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The Forest Vegetation of Mt. Kaya National Park, Korea

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가야산 국립공원의 삼림식생

정민호 · 김창환* · 길봉섭 · 유현경 · 신성은

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ABSTRACT

A census of the forest vegetation of Mt. Kaya National Park was taken with respect to the methods of ordination and classification. Eight groups were classified by cluster analysis : *Quercus mongolica, Q. mongolica-Sasa borealis, Q. serrata, Q. variabilis, Carpinus laxiflora, Cornus controversa, Fraxinus mandshurica* and *Pinus densiflora*. Among them, the *Q. mongolica* group and *Q. mongolica-S. borealis* group, the *F. mandshurica* group and *C. controversa* group showed similar floristic compositions to each other.

The interrelationship between the floristic compositon of the vegetation and soil environment was analyzed by PCA, the *Q. mongolica* group and the *Q. mongolica-S. borealis* group were distributed in areas of high CEC and total nitrogen content, while the *Q. serrata, Q. variabilis, C. laxiflora* and *Pinus densiflora* groups formed their communities in the more moderate areas of pH, soil moisture and soil organic matter. *F. mandshurica* and *C. controversa* groups were distributed in the areas of high soil moisture, soil organic matter, pH and available phosphate.

Key words : Forest vegetation, Mt. Kaya, PCA, Ordination, Classification, Cluster analysis.

INTRODUCTION

Ecologists have repeatedly investigated plant community structure in search of generalizable parameters for species co-occurrence-assembly rules(Zobel and Zobel 1988, Drake 1990, Wilson 1991, Wilson and Roxburgh 1994). Assembly rules have usually been sought by examining the spatial patterns of co-occurrences(Wilson *et al.* 1987, Zobel *et al.* 1993, Wilson 1989), but rarely have temporal patterns been examined.

The idea that community composition changes along environmental gradients is fundamental to much recent work in geobotany(Wilson and Mohler 1983). The understanding of this variation has greatly

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improved through the use of multivariate methods which are particularly valuable for indirect gradient analysis. The ordination axes extracted from a species-by-sample matrix(Gauch 1982) can be fruitfully compared with direct gradient analyses of single factors(ϕkland 1986b). A further advantage of ordination is the possibility of rescaling the gradient in terms of compositional turnover(Wilson and Mohler 1983, ϕkland 1986a).

Variation in cluster analysis is related to the number of tie values in the similarity matrix(Tausch *et al.* 1995). While classifying a square symmetric matrix of distances with TWINSPAN(Two-way indicator species analysis), we observed that the community classification produced different group memberships. PCA (Principal components analysis) can be particularly sensitive to effects from relationships in the data that are non-linear and non-monotonic(James and McCulloch 1990).

Lee and Cho(1993) reported that the structure of the *Abies koreana* community in Mt. Kaya was composed of four layers and that the heights of the tree and subtree layers were low. And Lee *et al.* (1993) showed that the forest vegetation of Mt. Kaya was classifiable into 3 communities(*Quercus mongolica, Lindera erythrocarpa* and *Pinus densiflora*) and 3 subunits(*Rhododendron mucronulatum, Platycarya strobilacea* and a typical subunit of a *Pinus densiflora* community). But these studies have not yet determined the relationships between communities and environmental factors.

The aim of this study is to determine the forest communities of Mt. Kaya by cluster analysis and PCA.

MATERIALS AND METHODS

Quantitative floristic data were obtained from April 1995 through September 1996 from 55 sample plots with topographic maps at a scale of 1:25,000. Quadrats, of at least 15×15 m minimal area in size, were set randomly at every releve(Oosting 1956).

Representative stands were selected on the basis of homogeneity and visually checked for uniformity in floristic composition.

All trees and shrubs of DBH(diameter at breast height)≥3 cm in every releve were measured for height. Plant names were recorded in order according to Lee(1979).

Soil samples were obtained from a place within the plant community. Soil samples were collected with a gouge auger(diameter 5.08 cm) from A horizon. Three cores were homogenized into one sample and of each station three samples were taken. Samples were air dried and weighed(fresh weight and dry weight) prior to analysis.

The following chemical analyses were performed. Soil moisture content was calculated as a percentage of water loss against dry weight at 105℃. Soil organic matter content was determined as a percentage of the loss-on-ignition against dry weight by Allen *et al.* method(1986). Soil pH was determined in solution(soil:distilled water = 1:5, W/V) by glass electrode. Cation exchange capacity was determined Brown's method(1952). Other analyses of soil components were done by soil chemical analysis(Rural Development Administration 1988). Soil analysis were carried out at the Soil Laboratory of the Rural Development Administration, Korea

The clustering technique applied to the species on site data was the CA method of Lance and Williams (1967).

To determine the correlation of vegetation to environmental factors, principal component analysis (PCA)(Austin and Orloci, 1966, Orloci, 1966, 1967, 1973, 1978) was used.

RESULTS AND DISCUSSION

Classification(Cluster analysis)

The pattern of clustering for the eight community types is summarized in the dendrogram(Fig. 1).

These types showed differences in species composition and environmental characteristics.

The dendrogram forms one main group. Further

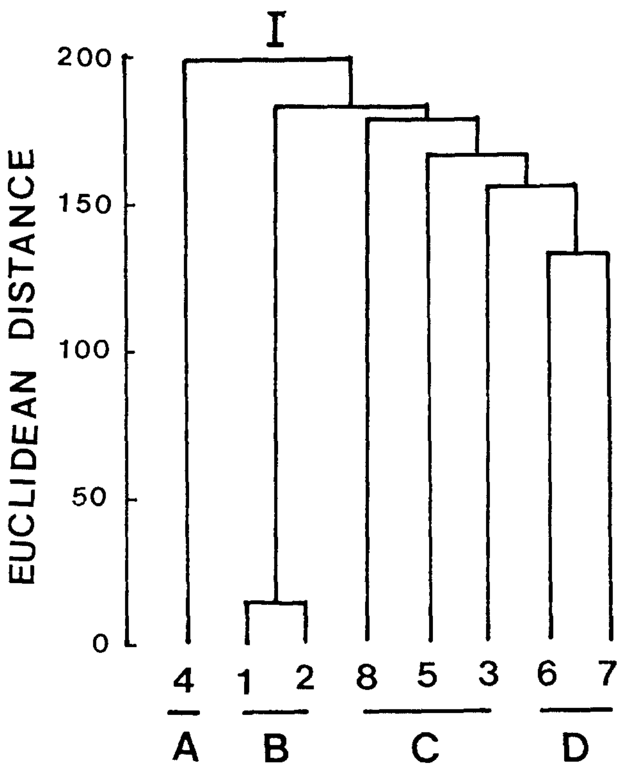

Fig. 1. Dendrogram of the clustering of eight communities type using Euclidian distance.
1: *Quercus mongolica*, 2: *Q. mongolica-Sasa borealis*, 3: *Q. serrata*, 4: *Q. variabilis*, 5: *Carpinus laxiflora*, 6: *Cornus controversa*, 7: *Fraxinus mandshurica*, 8: *Pinus densiflora*.

division of cluster I reveals that sites tended to cluster into 4 groups: A(*Quercus variabilis*), B(*Q. mongolica* and *Q. mongolica-Sasa borealis*), C(*Pinus densiflora*, *Carpinus laxiflora* and *Q. serrata*) and D (*Cornus controversa* and *Fruxinus mandshurica*).

Q. mongolica and *Q. mongolica-S. borealis* as group B are very similar as is group D, *C. controversa* and *F. mandshurica*.

The floristic composition of each community type shown in Fig. 1 will be briefly discussed in the following.

1. Community type 1(*Q. mongolica*)

Q. mongolica has a wide range of thermal distribution, WI 18-111(Yim 1977), and is the characteristic species of the cool-temperate deciduous broad-leaved forest zone in Korea, which includes almost all areas of the mountain.

The *Q. mongolica* communities are of wide distribution in the study area. These communities are distributed in mainly between 900 and 1,100 meters in altitude, but can descend to lower altitudes along valley slopes. The plant community is dominated mostly by *Q. mongolica*, *Rhododendron schlippenbachii*, *Symplocos chinensis* for. *pilosa*, and *Carex okamotoi*, in the tree-, subtree- and herb-layers, respectively.

The stems of *Q. mongolica* are 10~15 cm in diameter at breast height(dbh) and generally attain a height of 8~18 m.

2. Community type 2(*Q. mongolica-S. borealis*)

The *Q. mongolica-S. borealis* community generally corresponds to the *Q. mongolica* community. The structural characteristics of this community is distinguished by *Q. mongolica* in the tree stratum and *S. borealis* in the shrub layer. The habitat of this community is found at altitudes above 800 m.

3. Community type 3(*Q. serrata*)

In the study area, this community was mainly located on the middle parts of the slopes between 700 and 800 m in altitude. Associated trees in this community included *Q. mongolica*, *Q. variabilis*, *C. laxiflora* and *Stewartia koreana* in the upper tree layer but the lower tree layer was mainly composed of *F. sieboldiana*, *Acer mono*, *Stewartia koreana* and *S. borealis*. The height of the tree layer was 15~20 m.

4. Community type 4(*Q. variliabis*)

The distribution of this community in study area occurred more abundantly on the sunny mountain side and xeric hillsides between 700 and 900 m in altitude. Associated trees in this community included *Q. serrata*, *Q. mongolica* and *Maackia amurensis* in the upper tree layer, while the lower tree layer was mainly composed of *Styoax obassia* and *R. schlippenbachii*. The height of the tree layer was 12～18 m.

5. Community type 5(*Carpinus laxiflora*)

C. laxiflora has an optimal range of thermal distribution, WI 76-89(Yim and Kim 1985), and is a characteristic species of the southern and middle parts of the cool-temperate deciduous broadleaf forest on the middle and lower slopes of the mountain.

In the study area, this community is located on middle/low slopes below the 100 m altitude, the foot of mountains. The associated trees and shrubs include *Q. mongolica*, *Q. serrata* and *Betula costata*, *A. pseudo-sieboldianum* and *S. obassia*. The herb layer is composed mainly of *S. borealis* and *C. siderosticta*. The height of *C. laxiflora* is 15～18 m.

6. Community type 6(*Cornus controversa*)

The habitats of this community in the study area are mainly located on valley, mesic and nutrient rich slopes between 650 and 750 m in altitude.

In the tree layer of the *C. controversa* community, *Tilia amurensis* and *Alnus hirsuta* are found as companion species with lower coverage. The height of the tree layer is 8～12 m.

7. Community type 7(*F. mandshurica*)

The habitats of this community are located mainly in valleys above 800 m altitude. In the tree layer of *F. mandshurica*, *A. mono*, *C. controversa* and *C. cordata* are found as companion species with lower coverage. The shrub layer is *Deutzia parviflora*, *Alangium platanifolium* var. *macrophylum* and *Lindera erythrocarpa*. The herb layer is mainly composed of *Polystichum tripteron*, *Dryopteris crassirhizoma* and *Hydrangea serrata* for. *acuminata*. The stems of the trees are 10～30 cm dbh and 16～18 m in height.

8. Communiy type 8(*P. densiflora*)

The distribution of *P. densiflora* in Korea spreads from Cheju island to main peninsula(33° 20′ N). On Mt. Kaya, this community occurs more abundantly at the lower parts of the mountain. Habitats are situated on rocky upper slopes and/or convex ridges which are sometimes steep and usually exposed to intense light.

In the tree layer of this community, *Q. serrata*, *Q. variabilis* and *P. koraiensis* are found as companion species with lower coverage.

The shrub and herb layers are mainly composed of *R. mucronulatum*, *R. schippenbachii*, *F. sieboldiana*, *Rhus trichocarpa*, *Melampyrum roseum*, *S. borealis*, *Pteridium aquilinum* var. *latiusculum* and *C. okamotoi*.

Ordination(Principal Component Analysis)

Principal Component Analysis(PCA) is the most usual way of combining a number of environmental factors into fewer uncorrelated components. The results of the PCA are summarized by the eigenvalues and the eigenvectors.

Eigenvalues for the first three components of the eight communities were 10.2, 6.7, 5.9 and the percentage of trace by each eigenvalue was 28.4, 18.7, 16.3 over 63% of the total variation(Table 1).

The plant community coordinates were used to graphically display the eight communities within a coordinate system where the relative positions of the community reflect similarities(Fig. 2). Principal component I accounts for over 28% of the variation.

The results of communities ordination are given in

Table 1. Eigenvalues of the first five components of the 55 stands

Component	Eigenvalue	Proportion of variability	Cumulative proportion
I	10.23	28.4%	28.4%
II	6.72	18.7%	47.1%
III	5.85	16.3%	63.4%
IV	5.11	14.2%	77.6%
V	3.46	9.6%	87.2%

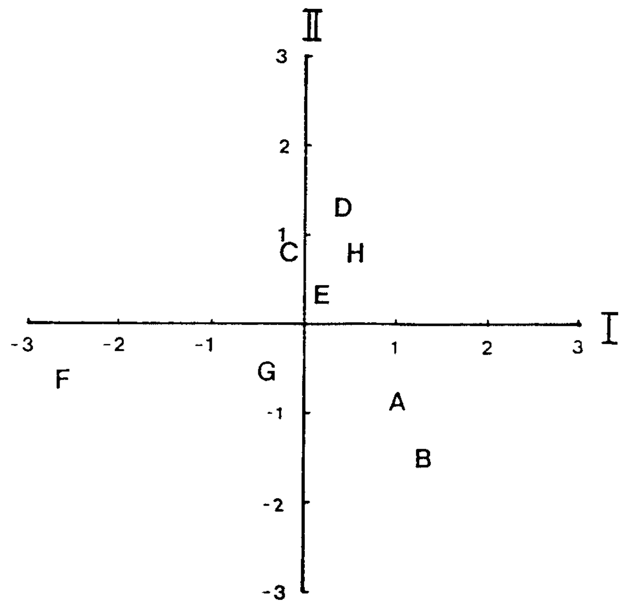

Fig. 2. Principal components ordination of eight communities in Mt. Kaya. Keys to species: A(*Quercus mongolica*), B(*Quercus mongolica-Sasa borealis*), C(*Quercus serrata*), D(*Quercus variabilis*), E(*Carpinus laxiflora*), F (*Cornus controversa*), G(*Fraxinus mandshurica*).

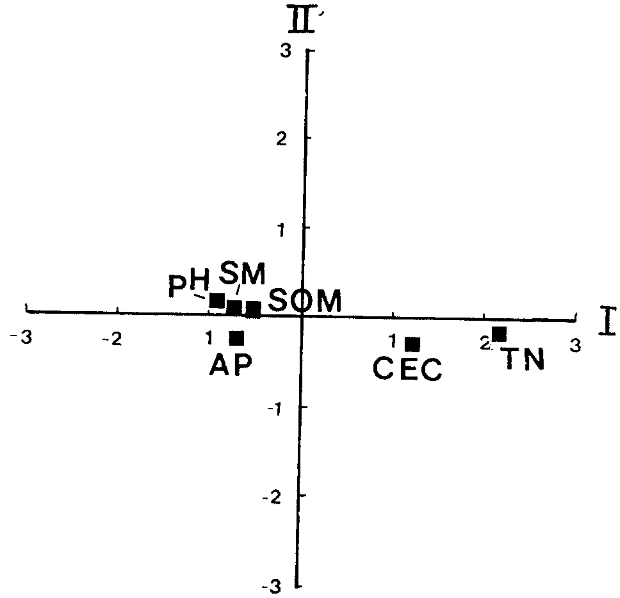

Fig. 3. Principal components ordination of six environmental factors in Mt. Kaya.
Note: TN; Total nitrogen, AP; Available phosphate, SM; Soil moisture, SOM; Soil organic matter, CEC; Cation exchange capacity.

Table 2. Eigenvalues of the first three components of the six environmental factors. The six environmental factors are soil moisture, soil organic matter, pH, available phosphate, cation exchange capacity and total nitrogen

Component	Eigenvalue	Proportion of variability	Cumulative proportion
I	7.85	98.2%	98.2%
II	0.12	1.5%	99.7%
III	0.02	0.3%	100.0%

Table 2 and Fig. 2. The ordination diagram of PCA is divided into 3 groups along the I and II axes(Fig. 2).

Communities 1(*Q. mongolica*) and 2(*Q. mongolica-S. borealis*) are very similar each other. Community 3(*Q. serrata*) is correlated with communities 4 (*Q. variabilis*), 5(*C. laxiflora*) and 8(*P. densiflora*). Also, communities 6 (*C. controversa*) and 7(*F. mandshurica*) are similar. Thus, group I(1 and 2), II(3, 4, 5, and 8), III(6 and 7) is divided along the I and II axes.

The *Q. mongolica, Q. mongolica-S. borealis, Q. valabilis, C. laxiflora* and *P. densiflora* communities were positively correlated with principal component I, but *Q. serrata, C. controversa* and *F. mandshurica* were negatively correlated with principal components I and II. *Q. mongolica* group(1 and 2) was negatively correlated with principal component II.

The relation between PCA ordination axes and environmental variables can be observed from Fig. 3. Eigenvalues of the first two components of the six environmental factors were 7.85 and 0.12. Thus, since the first two components between them account for over 99% of the total variation, we regard these as the principal components(Table 2). This is convenient since it means we can summarize 99% of the total information furnished by these data on two-dimensional graphs(Causton 1988).

Soil moisture, pH, soil organic matter, available phosphate, cation exchange capacity(CEC) and total nitrogen are the variables determining variation in communities along axes I. The variables of soil moisture, pH, soil organic matter and available phoshate are closely correlated to each other, but have strong negative correlation to CEC and to total nitrogen (Fig. 3).

Along axis I, the *C. controversa* community and the *F. mandshurica* community with high contents of soil moisture, pH, soil organic matter and available phosphate are differentiated from the other communities.

Among the communities, *Q. mongolica* and *Q. mongolica-S. borealis* are distributed at the highest content of CEC and total nitrogen. The *Q. serrata, Q. valiabilis, C. laxiflora* and *P. densiflora* communities are clumped together. These communities are distributed at adequate levels of soil moisture, pH and soil organic matter.

As analyzed by PCA, the environmental variables correlated with the *C. controversa* and *F. mandshurica* of Mt. Kaya forest are soil moisture, pH, soil organic matter and available phosphate, whereas for the *Q. mongolica* group they are CEC and total nitrogen.

The above results are congruent with the data of Song *et al.*(1987), Kim and Kil(1991) and Kim(1992).

적 요

국립공원 가야산의 삼림식생을 서열법(ordination)과 분류법(classification)을 이용하여 분석하였다.

Cluster analysis 방법에 의한 삼림식생 분류결과 신갈나무, 신갈나무-조릿대, 졸참나무, 굴참나무, 서어나무, 층층나무, 들메나무, 소나무의 8개 군으로 나누어졌다. 8개 군으로 구분된 이들 종, 군들은 신갈나무군과 신갈나무-조릿대군이 매우 유사한 종조성을 보였으며, 들메나무군과 층층나무군도 유사한 종조성을 나타냈다.

식생의 종조성과 토양 환경과의 상호 관계를 PCA (Principal component analysis)에 의하여 분석한 결과, 신갈나무, 신갈나무-조릿대 군은 CEC(Cation exchange capacity), 총 질소의 함량이 높은 곳에서 분포하고 있으며, 졸참나무, 굴참나무, 서어나무, 소나무군은 pH, 토양수분 함량, 토양 유기물함량이 알맞은 지역에서 군락을 형성하고 있다. 들메나무, 층층나무군은 토양수분함량, 토양유기물함량, pH, 유효인산이 높은 곳에서 분포한다.

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