Korean J. Ecol., 20(2): 125~132, 1997

Canonical Correspondence Analysis(CCA) on the Forest Vegetation of Mt. Tŏgyu National Park, Korea

Kim, Chang-Hwan and Bong-Seop Kil*

*Department of Forest Landscape Architecture, Iri National College of Agriculture and Technology, Iksan 570-110, Division of Life Science, Wonkwang University, Department of Biology Education, Iksan 570-749, Korea**

Canonical Correspondence Analysis(CCA)에 의한 덕유산 국립공원의 삼림식생분석

김 창 환 · 길 봉 섭*

이리농공전문대학 녹지조경과, 원광대학교 생명과학부 생물교육과*

ABSTRACT

A study of forest vegetation in Mt. Tŏkyu National Park was investigated by ordination technique.

By TWINSPAN(Two-Way Indicator Species Analysis) method, 10 groups were recognized as follows: *Pinus densiflora, Quercus variabilis, Quercus serrata, Quercus mongolica-Rhododendron schlippenbachii, Quercus mongolica-Abies koreana, Quercus mongolica-Acer pseudo-sieboldiamum, Quercus mongolica-Symplocos chinensis* for. *pilosa, Carpinus laxiflora, Fraxinus mandshurica* and *Taxus cuspidata* groups. The floristic composition of these groups showed high correlation to soil moisture(r=0.831), altitude(r=0.784), topography(r=−0.722), organic matter(r=0.642), and pH(r=−0.509) among various environmental factors.

According to the results of CCA(Canonical Correspondence Analysis) *Pinus densiflora* group and *Quercus variabilis* group were situated in a xeric area at a lower altitude where soil nutrients were poor compared with the other groups. *Fraxinus mandshurica* group was distributed throughout the valley with high soil moisture and good nutrients, *Quercus serrata* group and *Carpinus laxiflora* group were found in the low altitude region with good nutrients, *Quercus mongolica* group, at the high altitude region with good nutrients, and *Quercus mongolica-Acer koreana* and *Taxus cuspidata* at higher altitudes(1,400~1600 m).

Key words: Canonical correspondence analysis, Environmental gradient analysis, Forest vegetation, Mt. Tŏgyu.

INTRODUCTION

Ordination techniques are commonly employed as research tools in the study of vegetation. Ordination was divided into direct ordination by environmental gradient analysis of Whittaker(1951) and indirect ordination by continuum index of Curtis and McIntosh(1951), but since then many other methods have been developed.

Direct ordination is define as an ordination based directly on environmental factor. The ordination axes are either individual environmental factors, or are combination of several environmental factors which have been determined by definite mathematical procedures. Also, direct gradient analysis relates species presence or abundance to environmental variables on the basis of species data and environmental data from the same set of sample plots(Gauch 1982).

The simplest methods of direct gradient analysis involve plotting each species' abundance values against values of an environmental variable, or drawing isopleths for each species with a space of two environmental variables(Whittaker 1967). With these simple methods, one can easily visualize the relationship between many species and one or two environmental variables(ter Braak 1987).

By contrast, an indirect ordination is based on vegetation data; the ordination axes define gradients in the vegetation, but these gradients should reflect environmental gradients. Hence, the term 'direct' and 'indirect' refer to ordination activities in relation to environmental factors(Causton 1988). Such a conception of differential species distribution along environmental gradients has been central to the development of generalized models in community ecology(Clements 1916, Brown and Curtis 1952, Diamond 1978, Whittaker 1967, Grime 1980, Tilman 1984, Carleton 1990).

As direct gradient analysis, CCA(Canonical Correspondence Analysis) is a simple method for arranging species along environmental gradients(ter Braak 1987). CCA constructs those linear combinations of environmental variables along which the distributions of the species are maximally separated. The eigenvalues produeed by CCA measure this separation. Also, CCA is a correspondence analysis technique, but one in which the ordination axes are constrained to be linear combinations of environmental variables. The ordination diagram generated by CCA visualizes not only a pattern of community variation but also the main features of the distributions of species along the environmental variables(ter Braak 1987).

Consequently, CCA aims to visualize a pattern of community variation, as in standard ordination, and also the the main features of species' distribution along the environmental variables.

This study aims : (1) to describe the vegetation type and (2) to understand the ecological relationships between the forst vegetation and the environment, by CCA method.

THE STUDY AREA

This study was carried out at Mt. Tŏgyu National Park located in Chŏllabuk-do and Kyŏngsangnam-do(127° 41′~127° 50′E, 35° 45′~36° 00′N)(Fig. 1).

The total area of Mt. Tŏgyu is 219 km^2 and Hyangchŏkbong, the main peak, is 1,614 m high.

The forest vegetation is largely characterized by *Quercus*, *Carpinus*, and *Fraxinus*. Most regions of forest vegetation are influenced by man, so that secon-

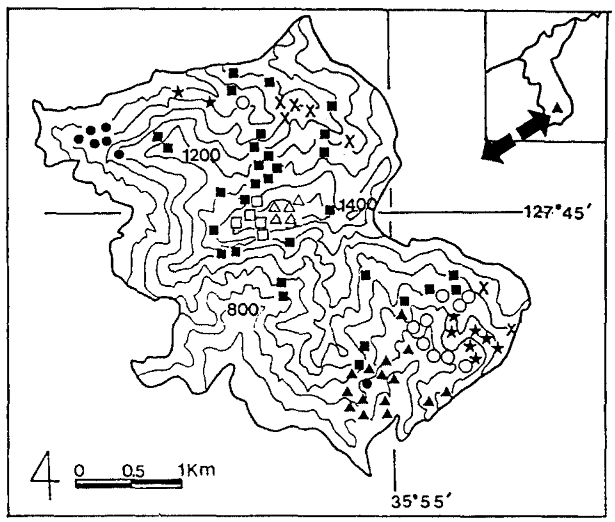

Fig. 1. Sampling sites(▲, ●, ★, ○, ×, △, ■, □) in Mt. Tŏgyu national park.
The symbols of the sites are; ▲=*Pinus densiflora*; ●=*Quercus variabilis*; ★=*Carpinus laxiflora*; ○=*Quercus serrata*; ×=*Fraxinus mandshurica*; △=*Taxus cuspidata*; ■=*Quercus mongolica*; □=*Quercus mongolica-Abies koreana*.

dary forest is now in various stages of regrowth. The area is meteorologically characterized as the cold -temperate deciduous broadleaf forest zone(Yim and Kira 1975).

According to Chŏnju meteorolongical observatory (1994) the study area has an average rainfall of 742 mm/yr peaking in July and August. Mean annual temperature is 10.7℃ with average minimum and maximum temperatures of −3.2 and 25.6℃ respectively. In particular, the average monthly rainfall is over 100 mm from May to September and the average daily minimum temperature during this time is below 0℃.

METHODS

Vegetation data and environmental data

Quantitative floristic data was obtained during April 1993~September 1993 from 89 sample plots with topographic maps at scale 1:25,000(Fig. 1). Quadrats, 15 m×15 m minimum, were set randomly in every plot(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 relevé were measured for height and dbh. The plant name was recorded according to Lee(1979).

Soil samples were obtained from quadrats with plant communities. Soil samples were collected with a gouge auger(diameter 5.08 cm) from the A horizon (upper layer). Three cores were homogenized into one sample and in each station three such samples were taken. Samples were air-dried and weighted(fresh weight and dry weight) prior to analysis.

The following physical and 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(Moore and Chapman 1986). Soil pH was determined in solution(soil: dist. water=1:5, W/V) by glass electrode. Cation exchange capacity (Brown's method) and potassium content(flame photometry) were determined. Other analyses of soil components were done by soil chemical analyses(Rural Development Administration 1988). Soil analysis were carried out at the Soil Laboratory of the Rural Development Administration, Korea.

For site description the altitude(m, a, s, l), slope (°), aspect(N, E, S, W, NE, SE, SW, NW) and topography(ridgeline, slope, valley) of each relevé was determined.

Data analysis

The clustering technique applie to the species in sites data was Two-Way Indicator Species Analysis (TWINSPAN)(Hill *et al.* 1975).

To determine the correlation of vegetation and environmental factores, canonical correspondence analysis(CCA)(ter Braak 1986) was employed.

CCA, a multivariate extention of weighted averaging ordination, was performed including 12 environmental variables.

The axes extracted by CCA represent those directions of variation in species composition that are related to supplied external variables.

CCA was performed with procedures in the program-package CANOCO(ter Braak 1988).

RESULT AND DISCUSSION

Inspection of the dendrogram produced by TWINSPAN(Fig. 2) reveals that sites tend to cluster into 10 groups: *Pinus densiflora*, *Quercus variabilis*, *Quercus mongolica-Rhododendron schlippenbachii*, *Quercus mongolica-Abies koreana*, *Quercus mongolica-Acer pseudo-sieboldiamum*, *Quercus mongolica-Symplocos chinensis* for. *pilosa*, *Quercus serrata*, *Crpinus laxiflora*, *Fraxinus mandshurica*, *Taxus cuspidata*.

A brief description of the plant communities and characteristics of species composition fallows.

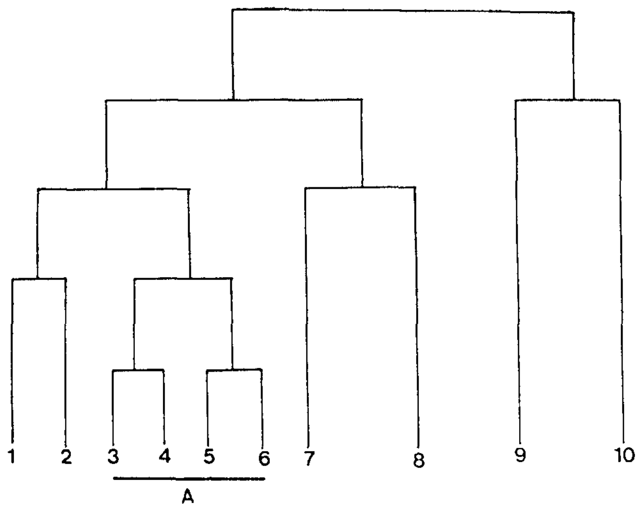

Fig. 2. The pathway subdivided into 10 groups of vegetation by TWINSPAN. Dominants: 1. *Pinus densiflora*; 2. *Quercus variabilis*; A. *Quercus mongolica* community group, 3. *Quercus mongolica-Rhododendron schlippenbachii*; 4. *Quercus mongolica-Abies koreana*; 5. *Quercus mongolica-Acer pseudo-sieboldiamum*; 6. *Quercus mongolica-Symplocos chinensis* for. *pilosa*; 7. *Quercus serrata*; 8. *Carpinus laxiflora*; 9. *Fraxinus mandshurica*; 10. *Taxus cuspidata.*

Quercus mongolica community

The distribution of this community in Mt. Tŏgyu is mainly between 900 and 1,500 m high, but it can descend to lower altitude along valley slopes. The plant community is dominated mostly by *Quercus mongolica, Acer pseudo-sieboldianum, Rhododendron schlippenbachii, Ainsliaea acerifolia* in the tree, subtree, shrub and herb layers, respectively. The stems are 20~25 cm in dbh(diameter at breast height) and generally attain a height of 15~25m. The average number of species was calculated as 30 spp./relevé.

Abies koreana-Quercus mongolica community

The habitats of this community in the study area were found at higher altitudes above 1,400 m. Structural characteristics of this community are completely mixed into one typical forest zone with *Abies koreana* and *Quercus mongolica* together in the tree stratum. The shrub layer is dominated by *Sasa borealis.*

The stems(dbh) of *Abies koreana* are 20~50 cm, and *Quercus mongolica* 15~25 cm. The heights of *Abies koreana* and *Quercus mongolica* are 20~25m and 10~15m, respectively. The average number of species was calculated as 32 spp./relevé.

Carpinus laxiflora community

In Mt. Tŏgyu, this community is located from medium slopes to lower slopes below 900 m high.

Structural characteristics are mixed with *Carpinus laxiflora* and *Carpinus tschonoskii* together in the upper, tree layer.

The lower tree layer is composed mainly of *Lindera obtusiloba* and *Acer pseudo-sieboldianum.* The shrub layer is dominated by *Sasa borealis,* and the field layer is dominated by *Ainsliaea acerifolia.*

The stems of the tree layer are 15~45 cm in dbh and generally attain a height of 12~20 m. The mean number of species was calculated as 34 spp./relevé.

Quercus variabilis community

The distribution of this community in Mt. Tŏgyu is more common on the steep sunny mountain side and xeric hillside between 700~900 m high The associated tree and shrubs include *Fraxinus sieboldiana, Styrax ohassia, Quercus mongolica, Lespedeza maximowiczii* and *Lindera obtusiloba.* The field layer is composed mainly of the sedge *Carex lanceolata* and grass *Sasa borealis.*

The stems of the trees are 12~30 cm in dbh with a height of 12~20 m.

The plant community is composed of an average of 34 species per relevé.

Quercus serrata community

In Mt. Tŏgyu, this community is located mainly on the middle parts of the slopes and somewhat mesic site between 700~1,000 m high.

Associated trees in this community include *Quercus monglica, Quercus variabilis, Carpinus laxiflora* and *Carpinus tschonoskii* in the upper tree layer. The lower tree layer is composed mainly *Styoax obassia* and *Lindera ohtusiloba.*

The shrub layer is poor and the field layer is dominated by *Sasa borealis* and *Aster scaber.*

The stems of the trees are 10∼45 cm in dbh with a height of 12∼15 m. The mean number of species was calculated as 30 spp./relevé.

***Pinus densiflora* community**

In Mt. Tŏgyu, this community occurs more abundantly at lower altitudes(900 m >) of the mountain, which were affected by human activity.

Habitats are situated on rocky upper slopes and/or convex ridges which are sometimes steep(ca. 25), usually dry with nutrient poor, shallow soils, and occasionally exposed to intensive light.

In the tree layer of this community, *Quercus veriabilis, Quercus serrata, Acer pseudo-sieboldianum,* and *Fraxinus sieboldian* are found as composition species with lower coverage.

The shrub layer is composed mainly of *Rhododendron mucronulatum, Rhododendron schippenbachii,* and *Lespedeza maximowiczii.* The field layer is dominated by *Milium effusum.* The stems are 10∼45 cm in dbh and generally attain a height of 12∼15 m. However some emergent trees attain heights of greater than 18 m. The average number of species is 37.3 spp./relevé.

***Fraxinus mandshurica* community**

The habitats of this community in Mt. Tŏgyu are located mainly on valley, mesic and nutrient rich slopes over 900 m high.

In the tree layer of *Fraxinus mandshurica*(Mt. Tŏgyu community), *Actinidia arguta, Acer mono, Cornus controversa,* and *Magnolia shaboldii* are found as componion species with lower coverage.

The shrub layer is composed mainly of *Deutzia glabrata, Alangium platnifolium, Hydrangea serrata* for. *acuminata,* and *Lonicera coreana.* The field layer is dominated by *Polystichum tripteron* and *Dryopteris crassirhizoma.*

The stems of trees are 10∼50 cm in dbh with a height of 12∼25 m. The average number of species obtained was 30 spp./relevé.

***Taxus cuspidata* community**

This community in Mt. Tŏgyu is situated on the top of mountain over 1,400 m high.

Associated trees in this community include *Acer harhinerv, Acer pseudo-sieboldianum, Abies koreana,* and *Betula costata.* The shrub layer is composed of *Tripterygium regelii* and *Rhodendron schippenbachii.*

The field layer is dominated by *Sasa borealis.*

The stems of trees are 8∼82 cm in dbh with a height of 8∼12m. The mean number of species was calulated as 29 spp./relevé.

The ordination diagram of CCA shows plant communities and environmental variables.

To interpret the CCA axes we used canonical coefficients and the correlation between the envionmental variables and the ordination axes. The relative importance of each environmental variable for the prediction of species composition along the ordination axes can be inferred from the signs and relative magnitude of the correlation coefficients(Table 1).

Species composition is divided into 8 groups alsong the Ⅰ, Ⅱ axes(*Pinus densiflora, Quercus variabilis, Quercus serrata, Quercus mongolica, Carpinus laxiflora, Fraxinus mandshurica, Taxus cuspidata, Quercus mongolica-Abies koreana* groups)(Fig. 3).

The relation between CCA ordination axes and environmental variables can be observed from Fig. 3.

Soil moisture, organic matter, potassium, lime, kaolin, cation exchange capacity(C · E · C), and topography are the environmental factor determining variation in species composition along axes Ⅰ. Altitude, pH and P_2O_5 are the environmental factor along axes Ⅱ. The variables, organic matter, C · E · C, and soil moisture are strongly correlated to one another. The

Table 1. Mt. Tŏgyu vegetation data from Fig. 3: canonical coefficients and the inter set correlation of environmental variables with the first two axes of CCA. For a description of variables, see Fig. 3 legend

Variables \ Axes	Canonical coefficient 1	Canonical coefficient 2	Canonical coefficient 1	Canonical coefficient 2
Altitude	0.253	0.707	0.233**	0.784**
Moisture	0.744	−0.051	0.831**	0.073
pH	0.157	−0.187	0.045	−0.509**
Organic matter	0.421	0.183	0.642**	0.204
P_2O_5	−0.186	−0.036	−0.026	0.369**
K	0.282	−0.099	0.517**	−0.173
Lime	0.108	−0.035	0.418**	−0.130
Kaolin	0.378	0.099	0.551**	−0.188
C・E・C	−0.327	−0.210	0.569**	0.093
Aspect	0.011	0.041	0.184	0.129
Topography	−0.166	0.011	−0.722**	0.269*
Slope	0.021	0.172	−0.263	0.060
Eigenvalue	1.216	0.758		

*P<0.5, ** P<0.01.

Note : C・E・C; Cation exchange capacity.

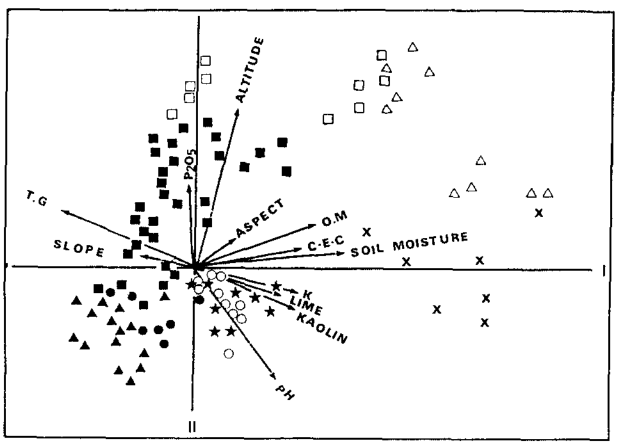

Fig. 3. Mt. Tŏgyu vegetation data: CCA(canonical correspondence analysis) ordination digram with sites (▲, ●, ★, ○, ×, △, ■, □) and environmental variables(arrows).

The symbols of the sites are: ▲=*Pinus densiflora*; ● =*Quercus variabilis*; ★=*Carpinus laxiflora*; ○=*Quercus serrata*; ×=*Fraxinus mandshurica*; △=*Taxus cuspidata*; ■=*Quercus mongolica*; □=*Quercus mongolica-Abies koreana*. The environmental variables are: O.M=Organic matter; C・E・C=Cation exchangeable capacity; P_2O_5=Available phoshorus concentration; K=Potassium concentration; T.G=Topography.

topography is strongly negatively correlated with pH and kaolin(Fig. 3).

Along axes Ⅰ, *Fraxinus mandshurica* group, and *Quercus mongolica-Abies koreana* with a high content of soil moisture and organic matter, are differentiated from the other communities. *Fraxinus mandshurica* is found in valleys and *Taxus cuspidata* and *Quercus mongolica-Abies koreana* are found at higher altitudes(1,400~1,600 m).

The arrangement of species along axes Ⅱ was also ecologically meaningful. The most important environmental variable along axes Ⅱ is altitude. *Quercus mongolica* group is found between 900~1,500 m high.

Quercus mongolica groups occupy the largest region in the study area. Fig. 4 shows the relationship between the quantitative distribution of *Quercus mongolica* and envirionmental variables throughout the 48 plots in the study area.

Axes Ⅰ of Table 2 shows high correlation between soil moisture and organic matter. Axes Ⅱ shows a high correlation between altitude and pH.

As in Fig. 4 the important value (ⅠV) of *Quercus mongolica* was shown to increase at a high altitude and a high content of P_2O_5 but to decrease at a low altitude along valley slopes.

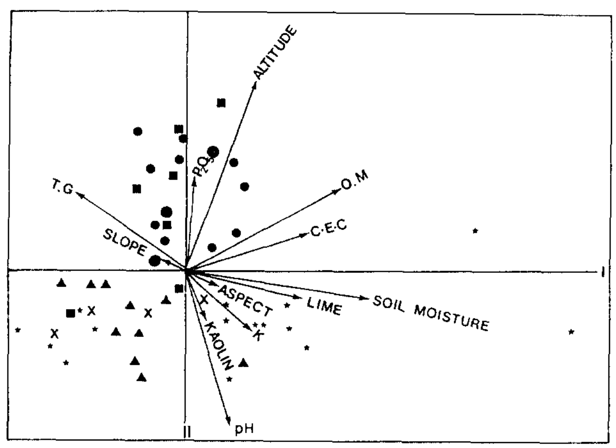

Fig. 4. Quantitative distribution of *Quercus mongolica* in the 48 sites of Mt. Tŏgyu: CCA ordiation digram with sites and environmontal variables(arrows).

Importance value[Xij=(dij+Di)/2]: ★, 10>; ▲, 11~20,; ×, 21~40; ■, 41~60; ●, 61~80; ●, 81~100.

Note: dij=relative density, Dij=relative dominance.

Table 2. Mt. Tŏgyu vegetation data from Fig. 4: canonical coefficients and the inter set correlation of environmental variables with the first two axes of CCA. For a description of variables. see Fig. 4 legend

Axes / Variables	Canonical coefficient		Canonical coefficient	
	1	3	1	2
Altitude	0.106	0.557	0.259	0.769**
Moisture	0.925	−0.225	0.817**	−0.114
pH	0.154	−0.328	0.189	−0.630**
Organic matter	0.290	0.204	0.693**	0.320*
P_2O_5	−0.162	0.010	0.032	0.403**
K	−0.025	−0.151	0.284*	−0.240
Lime	0.335	0.282	0.505**	−0.134
Kaolin	−0.058	0.126	0.069	−0.183
C · E · C	0.061	−0.387	0.528**	0.161
Aspect	−0.144	−0.064	0.113	−0.016
Topography	0.143	−0.049	−0.489**	0.331*
Slope	0.090	0.116	−0.112	0.053
Eigenvalue	1.169	0.880		

* P<0.5, ** P<0.01.

Note : C · E · C; Cation exchange capacity.

Song(1990) distinguished *Quercus mongolica* group into mesic type, middle type and xeric type, but our result is calculated to the highest important values (I V) in middle moisture gradient(Fig. 4). Thus, the optimal region of this community is considered middle type. Although middle type was the most suitable distribution area, mesic and xeric types were also significant in the distribution of *Quercus mongolica* group.

Quercus serrata group and *Carpinus laxiflora* groups are clumped together(Fig. 3). These groups are distributed at low altitude, high pH and high content of kaolin. In addition, *Pinus densiflora* and *Quercus variablis* groups are distributed at lower altitude, high pH and nutrient-poor soil.

As in data analyzed by CCA, the environmental variables correlated with the community type of Mt. Tŏgyu forest are the soil moisture[CCA; r=0.831], altitude[r=0.784], topograph[r=−0.722], organic matter[r=0.642], and pH[r=−0.509] among various environmental factors.

Altitude and soil moisture were strongly correlated with the dominant compositional gradient at localities examined in this study. They are the main factors in determing forest vegetation(Whittaker 1967, Peet 1981, Allen *et al.* 1991, Song 1990, Kim and Kil 1996). Also, topography and slope affect water availability, snow depth and incoming radiation among other factors(Daniels 1975).

The above result is congruent with the data of Song *et al.*(1987) Mt Tŏgyu and Kim and Kil(1991) for the Mt. Changan forest near Mt. Tŏgyu.

The ecological meaningful of the study was shown not only to classifying the plant communities on Mt. Tŏgyu, but also with determing how they were related to one another and to the environmental factors.

적 요

덕유산 국립공원의 삼림식생을 서열법(ordination)에 의하여 분석하였다. TWINSPAN에 의한 삼림식생의 분석 결과 소나무(*Pinus densiflora*), 굴참나무(*Quercus variabilis*), 졸참나무(*Quercus serrata*), 신갈나무-철쭉꽃(*Quercus mongolica-Rhododendron shlippenbachii*), 신갈나무-구상나무(*Quercus mongolica-Abies koreana*), 신갈나무-당단풍(*Quercus mongolica-Acer pseudo-sieboldiamum*), 신갈나무-노린재나무(*Quercus mongolica-Symplocos chinensis* for. *pilosa*), 서어나무(*Carpinus laxiflora*), 들메나무(*Fraxinus mandshurica*), 주목(*Taxuscuspidata*)의 10개 군으로 분류되었다.

식생의 종조성과 환경과의 상호관계를 분석한 결과 토양습도(r=0.831), 고도(r=0.784), 지형(r=−0.72), 유기물함량(r=0.642), pH(r=−0.509) 등이 높은 상관관계를 나타냈다.

CCA에 의하여 분석된 결과에 의하면 소나무와 굴참나무는 건조하고 보다 고도가 낮은 지대에서 분포하고 있으며 들메나무는 습하고 토양양분이 양호한 지역에, 졸참나무와 서어나무는 고도가 낮은 지역에서 군락을 형성하고 있으며 신갈나무-구상나무군과 주목은 보다 높은 지역(1,400∼1,600 m)에서 분포한다.

LITERATURE CITED

Allen, R.B., R.K. Peet and W.L. Baker. 1991. Gradient analysis of latitudinal variation in Southern Rocky Mountain forest. J. Biogeogr. 18: 123-139.

Brown, R.T. and J.T. Curtis. 1952. The upland conifer-hardwood forest of northern Wisconsin. Ecol. Monogr. 22: 217-234.

Carleton, T.J. 1990. Variation in terricolous bryophyte and macrolichen vegetation along primary gradients in Canadian boread forest. Journal of Vegetation Science. 1: 585-594.

Causton, D.R. 1988. Introduction to vegetataion analysis. London:Allen and Unwibn. 342 p.

Chŏnju Meteorological Observatory. 1994. Daily Meteorological Data. Chŏnju. pp. 33-35.

Clments, F.E. 1916. Plant succession: An analysis of the development of vegetation. In Ecology. M.E.D. Krebs. Harper and Row, New York. pp. 486-512.

Curtis, J.T. and R.P. McIntosh. 1951. An upland forest continuum in the preaerie-forest border region of Wisconsin. Ecol. 32: 476-496.

Daniels, F.J. 1975. Vegetation of the Angmagassalik direct of southeast Greenland. Ⅲ. Epilitic macrolichen communities. Medd. Gronl. 198: 1-5.

Diamond, J.M. 1978. Niche shift and the rediscovery of interspecific competition. Amer. Sci. 66: 322-331.

Gauch, H.G. 1982. Multivariate analysis in community ecology. Cambridge University Press, New York. 350 p.

Gradient analysis of latitudinal variation in Southern Rocky Mountain forests. J. Biogeogr. 18: 123-139.

Grime, J.P. 1980. Plant strategies and vegetation processes. Amold, London. 380 p.

Hill, M.O., R.G.H. Bunce and M.W. Shaw. 1975. Indicator species analysis: a divisive polythetic method of classification, and its application to a survey of native pine woodlands in Scotland. J. Ecol. 63: 597-614.

Kim, C.H. and B.S. Kil. 1991. Ordination analysis on the forest communities of Mt. Changan, Chŏnbuk. Korean J. Ecol. 14: 231-241.

Kim, C.H. and B.S. Kil. 1996. Species diversity of forest vegetation in Tŏgyusan National Park, Korea. Kroean J. Ecol. 19: 223-230.

Lee, C.B. 1979. Illustrated flora of Korea. Hyangmunsa, Seoul. 990 p.

Moore, P.D. and S.B. Chapman. 1986. Methods in plant ecology. Blaccwell Scientific Publications, Oxford. 589 p.

Oosting, H.J. 1956. The study of plant communities: An introduction to plant ecology. Freeman, San Francisco. 440 p.

Peet, R.K. 1981. Forest vegetation of the Colorade Front Range. Vegetatio. 45: 3-75.

Rural Development Administration. 1988. Method of soil chemical analysis. Seoul Yemuna. Seacl. 450 p.

Song, H.K., I.S. Woo, E.S. Min and N. Lee. 1987. Studies on the forest vegetation of Mt. Deokyu by classification and ordination techniques. Res. Rep. Env. Sci. Tech. Chungnam Univ. 5: 59-73.

Song, H.K. 1990. An analysis of vegetation-environment relationships of *Quercus mongolica* communities by detrended canonical correspondence analysis. Res. Rep. Env. Sci. Tech Chungnam Univ., Korea. 8: 1-5.

ter Braak, C.J.F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecol. 67: 1167-1179.

ter Braak, C.J.F. 1987. CANOCO-FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal components analysis and redundacy analysis(version 2.1). TNO institute of applied computer science, statistics department Wageningen. The Netherlands.

ter Braak, C.J.F. 1988. CANOCO an extention of DECORANA to analyze species-environmental relationship. Vegetatio. 75: 159-160.

Tilman, D. 1984. Plant dominance along an experimental nutrient gradient. Ecol. 65: 1445-1453.

Whittaker, R.H. 1951. A criticism of the plant association and climatic climax concepts. Northwest Sci. 25: 1731.

Whittaker, R.H. 1967. Gradient analysis of vegetation. Biol. Rev. 49: 207-264.

Yim, Y.J. and T. Kira. 1975. Distribution of forest vegetation and climate in the Korean Peninsular. I. Distribution of some indices of thermal climate. Japanes J. Ecol. 25: 77-88.

(*Received March 10, 1997*)