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The Forest Communities of Mt. Chombong Described by Combined Methods of Classification and Ordination[1*]

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Classification과 Ordination 分析法의 竝用에 의한 點鳳山一帶 森林群集의 解析[1*]

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ABSTRACT

Vegetation data of the mixed mesophytic forest in Mt. Chombong area were analyzed by the methods of classification and ordination. 'Weighted group average linkage cluster analysis' recognized five distinctive vegetation groups, based on the abundance data of 83 woody plant species in 70 sampling units. The species diversity was also examined for each group. The importance values of 42 tree species in the groups were subjected to principal component analysis (PCA). The PCA ordinated five vegetation groups on the first two axes, so as to compare similarity among them in terms of species composition. *Acer palmatum*, *Fraxinus rhynchophylla*, *Quercus mongolica*, and *Acer mono* had greatest influence on the determination of group scores with high eigenvectors (component loadings) in the first axis. Distribution of these four dominant species appeared to be important in determining community association in this diversified forest.

Key words : mixed mesophytic forest, cluster analysis, species diversity, principal component analysis (PCA).

要 約

江原道 點鳳山 일대 中生混淆林의 植生에 대하여 Classification과 Ordination을 병행 사용한 분석법을 시도하였다. 조사 삼림내의 70개 표본구에 나타난 83種의 木本植物의 數度를 바탕으로, Classification技法 중의 하나인 Cluster 분석에 의하여 다섯 植生群이 分類되었으며, 각 植生群 별로 樹種 多樣性도 비교 검토되었다. Cluster 분석이 분류한 植生群별 喬木 樹種의 重要値를 媒介變數로 하여 Principal component analysis (PCA)한 결과로써 각 식생군별 樹種 構成 狀態의 類似性을 비교할 수 있었다. 단풍나무, 물푸레나무, 신갈나무 그리고 고로쇠나무의 eigenvector 즉, 식생군이 ordination된 座標 위치를 결정하는 因子 附加率이 높게 나타남으로써, 본 연구대상 森林에서는 이들 네가지 樹種의 分布가 森林群叢 分類의 핵심이라 할 수 있다.

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INTRODUCTION

Numerical procedures for classification and ordination have been developed to improve multivariate quantitative analysis of vegetation data in plant ecology, being accompanied by the advancement of computer applications. They have played a remarkable role in evolution of vegetation science from having mainly a qualitative assessment aspect to its present state as a highly quantitative discipline. Various authors have reviewed and evaluated their technical development, stressed general discussion and comparison of the advantages for methods from one viewpoint to another (Whittaker, 1978a ; 1978b ; Gauch, 1982 ; Greig-Smith, 1983). Some authors have introduced mathematically related methodologies with explanation of details of individual techniques (Orloci, 1978 ; Gordon, 1981 ; Pielou, 1984 ; Ludwig and Reynolds, 1988). Even though various methods of classification and ordination have been developed and modified to analyze the natural ecosystem, the complexity and profundity of nature have never allowed the complete agreement among the methods. Until the 1970s classification and ordination were often regarded as totally separate groups of methods. However, the recent trend has been towards a 'complementary analysis', which employs both classification and ordination techniques in an analysis of the same data. This strategy of combined techniques can be applied to situations where the goal of vegetation description is to define and interpret forest communities (Kent and Ballard, 1988).

The vegetation data to be analyzed consist of the quantity of species lists recorded for a number of sampling units, resulting in a species-samples data matrix. The species quantity may be represented by density, coverage, frequency, phytomass, or integration of these values. Gauch (1980) has noted that the methods of classification and ordination of such data are concerned to identify similar and redundant samples, to identify outliers, and to elucidate relationships among samples.

The primary objective of this study was to apply these methods in a highly diversified deciduous forest of the Mt. Chombong area. Based on floristic composition, cluster analysis was utilized to form and identify similar groups and outliers among sampling units. From the results of cluster analysis, principal component analysis (PCA) was employed to develop a more detailed vegetation description for the study forest.

METHODS

Vegetation Data from Previous Study

The study area of Mt. Chombong (1424m) is located in the middle of the Taebak Mts., on the south border of Sorak-San National Park. Except for small patches of pine stands, the hardwood forest classified as a mixed mesothytic type extends through most of the area. The area has a typical continental climate with average maximum temperature of 33 degrees C in the summer and average minimum temperature of -19 degrees C in the winter. The mean annual precipitation is 1, 057mm. The predominant soils can be described as well drained loams to clay loams with a high amount of organic matter. Major dominant genera are *Acer*, *Quercus*, *Fraxinus*, *Carpinus*, *Tilia*, *Ulmus*, and *Betula* (Korea Nature Conservation Association, 1984 ; Yun, Han, and Kim, 1987).

In 1987, the research team of Forest Science Research Institute of Kangweon National University in cooperation with the author investigated the structure and environmental conditions of a virgin forest in Mt. Chombong area. The team examined and analyzed fundamental ecological aspects for the local forest vegetation and several micro-environmental characteristics (Yun, Han, and Kim, 1987). In previous work, vegetation data were collected on 70 temporarily established 10 m × 10m quadrats evenly distributed from the lower to upper slopes of the Mt. Chombong with reference to 1 : 25,000 topographic map of the study area. For the present study, density of all woody plant species from the same 70 sampling units were taken and re-examined to make a supplemental description and analysis by means of classification and ordination. The overview of study area and the methods of data collection were mentioned in detail in the previous publication by Yun, Han, and Kim(1987). Botanical nomenclature of the species follows Lee(1982).

Data Analysis

The density data for all 83 woody species and all 70 sampling units were subjected to 'weighted group average linkage cluster analysis'(Lance and Williams 1966). Since the author has noticed that, as Gower(1967) and Pielou(1984) have discussed in choosing strategies of methods, the study area is composed of a mixture of community types and the vegetation data is very unequally representative of the communities, the 'weighted' method was selected to prevent the abundantly sampled community from having overly large influence on the shape of the dendrogram. This method assigned an equal weight to every cluster, and hence unequal weight to the individual units. According to the degree of dissimilarity between pairs of sampling units, the agglomerative treatment consecutively coupled the units into groups.

Normalized Euclidean distance was used to measure dissimilarity between each pair of sampling units (Pielou, 1984). The normalization was chosen to disregard the absolute quantities of each species and to consider relative quantities instead. This was found to be appropriate in treating the vegetation data in which the species composition was more meaningful than the differences in overall abundance between each species. Likewise, we were able to reduce undesirable results caused by inequality of life form(shrubs vs. trees) and developmental stage (seedings and saplings vs. mature trees) in estimating dissimilarity between sampling units. A normalized Euclidean dissimilarity of 1.24 was selected to cluster 70 sampling units into five distinctive vegetation groups. Species diversity indices were estimated for each group following the method of Brillouin's diversity index (Brillouin, 1962 ; Brower and Zar, 1977).

Importance values of tree species for each group were calculated by summing up the relative density and relative frequency(Curtis and McIntosh, 1951). Coverage values were omitted merely because of insufficient information. The importance values were analyzed using principal component analysis of the centered covariance matrix. This was an attempt to display the groups in terms of their major tree species composition by reducing the data to a number of scores or principal components. These were then plotted in the first and second principal axes to compare positions between groups. Component loading, i.e. intensity of species influence, which determined group scores, were also plotted and tabulated. Multivariate Statistical Package (MVSP) which was developed by Kovach(1986), was utilized to carry out the cluster analysis and principal component analysis.

RESULTS AND DISCUSSION

Cluster Analysis of Sampling Units

The classification process was continued until all sampling units were connected together, computing average dissimilarity for each cluster. The dendrogram produced by average linkage cluster analysis distinguished five vegetation groups when the normalized Euclidean dissimilarity was 1.24 (Figure 1). The first three groups were characterized by the species dominance of *Acer* species, *Quercus mongolica*, and *Carpinus* species. The fifth group contained considerable occurrence of *Fraxinus rhynchophylla* and *Abies holophylla*, in addition. Group IV was more likely to be an outlier, composed of only four sampling units. The vegetation in the group IV appears to have been assembled by chance.

The Brillouin's species diversity indices are

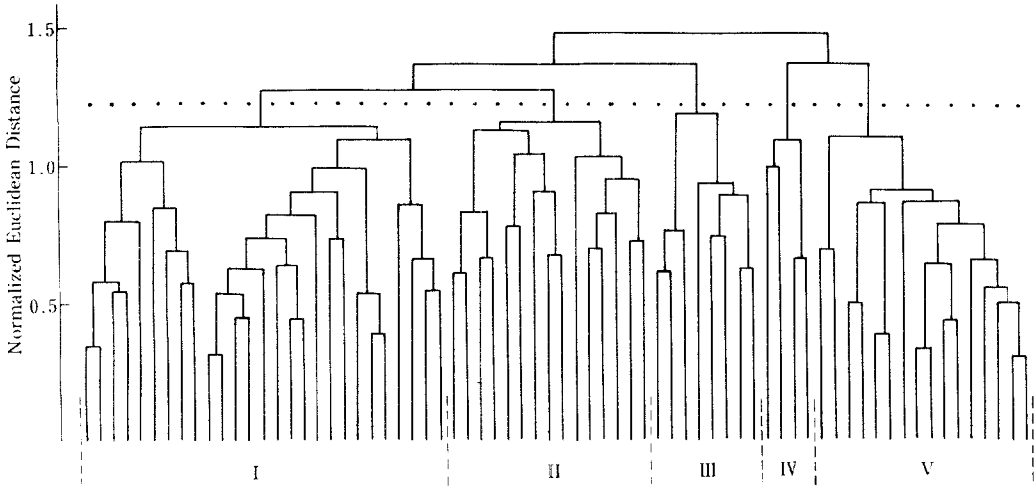

Fig. 1. Dendrogram showing relationship among 70 sampling units of the deciduous forest of Mt. Chombong. Clusters formed by using the weighted group average linkage method (Lance and Williams, 1966). Normalized Euclidean distance between units was based on the abundance of 83 woody plant species. A distance value of 1.24 resulted in five recognized vegetation groups.

presented in Table 1. Although the absolute numerical values of the indices themselves are rather meaningless, the values are used only in a relative mode to determine which species assemblages are more or less diverse than others. The value of Brillouin's species diversity index generally increases as the number of species increases, and as the number of individuals per species varies widely among species. The two factors work in combination. From these we can ascertain the distribution pattern of vegetation by comparing indices between groups. It is noticed that group I has more species than any other groups, but a smaller species index than group II, due to the evenness, which represents the degree of the individuals distribution among species(Table 1). Group II has more evenly distributed individuals than any other group. Groups III and V have the same number of species, but evenness has made group III hold a more diversified vegetation composition, meaning that more evenly abundant species are present. From the comparative point of view, the vegetation group with a higher diversity index and evenness may be one that is more stable and mature, hence one that is closer to the steady state(Odum, 1969). Group II best meets that criterion.

Table 1. Brillouin's species diversity index for five vegetation groups in the deciduous forest of Mt. Chombong.

	Diversity Index	Evenness	No. of species
Group I	3.0505	0.7335	64
Group II	3.2270	0.8207	51
Group III	2.9615	0.7709	46
Group IV	2.5542	0.7438	31
Group V	2.7149	0.7091	46

Each of the five vegetation groups had rather specific woody plant composition which distinguished it from the other groups. The list of four major dominant tree species in each group was summarized in Tabel 2. The description of more noticeable characteristics of each vegetation group is as follows.

Group I — This group was primarily associated with moist and nutrient rich sites on the outskirts of the valley (elevation of 500m-650m) and hillsides of mid-elevation (800m-900m). The soils were well drained dark colored loams to clay loams with high organic matter content (Yun, Han, and Kim, 1987). Occupying 27 sampling units out of 70, this vegetation group was the most widely distributed in the study forest. Thirty-three

Table 2. The dominant tree species in each vegetation group in the deciduous forest of Mt. Chombong.

	Species
Group I	*Acer palmatum* *Quercus mongolica* *Magnolia sieboldii* *Acer mono*
Group II	*Acer palmatum* *Acer mono* *Carpinus cordata* *Tilia amurensis*
Group III	*Carpinus cordata* *Acer mono* *Fraxinus rhynchophylla* *Ulmus davidiana* var. *japonica*
Group IV	*Fraxinus rhynchophylla* *Acer mono* *Cornus controversa* *Quercus mongolica*
Group V	*Quercus mongolica* *Acer palmatum* *Abies holophylla* *Fraxinus rhynchophylla*

tree species and 31 shrub species were tallied, providing a Brillouin's species diversity index of 3.05 and evenness of 0.73 (Table 1). *Acer palmatum* and *Quercus mongolica* were the dominant species, followed by *Magnolia sieboldii* and *Acer mono*. Significant shrub species included *Lindera obtusiloba*, *Stephanandra incisa*, *Symplocos chinensis* for. *pilosa*, and *Corylus sieboldiana*.

Group II — In addition to *Acer palmatum*, *Acer mono* and *Carpinus cordata* have made this group distinctive from others. *Quercus mongolica* was less important in this group. Typical shrub species were *Euonymus oxyphyllus*, *Staphylea bumalda*, *Symplocos chinensis* for *pilosa*, and *Syringa reticulata* var. *mandshurica*. Thirteen of the 15 sampling units in this category were located on the hillsides of upper elevation(900m-1100m), being most uniformly distributed in terms of physiography. Soils were classified as well drained brown colored loams, but less moist than those of group I (Yun, Han, and Kim, 1987). Twenty-seven tree species and 24 shrub species were present. This group had the highest species diversity, a Brillouin's diversity index of 3.23 and evenness value of 0.82 (Table 1).

Group III — The eight sampling units belonged to this group, related mainly to low elevation (500m-600m) and moist sites near the valley. This vegetation group was characterized by the dominance of *Carpinus cordata* and *Acer mono*, followed by *Fraxinus rhynchophylla*, *Ulmus davidiana var. japonica*, and *Tilia amurensis*. Major shrub species included *Staphylea bumalda*, *Lonicera maackii*, and *Euonymus oxyphyllus*. The unique feature of this group was that *Acer palmatum*, which held absolute dominance in groups I and II was not ranked as a primary species. The species diversity index was calculated as 2.95 with an evenness of 0.77 for 26 tree species and 20 shrub species (Table 1).

Group IV — With only four sampling units, this group appears to be an outlier. It is distinguished by the dominance of *Fraxinus rhynchophylla*, *Acer mono* and *Cornus controversa*, and by inferiority of *Acer palmatum* and *Carpinus cordata* which were major species in groups I, II, and III. In addition, increased presence of *Actinidia kolomikta* and *Alangium platanifolium* var. *macrophyllum* made this group much different from the others.

Group V — This vegetation group was associated with the highest elevations (1200m-1400m) of the mountain ridges in the study forest. The low productivity was caused mainly by poor soil moisture conditions and strong upcoming winds, making the trees into a shrubby and/or multi-stemmed form(Yun, Han, and Kim 1987). This group was characterized by the absolute dominance of *Quercus mongolica* and *Acer palmatum*, and by the absence of *Tilia amurensis*, *Ulmus davidiana* var. *japonica*, and *Fraxinus mandshurica*, which were commonly found in the other four groups. In addition to characteristic species, *Abies holophylla* and *Fraxinus rhynchophylla* were common in this vegetation group. The primary shrub species included *Rhododendron schlippenbachii*, *Tripterygium regelii*, and *Rhamnus davurica*. Twenty-three tree species and the same number of shrub species were present, providing a species diversity index of 2.71 and an evenness value of 0.71 (Table 1).

PCA of Vegetation Groups

An R-mode principal component analysis (PCA) was performed on the importance value of the 42 tree species in the five vegetation groups. PCA constructed linear axes through clouds of importance values in as many dimensions as necessary. The result of group ordination in two-dimensions (two axes) was illustrated in Figure 2. The groups are represented by points in such way that points that are close together correspond to groups that are similar in species composition, and vice versa. The percent of variation accounted by the eigenvalues for the first two principal components was 85.4% (Table 2), suggesting that an evaluation of axis 1 and axis 2 would be adequate.

As shown in Figure 2, groups II and III had the most similar tree species composition with a Sorenson's similarity index of 0.68 (see Goodall 1978). The main difference between these two groups was due to a higher abundance of *Fraxinus rhynchophylla* and *Ulmus davidiana* var. *japonica*,

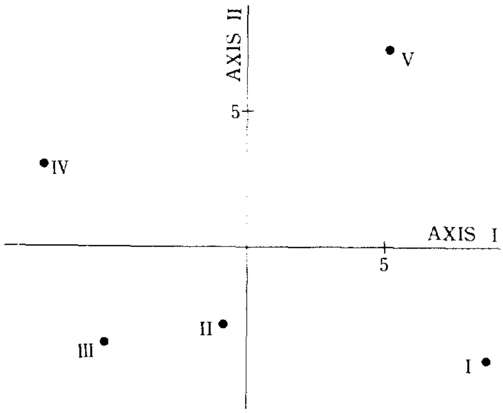

Fig. 2. Principal component analysis ordination diagram of five vegetation groups in Mt. Chombong. The analysis was based on the importance values of 42 tree species.

and less distribution of *Quercus mongolica* in group III.

Even though groups I and III occurred in the most similar physiographic positions (Yun, Han, and Kim, 1987) and had a high similarity index (0.68), as mentioned earlier, different dominant species made these two groups further apart in the scattergram (Figure 2). Possibly, the extent of gap openings by single tree removal and micro-environmental variables have made the groups maintain different dominant species in the forest. Further investigation for the environmental conditions and stand history is needed to find causes of the difference in species composition.

In order to clarify component loadings of tree species, the species correlations (positions) within two principal component axes were displayed in Figure 3. The component loadings on the first four principal components were also tabulated (Table 3). The axes of Figure 2 indicate a linear combination of all 42 tree species. The species with the highest absolute value of component loadings in Figure 3 had greatest influence on the

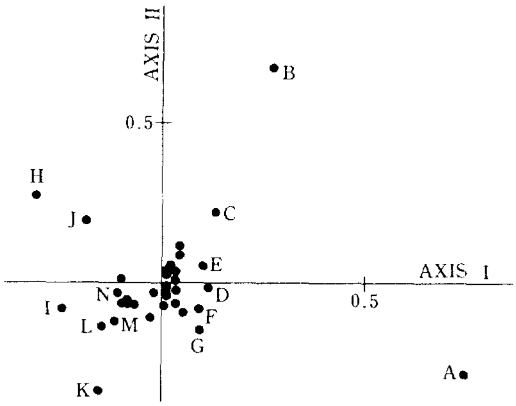

Fig. 3. Ordination scattergram of component loadings for 42 tree species on the first two axes of the principal component analysis. A-*Acer palmatum*, B-*Quercus mongolica*, C-*Abies holophylla*, D-*Carpinus laxiflora*, E-*Magnolia sieboldii*, F-*Macckia amurensis*, G-*Styrax obasia*, H-*Fraxinus rhyhophylla*, I-*Acer mono*, J-*Cornus controversa*, K-*Carpinus cordata*, L-*Ulmus davidiana* var. *japonica*, M-*Tilia amurensis*, N-*Acer mandshuricum*

Table 3. Component loadings (eigenvectors) for 14 major tree species on the first four axes of principal component analysis in the deciduous forest of Mt. Chombong.

Species	PC 1	PC 2	PC 3	PC 4
Acer palmatum	0.74	-0.29	0.30	0.12
Quercus mongolica	0.27	0.69	-0.06	-0.07
Abies holophylla	0.13	0.23	-0.34	-0.05
Carpinus laxiflora	0.11	-0.01	0.05	-0.03
Magnolia sieboldii	0.10	0.06	0.22	0.12
Maackia amurensis	0.09	-0.08	0.00	-0.03
Styrax obassia	0.09	-0.15	0.08	0.09
Fraxinus rhynchophylla	-0.31	0.28	0.32	-0.19
Acer mono	-0.25	-0.08	0.05	0.30
Cornus controversa	-0.19	0.20	0.32	0.42
Carpinus cordata	-0.16	-0.34	-0.26	-0.23
Ulmus davidiana var. *japonica*	-0.15	-0.14	0.34	-0.29
Tilia amurensis	-0.12	-0.12	0.08	0.16
Acer mandshuricum	-0.11	-0.02	0.03	0.18
Eigenvalue	230.5	104.5	38.2	19.1
Percent of Total Explained by Each Component	58.8	26.6	9.7	4.9

positions of the groups.

The results of the analysis indicate that *Acer palmatum* and *Quercus mongolica* were most positively correlated, and *Fraxinus rhynchophylla* and *Acer mono* were most negatively correlated with principal component 1. These differences imply that the vegetation groups were obviously separated on axis 1, based on the abundance of these species with their high values of component loadings. Groups I and V on the positive side were dominated by *Acer palmatum* and *Quercus mongolica*, and Groups III and IV on the negative side were dominated by *Fraxinus rhynchophylla* and *Acer mono* (Figure 2 and Table 2). Group II and more of a mixture of these high loading species with high value of evenness, moderating the position in the diagram.

A similar situation was observed on axis 2. *Quercus mongolica* and *Fraxinus rhynchophylla* were positively correlated, and *Carpinus cordata* and *Acer palmatum* were negatively correlated with principal component 2. Likewise, groups IV and V, with their abundance of *Quercus mongolica* and *Fraxinus rhynchophylla*, were expressed in the positive direction on axis 2, while groups I, II, and III, with their abundance of *Carpinus cordata* and *Acer palmatum*, were plotted in the negative direction on axis 2 (Figure 2 and Table 2).

Consequently, the vegetation group ordination was found to be associated with the absolute component loading values of the dominant species. From the dominance of 14 major tree species in Table 3, forest cover types could be determined in this diversified mixed mesophytic forest. Various cover types can be integrated to form certain ecological types, related to edaphic conditions, climax species and associates, and typical undergrowth plants (Kurmis *et al*, 1986). Such ecological types can be used not only in prediction of future vegetation changes based on community structure, species composition, and disturbance regime but also in detailed interpretation of the forest community. Forest communities belonging to the same ecological type are uniform in treatment response facilitating and improving management decisions.

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