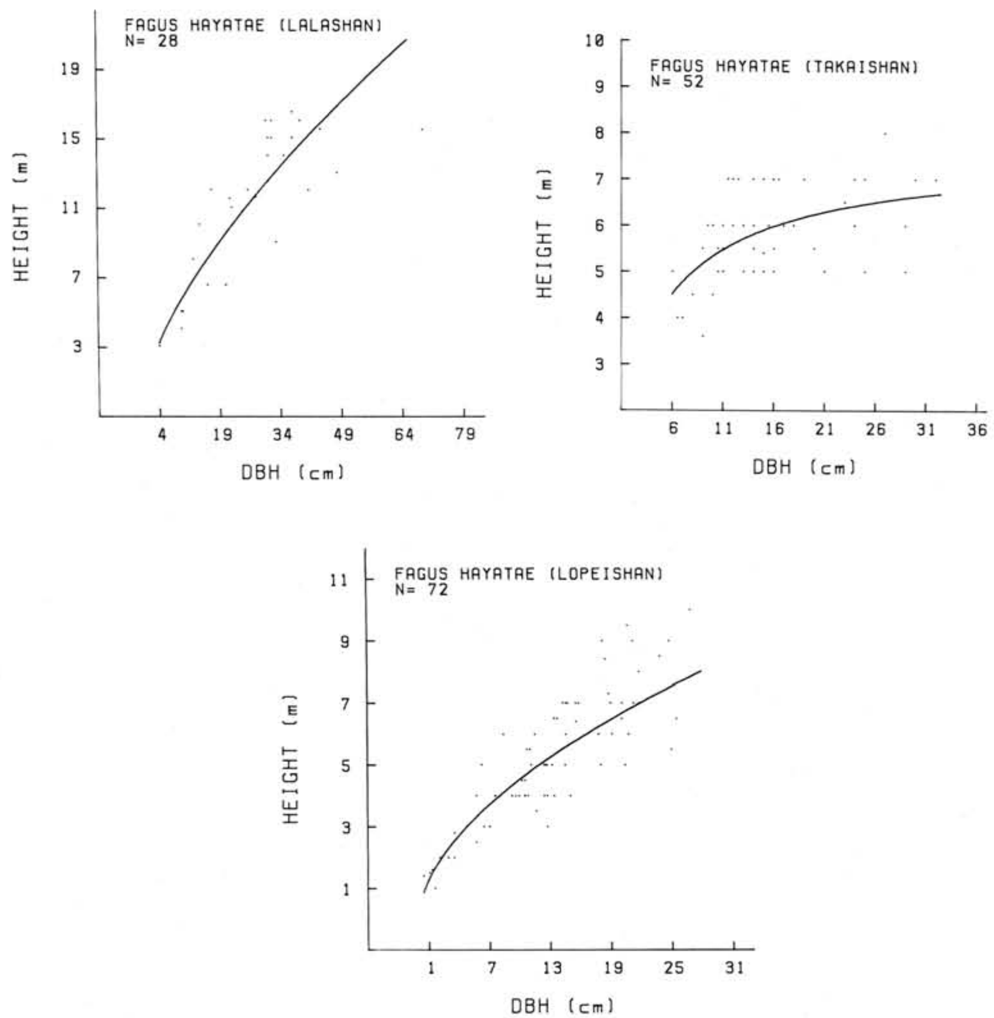


Fig. 11. Relationship of DBH to height for the beech.

other populations. By contrast, individuals of Lopeishan and Lalashan areas show a significant relationship between DBH and height (Lopeishan: Height$=e^{.23}\times \mathrm{DBH}^{.55}$, R=0.90; Lalashan: Height$=e^{.21}\times \mathrm{DBH}^{.67}$, R=0.89).

DISCUSSION

Floristic affinities to other beech forests

Previous descriptions of the beech forests in southeastern China (Tsien *et al.*, 1975) and Japan (Numata *et al.*, 1972; Hara, 1983; Hakusima, 1988) were examined to assess their floristic composition and dominance hierarchies in relation to those of the beech forest in Taiwan.

Patterns of *Fagus*-dominated communities have been described in Mt. Fanchingshan of Kweichow Province in southeastern China. The beech forest is regarded as one vegetation type of the subtropical montane deciduous braod-leaved forest. It is distributed at elevations of 1100 to 1900 m, and is characterized principally by *Fagus lucida*, with *F. engleriana*, *F. longipetiolata*, *Quercus gracilis*, *Q. stewardiana*, *Q. engleriana*, *Enkianthus serrulata*, and *Rhododendron hypoglaucum* as secondary dominants. The subcanopy layer is moderately developed, and the frequent species include *Actinodaphne reticulate*, *Camellia cuspidata*, *Eurya brevistyla*, *E. aurea*, *Acer davidii*, *Illicium griffithii*, *Ilex trifolia*, and *Lindera merriliana*. In shrub layer, the dwarf bamboo (*Sinarundinaria ohungii*) grows luxuriantly and is a total dominance. As compared with Table 1, the similarities in physiognomy and generic composition are remarkable. However, the comparison of the forest habitat shows that the annual precipitation is much lower in Fanchingshan (960–1267 mm), and the distribution of *F. lucida* is mainly confined to the southeastern slopes.

Similarities between beech forest in Taiwan and Japan are more limited than is the case with China. However, there are also compositional identities at the generic level, essentially most of the genera mentioned above. In Japan, Hara (1983) reported basal area value of 29.73 m/ha and density value of 2013 stems/ha for Japanense beech forest in Tohoku District. Compared to these values, Taiwan beech has much higher values (56.56 m/ha and 5700 stems/ha), due to a relatively high number of thick trees on the ridges.

No attempt was made to compare the beech forests between Taiwan and North America. However, the dense drarf bamboo understory in Taiwan, China, and Japan appears to have no analogies anywhere in North America.

Population structure

It has been mentioned that the regeneration of beech in Taiwan was attended with considerable difficulties (Liu and Su, 1972). Although nuts were produced in moderate to fair quantity every other year and abundantly at longer intervals, yet observations showed that seedlings might not appear as a result. The scattergrams of age vs. DBH (Fig. 9) doesn't show any pattern like a wide range in age for a narrow range in DBH. Nor the radial growth shows the evidence of release from suppressed growth (as seen in wider annual rings). It, therefore, suggests that Taiwan beech seems likely to be shade-intolerant, and regeneration may be excluded until canopy openings are formed.

The size-class distribution pattern of the beech in Takaishan stand, showing more abundant individuals in smallest class than any other sites, can be attributed to the greater potential of the stand for gap creation (e. g. shallow soils, very narrow ridges, emergent summits, etc.).

The main ridge of the Lalashan Nature Reserve forms the highest barrier in northern Taiwan. It faces strong sweeps of northeastern monsoons in winter and typhoons in summer. Based on size, number and frequency of the gaps formed, the size-structure distributions of the beech forests may vary from one major peak to irregular pattern.

It appears from the results of this study that Taiwan beech is probably a senescent species. It has no ability to compete with other shade-tolerant canopy species of broad-leaved forests on the slopes. The absence of seedlings and saplings under close canopies suggests a gap-phase mode of regeneration.

ACKNOWLEDGEMENTS

The writer desires here to acknowledge his indebtedness and to express his appreciation to the Council of Agriculture and Council of Economic Planning and Development, Executive Yuan.

LITERATURE CITED

GAUCH, H. G., R. H. WITTAKER and T. R. WENTWORTH, 1977. A comparative study of reciprocal averaging and other ordination techniques. J. Ecol. **65**: 157-174.

GOODALL, D. W., 1978. Numerical classification. *In* Classification of Plant Communities. Edited by R. H. Whittaker. Junk. The Hague. pp. 247-286.

HAKUSIMA, T., 1988. The ecology of a beech forest on Mt. Sanpoiwadake, Hakusa National Park, Japan. I. Braun-Blanquet, TWINSPAN and DCA analysis. Ecol. Res. **3**: 89-100.

HARA, M., 1983. A study of the regeneration process of a Japanese beech forest. Ecol. Rev. **20**: 115-129.

HILL, M. O., 1973. Reciprocal averaging: an eigenvector method of ordination. J. Ecol. **61**: 237-249.

________, 1974. Correspondence analysis: a neglected multivariate method. J. Royal Statist. Soc., Series C. **23**: 340-354.

HSIEH, C. F. and Z. S. CHEN, 1987. Developing an Ecological Data System for Nature Reserves. Ecological Research Series No. 26. Council of Agriculture.

LIU, T. S. and H. J. SU, 1972. Synecological survey on the summer-green forest of North Chia-tien Mountains. Bulletin of Taiwan Museum. **15**: 1-16.

MARGALEFF, D. R., 1958. Information theory in ecology. Yearbook of the Society for General Systems Research. Vol. **3**: 36-71.

MILLIGAN, G. W., 1980. An examination of the effect of six type of error perturbation on fifteen clustering algorithms. Psychometrika **45**: 325-342.

NUMATA, M., A. MIYAWAKI and D. ITOW, 1972. Natural and seminatural vegetation in Japan. Blumea **20**: 435-481.

ORLO'CI, L., 1967. An agglomerative method for classification of plant communities. J. Ecol. **55**: 193-206.

SEVERINGHAUS, S. and C. E. DEVOL, 1974. Notes on the distribution of Taiwan beech. Taiwania **19**: 235-237.

SHEN, C. F. and D. E. BOUFFORD, 1988. *Fagus hayatae* (Fagaceae)—A remarkable new example of disjunction between Taiwan and central China. J. Jap. Bot. **63**(3): 96-101.

SIMPSON, E. H., 1949. Measurement of diversity. Nature **163**: 688.

TANG, C. H. and C. T. YANG, 1976. Mid-Tertiary Stratigraphic break in the northeast Hsuehshan Range of Taiwan. Petroleum Geology of Taiwan **13**: 139-147.

TSIEN, C. P., T. S. YING, C. S. CHANG and T. L. MING, 1975. The distribution of beech forests of Mt. Fanchingshan and its significance in plant geography. Acta Phytotaxonomica Sinica **13**(1): 5-18.

TSOONG, P. C. and L. M. CHANG, 1954. A preliminary survey of the vegetation of the South Cha-tian Mountains. Bulletin of Taiwan Forestry Research Institute, No. 41.

WARD, J. H., 1963. Hierarchical grouping to optimize an objective function. American Statistical Association Journal **58**: 236-244.

臺灣山毛櫸森林之組成與結構

謝 長 富

摘 要

臺灣山毛櫸森林爲拉拉山保護區最具特色之生態體系，屬落葉林。其分佈北起逐鹿山海拔 1,350 公尺之稜線，向西南延綿經喀博山、羅培山、塔開山、至盧平山，再朝南延伸至拉拉山。一般多生長於稜線上，數量上以塔開山以北爲多。爲了解山毛櫸森林之組成結構，於其分佈區之北、中、南三處設置32樣區，每一樣區爲 100 平方公尺。分別調查各樣區內之植物種類、植株數目、胸高直徑及百分比覆蓋度，並鑽取材心以測定年齡。所得資料經分析後顯示山毛櫸森林是由 172 種所組成其中以山毛櫸佔絕對優勢，其他較常出現的種類有臺灣杜鵑、日本吊鐘花、尾葉灰木、紅星杜鵑、錐果櫟及異葉木犀。林下植物以玉山矢竹及臺灣瘤足蕨之覆蓋度最大。各樣區出現之種數自 19～59 種，喬木株數自 8～25 株。Shannon-Wiener Index 介於 1.74 與 2.93 之間，平均爲 2.32。Simpson's Index 介於0.05 與 0.28之間，平均爲 0.12。對應分析 (Averaging reciprocal analysis) 的結果顯示海拔高度是影響山毛櫸森林組成之最重要環境因子。最小變異分析法 (Minimum variance analysis) 的結果可將 32 樣區劃分爲二主要社會類型。第一類型以塔開山及拉拉山之樣區爲主，另一類型以羅培山之樣區爲主。山毛櫸樹幹大小結構隨區域而異。拉拉山區以大樹較多，塔開山及羅培山之植株偏小，幼樹所佔比例較拉拉山爲大。羅培山山毛櫸年齡結構之分析顯示山毛櫸森林是由不同年齡之植株所組成，但幼齡植株偏低。