THE SECONDARY FORESTS OF YENLIAO AREA

CHANG-FU HSIEH, SHING-FAN HUANG
and TSENG-CHIENG HUANG

Abstract: The floristic differences found in the secondary forests of the Yenliao area were sampled by the placement of 35 quadrats of 10 × 10 m over a wide range of habitats. The present study was undertaken to (1) use both clustering and ordinations to elucidate vegetational structure and community relationships; (2) determine the principal factors controlling or closely related with forest composition; (3) evaluate the successional status of the forests.

About 221 species were encountered. Vascular species richness per quadrat averaged 50. The Shannon-Wiener diversity measure of the tree stratum averaged 2.56 (natural log) and Simpson's index (complement) averaged 0.92. Dominance is shared by *Ardisia sieboldii, Ficus virgata, Cleyera japonica, Ficus fistulosa, Cyclobalanopsis glauca, Schefflera octophylla, Glochidion rubrum,* and *Persea thunbergii.*

Three major community types were defined using minimum variance cluster analysis with basal area and species cover data. The results of reciprocal averaging (RA) and principal component analysis (PCA) indicated a strong response in both quadrat and species characteristics to topographical, moisture, and oceanic complex gradients.

Analysis of species compositional change across a progression of diameter-based size-strata has been used to reveal the successional relationships which exist between species of tree stratum. It shows a clear trend toward dominance by *Bridelia balansae, Persea thunbergii, Ardisia sieboldii* and *Schefflera octophylla* in the near future.

Besides, the relative density data for each species' size class were determined, and three population structure patterns were recognized.

INTRODUCTION

The Yenliao Area is located in the northeastern part of Taiwan (Fig. 1). Physiographically it is within the region known as the Ayuh Slate Mountains (Lin, 1957). The area is bounded on the east by the Pacific Ocean, and on the north and south by the Shihting and Shuangchi Rivers respectively. It is topographically subdivided into two portions. The eastern part comprising about one third of the total area is a narrow alluvial plain (300-500 m wide) laid along the seashore. The western part is hilly and has elevation up to 200 m toward the western border. The main hill ridge runs almost in an NW direction. The slopes form a large portion of the area of the hill region; it has been estimated that most of the surface has less than 30 degrees of slope. Yunliaochi is a small short stream in the middle of the study area flowing into the Pacific Ocean.

The rocks of this region belong to the Upper Wulai Group of possible Oligocene age (Tang and Yang, 1976). They are separated into two Formations, the Tatungshan Formation (dark

(謝長富、黃星凡、黃增泉) Department of Botany, National Taiwan University, Taipei, Taiwan, ROC.

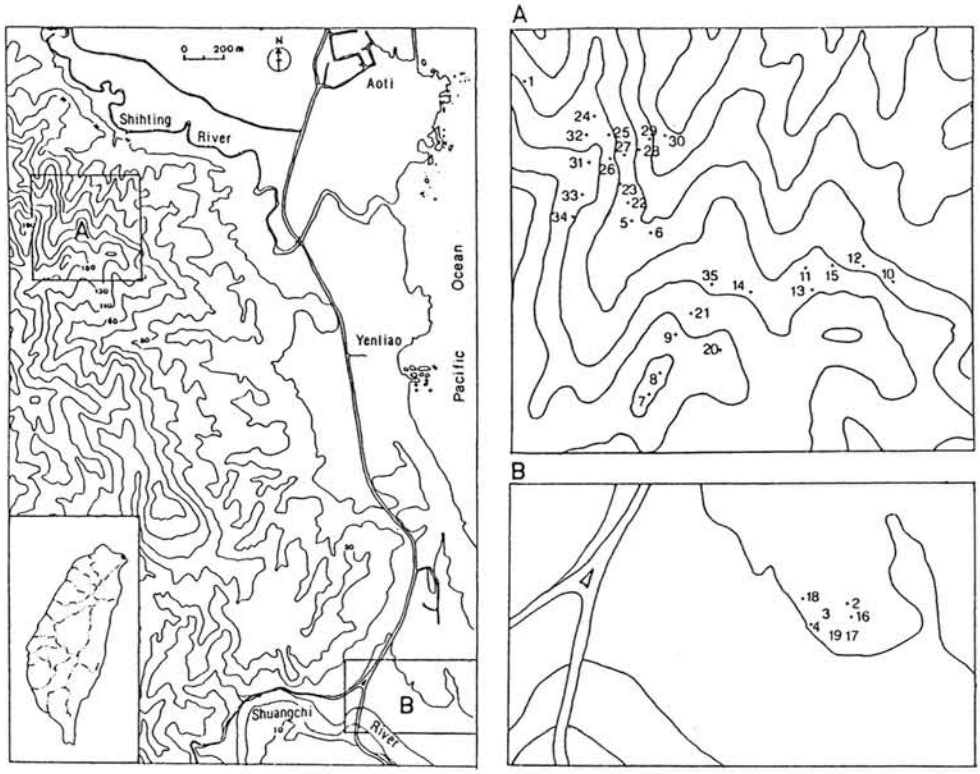

Fig. 1. Map of the Yenliao area, showing locations of the 35 quadrats.

gray shale locally with abundant concretions) to the north of Pawtaishan and the Makang Formation (gray to light gray sandstone interbedded with dark gray shale) to the south. The Tatungshan Formation extends northward to the Shihting River, where it is cross-cut by the Hsinliaotzu thrust fault.

The soil of the hill region has been classified as Haplaudalfs and Arents, and are characterized as argillic on gentle slopes and loamy on very steep and unstable slopes (Su *et al.*, 1987). The soils are yellowish brown to dark brown in color, and strongly acidic in reaction.

The climate of the study area is characterized by frequent rains in the winter. Meteorological records from the nearby TAI Power weather station (from 1966 to 1971), indicated that the average annual rainfall was 2778.7 mm, with average monthly precipitation vary between 66.1 and 494.6 mm. January and July mean temperatures were 15.1 and 28.4°C respectively; the mean annual temperature was 21.9°C.

Due to the long history of human occupy and cultivation, the native vegetation of this area has almost been eliminated. It followed that *Phyllostachys makinoi, Acacia confusa* and *Pinus luchuensis* were abundantly planted on the hill region; rice was the main crop in alluvial plain; semi-primeval and secondary forests only remained fragmentarily along stream valleys and on the ridges.

Recently the planning of the Fourth Nuclear Power Plant along Yenliao coastal region prompted the Atomic Energy Council to support several diverse research studies on the area. These included investigations on vegetation, fauna and culture (Su *et al.*, 1982, 1986, 1987).

The present paper is the outcome of the continuation of the study done in 1987. The main interest was secondary forests. The major objectives were (1) to describe the vascular floristic composition of the secondary forests; (2) to classify these forests into major community types based on variations in floristic composition; (3) to determine the principal factors controlling or closely correlated with forest composition; and (4) to assess the successional status of the forests.

METHODS

1. Sampling

All sampling was done on thirty-five quadrats (Fig. 1). Twenty-eight of these were located on the western hill region of Yenliao; the remaining seven were located near Shuangchi River. Each quadrat was 10 × 10 m in size and appeared relatively homogeneous in vegetation structure and topography.

Within each quadrat, basal area was measured for each tree individual >1 cm in diameter at breast height (dbh, 1.4 m above ground), and percentage cover data collected separately for shrub and herb species. Then the data were summed to obtained overall basal area (in square meters per hectare) and cover values of the species. These values were interpreted as important value for the following analyses. For commensurability, the data used for clustering and ordinations were transformed by the function: $X_{ij}/(\max X_i\text{-}\min X_i)$, in which X_{ij} is the data measured for the jth quadrat on the ith species; max and min specify maximum and minimum values.

In addition to these data, quadrat age was estimated from increment cores taken 1.4 m above ground from the largest trees. Topographic steepness, exposure and aspect were also recorded.

2. Data analysis

(1) Data reduction

Deletion of the rare species from a species × sample data matrix prior to multivariate analysis has been mentioned by many authors (Austin & Greig-Smith, 1968; Orlóci & Mukkattu, 1973; Goff, 1975). There are two basic motivations: (a) Most multivariate techniques are affected very little by rare species carrying such a small percentage of the overall information. (b) Deletion of rare species reduces the amount of data storage required.

For the present study, the reduction was made objective and quantitative through the use of two criteria. The first is occurrence, with those species occurring in the maximum number of sampled quadrat ranked highest. The second criterion on which species were ranked are their maximum basal area or cover values among all quadrats.

(2) Species diversity

Three aspects of alpha diversity were measured for each quadrat on tree species. The first is a direct diversity expression, S (Whittaker, 1972), and is measured as the number of species in a sample of standard size (10 × 10 m). The second is the Shannon-Wiener information index (Margaleff, 1958):

$$H = -\sum_{i=1}^{S} \frac{ni}{N} \log \frac{ni}{N}$$

S is the number of species; n is the number of individuals of a single species; and N is total number of individuals of all species. It ranges from 0, if all of the individuals are of one species to log N, if the number of species equals the number of individuals.

The third is the complement of Simpson index (Simpson, 1949; Eberhardt, 1969):

$$D = 1 - \sum_{i=1}^{S} ni(ni-1)/N(N-1)$$

This expression can be interpreted as a frequency of encounters between individuals of different species. D can range from 0 to approximate 1.

All calculations were made using data for all tree species with individuals 1 cm dbh or greater.

(3) Classification

Quadrats were classified using minimum-variance cluster analysis (Ward, 1963), a polythetic, hierarchical, agglomerative technique.

(4) Ordination

Ordination serves to summarize community data by producing a low-dimensional ordination space (of typically one to three dimensions) in which similar species and samples are close together and dissimilar entities far apart. The ordination techniques used are R-algorithm of principal component analysis, PCA (Orlóci, 1966, 1973) and reciprocal averaging, RA (Hill, 1973, 1974; Gauch *et al.*, 1977). Geometrically, both are closely related. However, for most community data sets, RA has been shown to be superior to PCA or other eigenvector techniques (Hill, 1973).

(5) Successional dynamics

For examination of compositional dynamics, the tree data for each quadrat were partitioned into three diameter size-classes: 1-6, 7-12, ⩾13 cm dbh. The dynamics index applied was similar to that of Peet and Loucks (1977). It is based on the changing importance of each species across the three size-strata. Because of the changing composition of the forests, the shade tolerant species are most frequent in the lower strata. Similarly, the shade intolerant species have their greatest importance in the larger size-classes. The average percent change in the relative density of each species between the three strata was calculated. Then each change between strata was weighted by the quantity of the species in the larger of the two strata relative to the total occurrence of the species in all quadrats.

The derivation of this dynamics index can be represented by letting RE = relative density within a stratum, with i specifying the species, j the quadrat, and k the stratum:

$$\mathrm{SUM}_{i,k} = \sum_{j=1}^{35} (\mathrm{RE}_{i,j,k}) \qquad K = 1 \rightarrow 3$$

$$\mathrm{DEL}_{i,k} = \sum_{j=1}^{35} (\mathrm{RE}_{i,j,k+1} - \mathrm{RE}_{i,j,k}) \times \frac{\mathrm{RE}_k}{\mathrm{SUM}_{i,k}}$$

$$\mathrm{DAV}_i = (\sum_{k=1}^{2} \mathrm{DEL}_{i,k}) \ / \ 2$$

If a community is undergoing compositional change, those species classified as very shade tolerant will have the maximum value. The dynamics indices were obtained for those of canopy species only.

Another approach for interpreting succession was to determined the total number of individuals of each species in all the quadrats belonging to each size class (1-7, 8-12, 13-18, 19-24, $\geqslant$25 cm dbh). The size class totals for each species were divided by the total number of tree individuals in all size classes of all species, thus giving relative density of each size class for each species. These relative density data for each species's size class provided an estimate of population structure and were used for evaluating the successional status of each species in Yenliao area.

RESULTS

1. Species richness

The vascular flora of the 35 quadrats is composed of 221 species. In terms of major growth forms, there are 70 trees, 32 shrubs or subshrubs, 40 scandent shrubs or vines, 41 herbs and 38 pteridophytes. The total vascular flora of Yenliao area includes more than 493 species (Su *et al.*, 1986).

The mean number of vascular species recorded per quadrat is 50, and ranges from 18 to 70. The percentage of quadrats in which a species was recorded present, the frequency, was calculated for all 221 species. Table 1 shows species with higher important value together with frequency. Species of higher important value include *Ardisia sieboldii, Ficus virgata, Cleyera japonica, Ficus fistulosa, Cyclobalanopsis glauca, Lagerstroemia subcostata, Acacia confusa, Sapindus mukorossi, Cerbera manghas, Glochidion rubrum, Persea japonica, Persea thunbergii, Schefflera octophylla* and *Bridelia balansae* of the tree stratum; *Psychotria rubra, Arenga engleri, Lasianthus obliquinervis, Eurya chinensis* and *Lasianthus plagiophyllus* of the shrub stratum; *Oplismenus undulatifolius, Alocasia macrorrhiza, Elatostema lineolatum var. major* and *Nephrolepis biserrata* of the herb stratum. Twenty-six species, including 10 trees, 7 shrubs, 5 scandent shrubs or vines, 2 herbs and 2 ferns, occurred in more than 50 percentage of the quadrats.

Based on the species reduction criteria stated earlier, 80 species were selected for use. These included 55 trees, 11 shrubs, 5 vines and 9 herbs.

2. Species diversity

Table 2 lists the tree species density, diversity, and total basal area for each quadrat. The

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

Species		Important value	Species		Important value
Trees			25	*Eurya chinensis*	129.0
1	*Ardisia sieboldii*	201.2	26	*Lasianthus plagiophyllus*	115.8
2	*Ficus virgata*	114.1	27	*Caesalpinia crista*	90.5
3	*Cleyera japonica*	108.9	28	*Lasianthus fordii*	54.4
4	*Ficus fistulosa*	87.5	Scandent shrubs or vines		
5	*Styrax suberifolia*	48.8	29	*Piper kadsura*	100.4
6	*Cyclobalanopsis glauca*	45.5	30	*Bauhinia championii*	64.4
7	*Lagerstroemia subcostata*	43.6	31	*Daemonorops margaritae*	51.8
8	*Acacia confusa*	39.2	32	*Derris laxiflora*	49.9
9	*Sapindus mukorossi*	35.1	33	*Psychotria serpens*	39.3
10	*Cerbera manghas*	34.6	34	*Heterosmilax japonica*	19.5
11	*Glochidion rubrum*	33.8	35	*Smilax china*	15.3
12	*Persea japonica*	33.7	Herbs		
13	*Persea thunbergii*	30.8	36	*Oplismenus undulatifolius*	112.1
14	*Schefflera octophylla*	29.3	37	*Alocasia macrorrhiza*	103.1
15	*Bridelia balansae*	28.7	38	*Elatostema lineolatum major*	40.0
16	*Pinus luchuensis*	26.1	Ferns		
17	*Radermachia sinica*	25.5	39	*Nephrolepis biserrata*	155.1
18	*Ficus microcarpa*	23.8	40	*Arachniodes rhomboides*	65.0
19	*Ficus nervosa*	21.9	41	*Pronephrium triphyllum*	61.8
20	*Wendlandia formosana*	20.3	42	*Colysis wrightii*	48.8
21	*Celtis formosana*	20.0	43	*Angiopteris lygodiifolia*	48.0
Shrubs			44	*Arachniodes pseudo-aristata*	39.0
22	*Psychotria rubra*	569.1	45	*Athyriopsis japonica*	26.1
23	*Arenga engleri*	199.4	46	*Diplazium dilatatum*	20.7
24	*Lasianthus obliguinervis*	174.5			

mean species diversity (S) of the secondary forests is 20, with the individual quadrat diversity ranging from 11 to 28. The H and D indices vary in a somewhat parallel manner, with mean H = 2.56 and mean D = 0.92. It does not seem to show a strong relationship to environmental condition. However, density and basal area vary considerably among quadrats, generally being lower in the quadrats of ravine areas.

3. Classification

The result of minimum variance cluster analysis is shown in Fig. 2. Three major clusters can be distinguished.

Cluster 1 consists of 10 quadrats (1, 23, 25, 26, 27, 29, 31, 32, 33, and 34) of the hill region. Its tree stratum is typically dominated by *Cyclobalanopsis glauca, Diospyros erianthus, Styrax suberifolia, Syzygium buxifolium,* and *Styrax formosana.*

Table 2. Measures of species diversity for trees (S: number of species per unit area; H: Shannon-Wiener index; D: complement of Simpson index) together with density and total basal area (m/ha) in the 35 quadrats

Quadrat No.	Density	Diversity (S)	Diversity (H)	Diversity (D)	Total B.A.
1	0.28	15	2.53	0.94	187.35
2	0.47	16	2.45	0.91	320.60
3	0.39	15	2.43	0.91	263.20
4	0.41	14	2.25	0.87	271.25
5	0.31	14	2.34	0.91	214.05
6	0.20	14	2.55	0.96	204.34
7	0.55	19	2.32	0.84	430.00
8	0.56	17	2.46	0.90	372.40
9	0.54	18	2.49	0.90	316.40
10	0.54	16	2.43	0.91	264.00
11	0.34	13	2.20	0.86	204.30
12	0.41	19	2.65	0.93	216.40
13	0.37	14	2.37	0.91	226.40
14	0.62	17	2.38	0.89	424.09
15	0.41	20	2.84	0.96	132.60
16	0.61	17	2.53	0.92	347.05
17	0.61	18	2.65	0.93	302.06
18	0.64	20	2.31	0.82	292.37
19	0.47	13	2.33	0.90	161.10
20	0.51	17	2.54	0.92	288.24
21	0.58	19	2.60	0.92	287.04
22	0.20	11	2.22	0.92	97.30
23	0.26	14	2.56	0.95	222.48
24	0.39	18	2.79	0.96	234.63
25	0.36	15	2.58	0.94	188.40
26	0.54	24	3.04	0.96	263.98
27	0.50	22	2.96	0.96	286.18
28	0.41	23	2.96	0.96	213.32
29	0.28	17	2.64	0.95	231.81
30	0.37	19	2.65	0.93	179.52
31	0.54	23	2.83	0.94	338.55
32	0.76	23	2.96	0.95	427.47
33	0.97	28	3.03	0.95	555.20
34	0.70	22	2.54	0.88	364.73
35	0.66	21	2.75	0.93	341.93

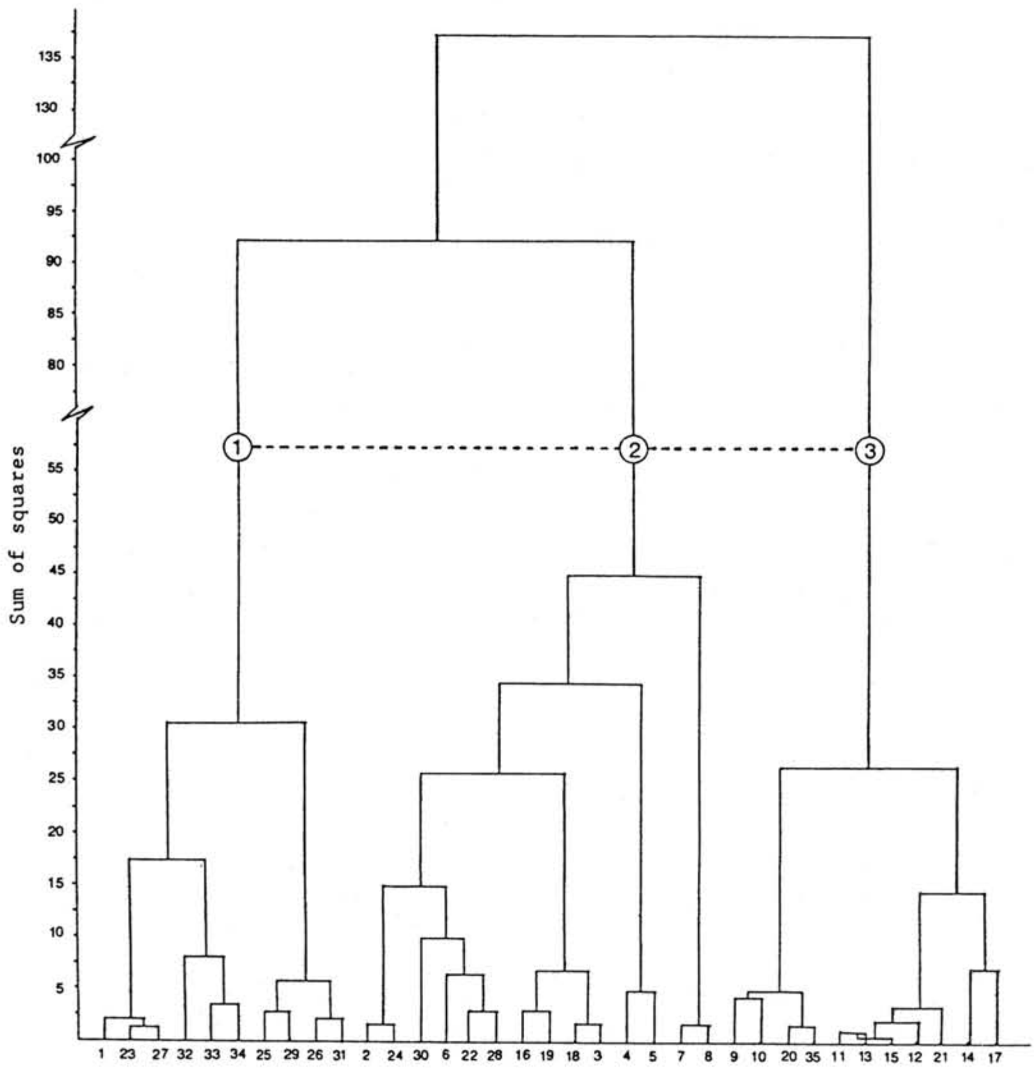

Fig. 2. Minimum variance cluster analysis dendrogram of the 35 quadrats.

Cluster 2 consists of 14 quadrats (2, 3, 4, 5, 6, 7, 8, 16, 18, 19, 22, 24, 28, and 30) near the Shuangchi River and on the valley bottom of the hill region. *Ardisia sieboldii, Cerbera manghas, Sapindus mukorossi, Liodendron formosanum, Crateva religiosa, Cleyera japonica,* and *Ficus virgata* usually dominate the tree stratum, and *Psychotria rubra* is the dominant shrub.

Cluster 3 consists of 11 quadrats (9, 10, 11, 12, 13, 14, 15, 17, 20, 21, and 35). Almost all of them were located on the northerly slopes of the hill region. *Ficus fistulosa* strongly dominates the tree stratum, with *Schefflera octophylla, Lagerstroemia subcostata,* and *Fisus ampelas* locally abundant. *Lasianthus plagiophyllus* and *Psychotria rubra* are the most important understory shrubs.

4. Ordination

Fig. 3 shows the positions of the 35 quadrats and 80 species in the first two RA axes (Fig.

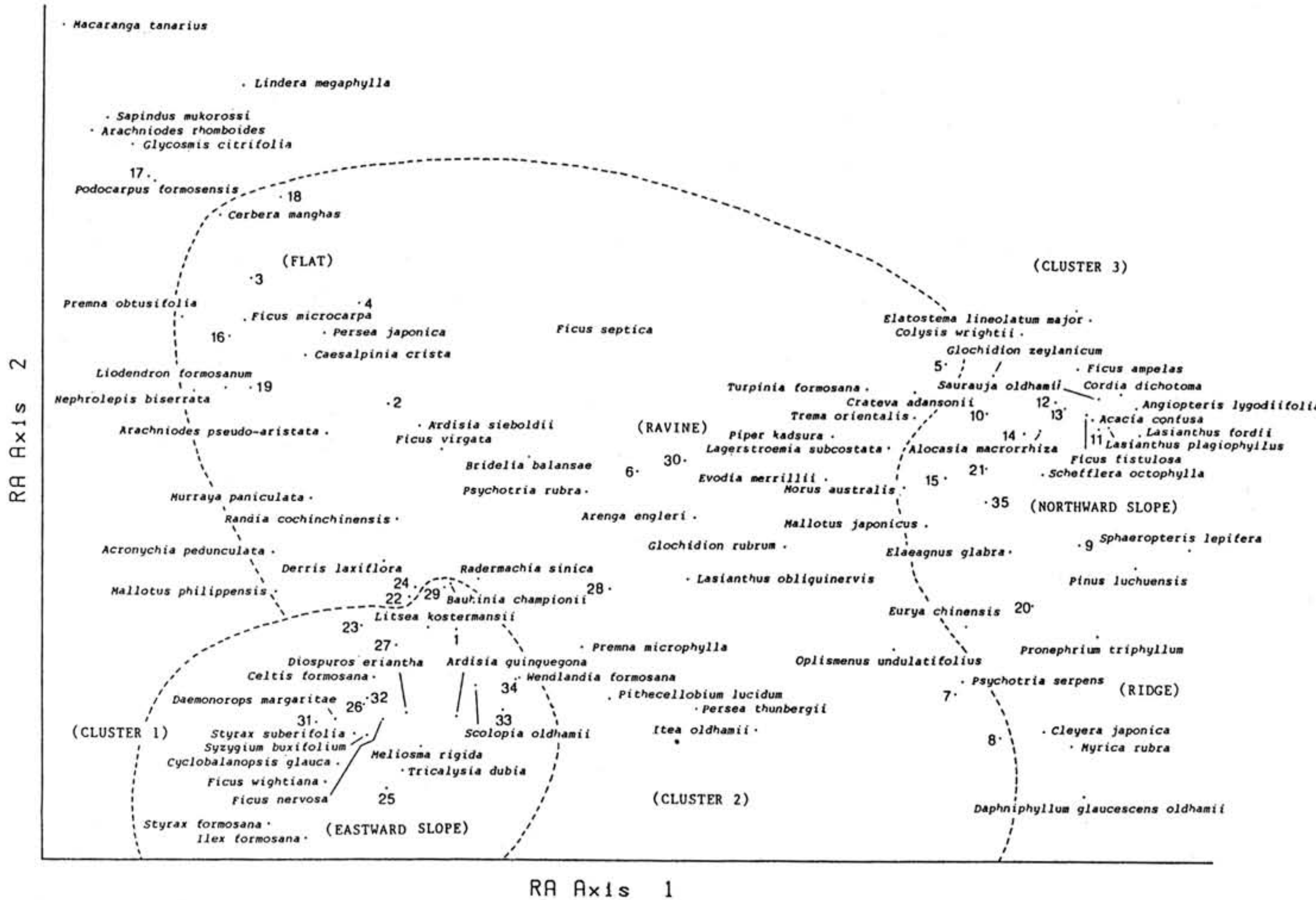

Fig. 3. RA (reciprocal averaging) representation of 35 quadrats and 80 species in the first two dimensions. Numbers identify quadrats. Major community types arising from cluster analysis (Fig. 2) are circled with dashed lines. Main environmental factors are also indicated.

3). Locations of the main clusters mentioned above are also shown on the ordination.

The first axis accounts for 12% of the total variance. It separates quadrats of ridges, open and northerly slopes from more or less sheltered quadrats of flat, ravine and slopes adjoining the valley bottoms.

The second axis accounts for 9% of the total variance. It reflects the difference between ravine and ridge variation. Along this axis, species such as *Cleyera japonica, Daphniphyllum glaucescens oldhamii, Myrica rubra, Itea oldhamii, Cyclobalanopsis glauca,* and *Syzygium buxifolium* decrease in importance with departure from their center on the ridge toward valley bottom.

The gradient from lowland of coastal region to hill slope of inland area is also recognizable on the second axis. The occurrences of *Liodendron formosanum, Podocarpus formosensis, Glycosmis citrifolia,* and coastal element, *Cerbera manghas*, contribute most of their distinctiveness.

The results from PCA are shown in Figs. 4-5. Quadrats that do not clearly separate in the first two axes are shown in the plane of the first and third axes.

Again the axes are readily identified: the first axis (component) reflects physiographic differences; the second axis coastal/inland trend; the third axis identifies ridge effect, with quadrat 7, 8, 9 and 20 concentrated more or less at one end of the third axis.

These three components account for 34% of the total variation. The fourth component has been examined but no interpretation could be made.

5. Successional status

Quadrat ages range from 13 to 40 years old, 74% being 20-30 years. They are probably too young for definitive predictions to be made for a long-term, steady-state forests of the Yenliao site. Anyway the dynamics index as previously stated does suggest likely possibilities.

The dynamics index values of the species from different physiographic provinces (Table 3) show that *Styrax suberifolia, Cleyera japonica,* and *Styrax formosana* have lower values reflecting relative intolerance of shade. On the other hand, *Bridelia balansae, Persea thunbergii, Ardisia sieboldii,* and *Schefflera octophylla* have higher index value indicating their strongly competitive role in the near future.

It is problematic whether *Cleyera japonica* will maintain its dominance in the ridge communities such as quadrats 7, 8, 9, and 20, but an interpretation of the dynamics index values indicates a clear trend toward dominance by species such as *Ardisia sieboldii, Schefflera octophylla,* and *Persea thunbergii.*

By examining the size-class data or each species in all quadrats, three patterns of population structure could be recognized (Figs. 6-8). These patterns appear to be typical for the species as they now exist in the secondary forests in Yenliao area.

Fig. 6 shows a population structure of two species that are capable of reproducing in the forest understory. It seems clear that they will persist in the forests, possibly becoming more abundant in the near future. Species with this pattern include *Ardisia sieboldii, Ficus fistulosa, Ficus virgata, Glochidion rubrum, Persea japonica, Persea thunbergii,* and *Schefflera octophylla.*

A second pattern is illustrated by those species that apparently characterized by having abundant small individuals (Fig. 7). They may be small at maturity or new canopy species that are just now invading. In either case, they are to some degree tolerant of the understory environment. Species in the category include *Acronychia pedunculata, Bridelia balansae, Dispyros eriantha, Glycosmis citrifolia, Itea oldhamii, Liodendron formosanum, Murraya paniculata, Saurauja oldhamii,* and *Scolopia oldhamii.*

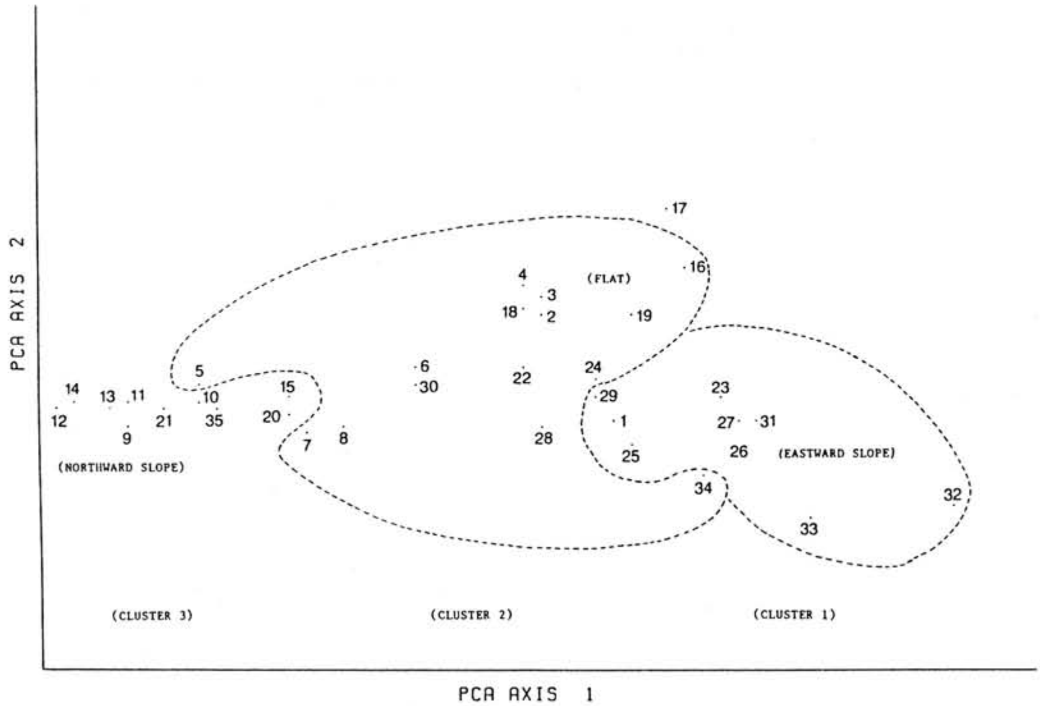

Fig. 4. Scatter diagram of the first two axes of the quadrat ordination derived by PCA (principal component analysis).

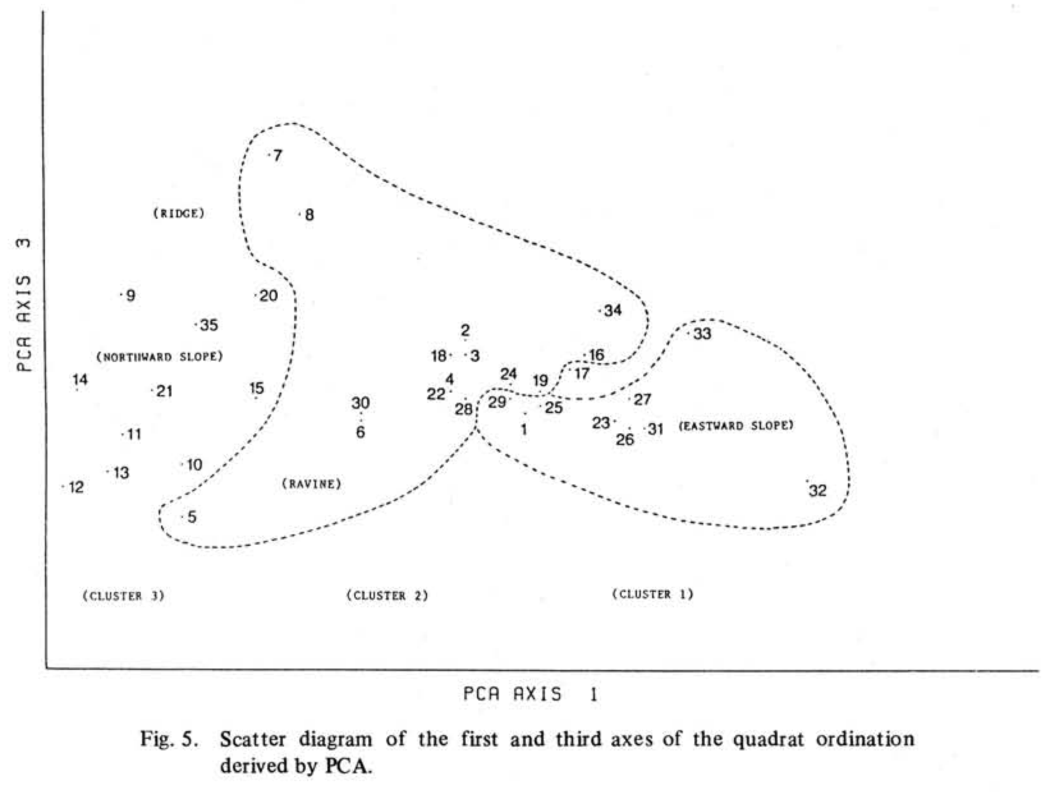

Fig. 5. Scatter diagram of the first and third axes of the quadrat ordination derived by PCA.

Table 3. Species dynamics index values

Species	Index	Species	Index
Styrax suberifolia	−2.43	*Syzygium buxifolium*	2.95
Cleyera japonica	−2.22	*Glochidion rubrum*	3.41
Styrax formosana	−1.03	*Ardisia sieboldii*	6.86
Ficus virgata	0.17	*Schefflera octophylla*	6.96
Persea japonica	1.46	*Persea thunbergii*	9.99
Cyclobalanopsis glauca	1.86	*Bridelia balansae*	10.41

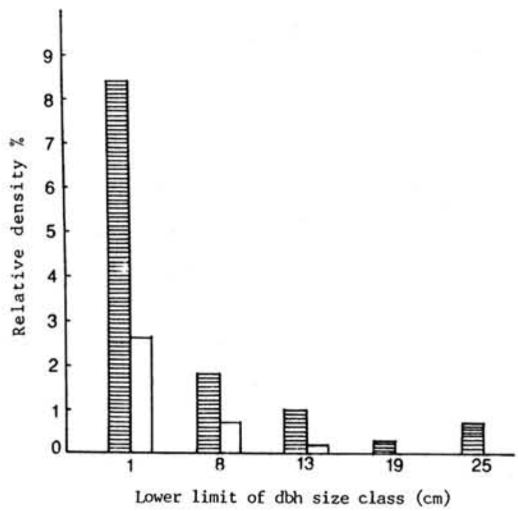

Fig. 6. Size-class distribution diagram for *Ardisia sieboldii* (shaded columns) and *Persea thunbergii* (open columns).

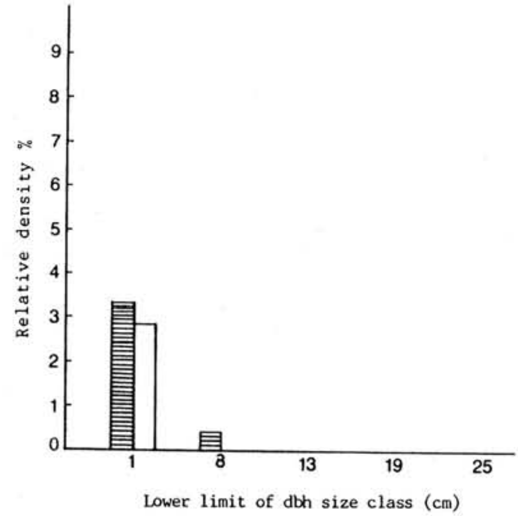

Fig. 7. Size-class distribution diagram for *Bridelia balansae* (shaded columns) and *Saurauja oldhamii* (open column).

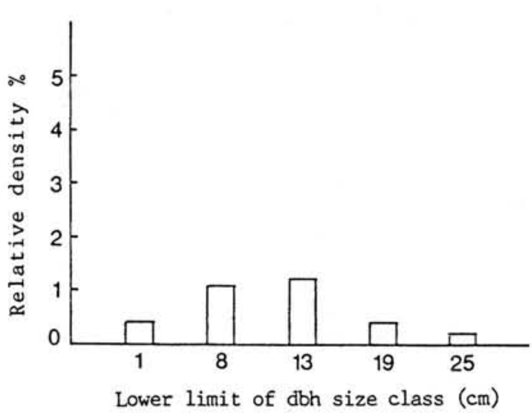

Fig. 8. Size-class distribution diagram for *Cleyera japonica*.

The last pattern is characterized of the species *Cleyera japonica* (Fig. 8). The most abundant size classes are the intermediate ones, with fewer small and large individuals. This pattern may suggest that the species is not reproducing as well in the past or show more rapid current growth.

In sum, the dynamics index value obtained are largely consistent with the size-class approach. The relatively high proportion of the small trees shows that the forests of Yenliao area are still at young stage of secondary succession, and changes will occur rapidly in the near future.

CONCLUSION

The evidence currently available indicates that the secondary forests of the Yenliao area is composed of a system of interacting communities, and the balance among them shifts with change in environment. In Yenliao area the major environmental complex gradients, topography and moisture, play an important role in shaping the regional vegetation pattern. The effects of topography and moisture are clearly seen in the hill regions. Other effect such as oceanic factors is hard to separate from the effects of other variables, but it is probably important in determining the generally east-west arrangement of vegetation types in the lower flat areas. The entering of coastal elements into quadrats near Shuangchi River is an example.

The inspection of the ordinations indicate that the first two axes of RA account only for 21% of the total variation (34% for the first three PCA axes), and it could appear that the heterogeneity of the secondary forests may be too great for the analysis to be completely efficient.

Because it was impossible to find a neat chronosequence of plots where time since abandonment was the only important variable, dynamics index and size structure were used for outlining the successional relationships between species of forest trees. The results of the method reveal a clear trend toward dominance by *Bridelia balansae, Persea thunbergii, Ardisia sieboldii* and *Schefflera octophylla* in the near future. This view is largely consistent with pattern previously reported (Su *et al.*, 1986).

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鹽寮地區的次生林

謝長富 黃星凡 黃增泉

摘要

爲調查鹽寮地區的次生林，總共設置了 35 樣區，每一樣區之大小爲 10×10 m。研究之目的爲：(1)利用歸類及散佈法以說明植被組成與植物社會之關係；(2)探討影響森林組成之主要環境因子；(3)評估森林演替之狀況。

全部樣區計含維管束植物 221 種，平均每一樣區種數爲 50。木本層 Shannon-Wiener 歧異度指數之平均爲 2.56（自然對數），而 Shimpson 指數（互補數）之平均爲 0.92。森林之優勢樹種爲樹杞、島榕、楊桐、水同木、青剛櫟、江某、細葉饅頭果及紅楠等。

依據胸高直徑及種覆蓋度進行最小變異歸屬分佈，其結果顯示三種主要社會類型。對應分析及主成分分析的結果則顯示樣區組成與地形、水分及海洋等因子有所關連。

利用木本層中每一種在各樹幹直徑級間的數量變化狀況以評定各樹種間之演替關係。其結果顯示三類族羣結構，同時在沒有遭到人爲及自然破壞之下，最近未來的森林將以刺杜密、紅楠、樹杞及江某等爲優勢種。