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Natural Environment Assessment and Management Using Geographic Information System[1*]

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지리정보체계를 이용한 자연환경평가 및 관리[1*]

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ABSTRACT

Development pressures are increasing on Korea's unique forest resources. To assess forest stand quality and provide effective information for generating management alternative, seventy three plots were established and surveyed in Mt. Minjuji, located in central of Korea. Using Plant Data Analysis Package (PDAP), twenty seven variables of vegetation and geographic data were prepared and analyzed. Ordination and factor analysis methods were used for data reduction tasks. Five types of vegetation structures were explained with the seral dynamics in Korea, and DCA ordination technique demonstrates that five types of vegetation are heterogeneous. In the factor analysis, thirteen variables were trimmed to five factors: factor 1 is the species richness; factor 2, a biomass; factor 3, stand density; factor 4, average age of stand; factor 5, geographical characteristics. The five factors were mapped. A model predicting successional state were estimated using multiple regression. The mode parameters include depth of organic matter, Shannon' s diversity index, DBH in the canopy layer and elevation.

KEY WORDS : FOREST, ASSESSMENT, MANAGEMENT, GIS

요 약

최근 개발의 압력을 받고 있는 충청북도 영동 민주지산을 대상으로 산림의 질을 평가하고 관리대안을 제시하고자 73개 조사구를 설정하여 조사를 실시하였다. 분석을 위해 27개의 식생과 지리정보변수를 마련하였다. 자료의 양을 줄이기 위해 ordination 기법과 요인분석을 사용하여 변수를 축소시켰다. 식생을 분석한 결과 다섯 개의 군집으로 분류되었으며, 이는 DCA에서도 비슷한 경향을 나타내었다. 요인분석에서는 13개의 변수가 5개의 요인으로 압축되었는데, 요인 1은 수종의 풍부도, 요인 2는 건중량, 요인 3은 밀도, 요인 4는 임령 그리고 요인 5는 지리적 특성으로 나뉘어졌다. 천이상황를 예측하는 모형은 다중회귀로 표현되었고, 주요 변수로는 유기물의 깊이, Shannon의 종다양도 그리고 흉고직경이 사용되었다. 그리고 GIS를 이용한 산림관리의 의사결정과정을 도출하였다.

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주요어 : 삼림, 평가, 관리, GIS

INTRODUCTION

Mt. Minjuji is located in the central part of South Korea. For the past time being, that mountain have been preserving with plentiful fauna and flora ecosystem. But in 1991, the plan of Youngdong comprehensive resort was performed using simple and unverified naturalness assessment. Local residents, researchers and environmentalists etc. are protesting against the development. A verified model for evaluating the naturalness of the forest ecosystem is needed.

Numerous studies have been carried out forest assessment (Peterken, 1974; Ratcliffe, 1977; Usher, 1980; Goldsmith, 1983; Kirby, 1986; Fehringer et al., 1997) and management (Covington et al., 1986; Dewhurst et al., 1995; Zybach et al., 1995; Voinov et al., 1997). Forest assessment studies have centered on the conservation biology and environmental impact assessment (EIA), while management studies have increasingly appeared with use of geographic information system (GIS) to incorporate related geospatial data.

Due to the many environmental factors available for analysis and difficulty of establishing criteria for assessing forest quality, criteria suggested or used by many studies are different (Goldsmith, 1983). For example, Kirby (1986) has chose basic criteria such as naturalness, species richness, rare or special species, history and prospect etc. and Ratcliffe (1977) has suggested 10 criteria; those are size, diversity, naturalness, rarity, typicalness, fragility, recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal. In spite of different sets of criteria, Usher (1980) suggested that there are some criteria for selecting area for nature reserves in common use which include number of habitats and/or species, naturalness and rarity of both habitats and species and area. As such the studies of forest assessment seemed to concentrate focus on identifying the evaluation factors.

Since the introduction of geographic information systems (GIS) in the early 1960' s, use of GIS in forest management has increased greatly. The essence of GIS is its multidisciplinary character. For this reason, in combining GIS and forest data increases the efficiency of management. GIS has been developed, for natural-resource management and landuse planning. It relys on data from existing maps, or on data can be mapped readily (Star & Estes, 1990). A very powerful use of GIS is the ability to model management practice in relation to the predefined ecological units (Lachowski et al., 1994). Due to the powerful functions of GIS, in the U.S. government during the past two decades, resource management concerns development of spatial data processing systems (Star & Estes, 1990). The recent advances in GIS will contribute to further development of computer based method of forest evaluation by potentially expanding the types of factors taken into consideration and explicitly representing spatial correlations along with factor correlation, making it a potentially important tool for evaluation, monitoring and managemet of change (Spellerberg, 1992).

To date, many studies related to forest assessmet in Korea have dealt with structure or succession. Recently, however, with increasing development pressure on forest resources, there is the need to develop efficient assessment and management studies.

The objective of this research is to (1) evaluate the explanatory power of various factors identified from the literature, (2) undertake reduction methods to economize on information requirements, (3) determine statistical relationships between factors and successional states, and (4) employ a descriptive model to guide management planning activities.

STUDY AREA

This study was conducted in the area of Mt. Minjuji (36° 02′ 30″N, 127° 52′ 30″E). It is located between Youngdong-Gun, Choongcheongpuk-Do and Muju-Gun, Chollapuk-Do in the central part of South Korea(Figure 1). The elevation of the study area ranged from 560m to 1142m, and the area is about 843ha. As a part of Soback Mountain Range(the major mountain range in Korea), it has a varied fauna and flora ecosystem. Most of the forest stands are secondary growth. Primary species of vegetation are: *Quercus mongolica, Q. variabilis, Pinus densiflora, Carpinus laxiflora* and mixed forest consisting of *Fraxinus mandshurica, Carpinus cordata, Acer mono, Cornus controversa,* and *Ulmus davidiana* var. *japonica* (Choi *et al.*, 1997). The study area is generally heterogeneous across vegetation types. The forest contains stands at various stages of maturity from early successional to climax.

For the period 1983～1992, the average annual temperature was 11.6℃, the average annual highest temperature was 34.0℃ and the average annual lowest temperature was -13.9℃. Annual precipitation averages is 1214.0mm, but c. 68% of the total rainfall is occurs during the months from June to September (KMA, 1991).

MATERIAL AND METHODS

1. Material

Seventy three $100m^2$(10m × 10m) plots were selected in the study area in a stratified (by predominat species) random sample (Figure 1) (Lee *et al.*, 1992; Choi *et al.*, 1997). Three vertical layers were sampled as canopy, understory and shrub. All woody plants of 1cm DBH (Diameter at Breast Height) or larger within the plot, were identified. To estimate the average age of each forest stand, tree ring were extracted by increment borer from selected tree based on the average DBH. Depth of organic matter was recorded by averaging the three observations in each plot. Elevation data were obtained for the study area from the measurement with derivative slope and aspect products calculated using the GIS.

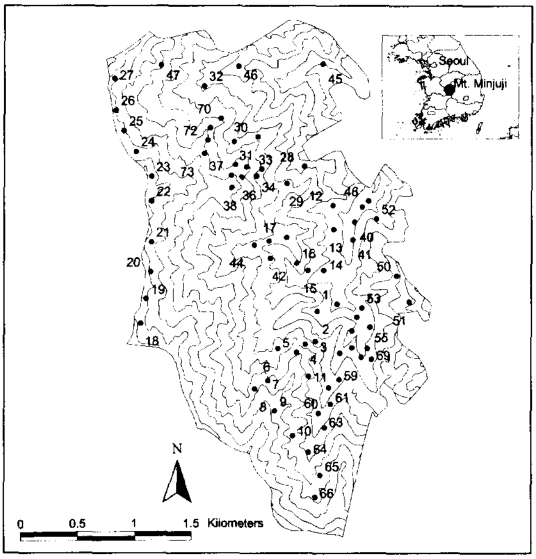

Figure 1. Location of the study area and survey plots

2. Methods

(1) Vegetation structure

All the vegetation data were collected in the format of PDAP (Plant Data Analysis Package) developed by the Environmental Ecology Laboratory at the University of Seoul in Korea. Data collected from the survey plots included vegetation type, frequency, basal area, DBH, and depth of organic matter (Table 1). Other data include geographic characteristics of the study area.

Vegetation data frequencies collected from the field plots were used to compute a series of

Table 1. List of variables

Data	Code name	Description of variable
Vegetational	VEGE_T	Vegetation type
	SHANNON	Index of Shannon's diversity
	SIMPSON	Index of Simpson's diversity
	PIE	Index of PIE diversity
	EVEN	Index of evenness
	DOMI	Index of dominance
	MAX_H	Index of maximum diversity
	INDI_C	Number of individuals in canopy layer
	INDI_U	Number of individuals in understory layer
	INDI_T	Number of Total individuals
	N_SPEC	Number of species
	BA_C	Basal area of canopy layer
	BA_U	Basal area of understory layer
	BA_T	Total basal area
	DBH_C	Average DBH in canopy layer
	DBH_U	Average DBH in understory layer
	DBH_T	Average DBH in total layer
	AGE_F	Age of forest
	OM	Depth of organic matter
	QMIV	Importance value of *Quercus mongolica*
	QVIV	Importance value of *Quercus variabilis*
	CLIV	Importance value of *Carpinus laxiflora*
	PDIV	Importance value of *Pinus densiflra*
	MBIV	Importance value of Mixed forest
Geographic	SLOPE	Slope
	ALTI	Altitude
	ASPT	Aspect

metrices of relative uniqueness and dominance of any particular surveyed species. These metrics include an index of importance value (I.V.), a weighted mean importance value (M.I.V.) (Curtis & McIntosh, 1951; Choi & Lee, 1993), and several diversity including Shannon-Weaver's (Shannon & Weaver, 1963), Simpson's (Simpson, 1949), and Hurbert's PIE (the Probability of Interspecific Encounter) (Hurbert, 1971) diversities, and indices of maximum diversity, dominance and evenness (Odum, 1983).

The importance value (I.V.) and mean importance value (M.I.V.) were obtained as follows:

$$\text{I.V.}=(\text{Relative density}+\text{Relative coverage})/2$$

$$\text{M.I.V.}=(3\times IV_{up}+2\times IV_{mid}+1\times IV_{low})/6,$$

where I.V. = 0 if species not present, and subscript up, mid and low indicate canopy, understory and shrub layer respectively. Relative (per cent) density and relative (per cent) coverage were estimated in the ordinary manner (Raunkiaer, 1934, Curtis & McIntosh, 1950).

(2) Ordination

Ordination methods reduces the many dimensions of the system to a very few, with minimum loss of information, and orders plant communities according to the environmental gradient. The results of ordination should enhance the clarity of major patterns of variation (Beals, 1984).

In order to summarize the five vegetation types, ordination method was used with Detrended Correspondence Analysis (DCA) technique (Ludwig & Reynolds, 1980). The DCA is a weighted averaging methods which applying alternating weighed averaging regressions and calibrations to a species-by-site data table (Hill, 1973). Hill & Gauch (1980) developed DCA as a heuristic modification of correspondence analysis (CA) designed to remedy both the edge effect and the arch effect. DCA often works remarkably well in practice (Hill & Gauch, 1980; Gauch *et al.*, 1981).

The data file for analyzing the DCA was prepared by PDAP, and in order to analyze the DCA ordination, DECORANA was used (Hill, 1979; Lee *et al.*, 1992). The ordination technique based on DCA represents community data in ordination diagrams (Ter Braack & Prentice, 1988).

(3) Factor analysis

To eliminate the codependent variable, factor analysis methods were applied to the data set. This reduction produces combinations of the original data, and supports further analysis, such as multiple regression (Shaw & Wheeler, 1994). Principal components analysis (PCA) was used to define the new factors using SPSS/PC+ software and the resulting factors were incorporated into the GIS database for future assessment and management activities. Finally, multiple regression was used to estimate a model testing the strength of relationship between factor components and forest vegetation structure.

RESULTS AND DISCUSSION

1. Vegetation structure

Succession has been recognized as a fundamental ecological process (Odum, 1969; Halpern *et al.*, 1997). Competitive displacement is often assumed to be the mechanism for species replacement during succession (Connell & Slatyer, 1977; Tilman, 1985; Armesto & Pickett, 1986; Choi & Lee, 1993). In the temperate zones of middle part of Korea, the successional trend was believed to be from *P. densiflora* through *Quercus* spp. to *Carpinus laxiflora* or *C. cordata* (Lee *et al.*, 1992, 1994). But in recent study of Mt. Minjuji area, mixed forest consisting with *Fraxinus mandshurica, Cornus controversa* etc. was reported to be an edaphic climax forest (Choi *et al*, 1997). As such five communities were distributed heterogeneously, and can be explained by successional dynamics, rather than a static progression from one species state to the next.

Using PDAP, importance value (I.V.) and mean importance value (M.I.V.) are calculated. Figure 2 shows the distribution of M.I.V. among the five communities. M.I.V. is recorded over 40% in *Q. mongolica*(44.5%), *P. densiflora*(43.3%) and mixed broad-leaf(53.3%) community respectively. The other communities were *Q. variabilis*(24.3%) and *C. laxiflora*(34.5%).

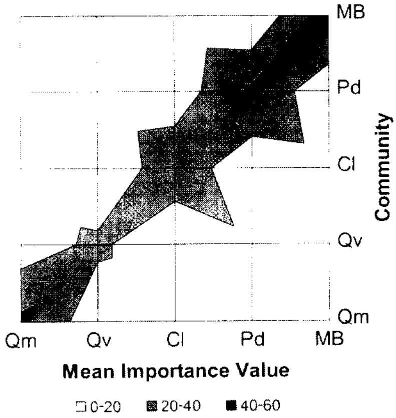

Figure 2. Distribution of mean importance value(M.I.V.) among vegetation communities(Qm:*Quercus mongolica*, Qv: *Q. variabilis*, Cl: *Carpinus laxiflora*, Pd: *Pinus densiflora*, MB: mixed broad-leaf forest)

The relationship between major species within

Table 2. Importance value and mean importance value of major woody species by layer in each community

Community/Species	I.V.(%)			M.I.V.(%)
	Canopy	Understory	Shrub	
Community I				
Quercus mongolica	69.1	27.3	4.9	44.5
Q. variabilis	9.1	3.0	1.8	5.9
Pinus densiflora	4.4	0.9	0.1	2.5
Fraxinus mandshurica	3.4	7.9	4.3	5.5
Acer pseudosieboldianum	0.0	11.1	1.5	4.0
Symplocos chinensis for. *pilosa*	0.0	9.4	5.4	4.1
Carpinus cordata	0.0	5.4	0.4	1.9
Stephanandra incisa	0.0	0.0	6.2	1.0
Others	14.0(10)	*35.0(39)	75.4(32)	31.3(52)
Community Ⅱ				
Quercus variabilis	37.2	14.6	5.1	24.3
Pinus densiflora	31.0	0.9	0.0	15.8
Quercus mongolica	8.2	11.2	5.5	8.7
Carpinus laxiflora	1.8	0.0	0.4	1.0
Vaccinium oldhami	0.0	10.8	2.4	4.0
Lindera obtusiloba	0.0	3.2	11.1	2.9
Lespedeza cyrtobotrya	0.0	0.0	17.9	3.0
Others	21.8(7)	59.4(21)	57.7(26)	40.3(33)
Community Ⅲ				
Carpinus laxiflora	38.0	43.0	7.0	34.5
Querucs serrata	17.5	3.1	3.2	10.3
Fraxinus mandshurica	14.0	0.0	0.0	7.0
Quercus mongolica	9.3	2.1	0.1	5.4
Pinus densiflora	3.4	6.2	0.0	3.8
Acer pseudosieboldianum	0.0	14.4	4.8	5.6
Styrax obassia	0.0	10.8	9.2	5.1
Others	17.8(6)	20.6(16)	75.8(20)	28.4(30)
Community Ⅳ				
Pinus densiflora	81.3	7.9	0.0	43.3
Quercus varialibis	4.8	5.5	0.2	4.3
Q. mongolica	2.1	5.8	1.3	3.2
Q. serrata	0.8	11.1	7.7	5.4
Carpinus laxiflora	0.6	14.8	15.7	7.9
Vaccinium oldhami	0.0	10.3	0.2	3.5
Weigela subsessilis	0.0	0.9	6.8	1.4
Others	10.4(6)	43.7(33)	68.2(40)	31.1(54)
Community Ⅴ				
Fraxinus mandshurica	39.9	5.8	5.2	22.7
Cornus controversa	18.1	3.9	0.2	10.4
Acer mono	11.5	11.9	2.7	10.2
Carpinus cordata	6.1	8.4	6.1	6.9
Ulmus davidiana var. *japonica*	6.1	0.3	0.0	3.1
Carpinus laxiflora	3.3	2.8	0.0	2.6
Staphylea bumalda	0.0	7.5	14.7	4.9
Others	15.2(16)	59.5(34)	71.2(39)	39.3(49)

*The parentheses include the rest of number of species.

each layer was shown by the species composition of each community (Table 2). From the I.V. and M.I.V. calculations, five communities (*Q. mongolica*(Ⅰ), *Q. variabilis*(Ⅱ), *C. laxiflora*(Ⅲ), *P. densiflora*(Ⅳ) and mixed broad-leaf species(Ⅴ)) were identified.

In the case of community Ⅰ, canopy(I.V. 69.1%) and understory(I.V. 27.3%) layers were dominated by *Q. mongolica*. *P. densiflora*, pioneer species in the sere, has lost its niche because *P. densiflora* is needle leaf and, hence, it has poor low light tolerance.

In community Ⅱ, *Q. variabilis* was the dominant species in both the canopy and understory layer even though *P. densiflora* was recorded relatively frequently in the canopy layer. Like community Ⅰ, it is supposed that I.V. of *P. densiflora* will decrease precipitously from the results of competition with *Q. variabilis* through all layers because *P. densiflora* was rarely found in the understory and shrub layer.

In community Ⅲ, *C. laxiflora* was the dominant species through all layers. Although *Q. mongolica* has occupied the same niche, it will replace by *C. laxiflora* under the climate seral dynamics in Korea.

In community Ⅳ, the canopy layer overwhelmed the other species with *P. densiflora*, but *C. laxiflora* was the dominant species in understory and shrub layers. It was assumed that *C. laxiflora* will ultimately out-compete *P. densiflora* through the interspecific competition.

In community Ⅴ, a broad-leaf species mix consisting of *Fraxinus mandshurica, Cornus controversa, Acer mono, Carpinus cordata*, and *Ulmus davidiana* var. *japonica* has a shared similar niche.

In summary, communities Ⅰ - Ⅳ represent the expected successional pregression for this climate sere with community Ⅳ in transition from a pioneer community to an intermediate state, community Ⅰ in transition to a climax community, community Ⅱ moving directly from a pioneer to a climax state, community Ⅲ in a climax state, and community Ⅴ is an unexpected, but climax, community.

Shannon's diversity index was calculated for the number of individuals in and basal area in canopy layer. One-way ANOVA tests were used to compare those variables (Table 3). The *Q. variabilis* community recorded the highest value 0.9518, while the *Q. mongolica* community had the lowest value of 0.6801. The value of *Q. variabilis* community differ significantly from *Q. mongolica* and mixed broad-leaf forest communities.

The number of individuals in canopy layer, was highest (13.5/100m^2) in the *Q. variabilis* community, and significantly lower in the mixed broad-leaf community. The basal area of the *P. densiflora* community was significantly higher than other communities.

Competition from the seral plant community reduced the size and abundance (cover and biomass) of community (Coombs, 1976; Connell, 1978; Choi, 1992; Halpern *et al.*, 1997).

Table 3. Statistically significant differences among major vegetation variables (oneway-ANOVA, Sig. $p<0.05$) are indicated by superscripts (Unit:/100m^2)

	Shannon's Index	# of indi. in canopy layer	Basal area in canopy layer
Qm	0.6801^a (0.6056-0.7545)	11.94^a (9.96-13.91)	3325.68^a (2771.21-3880.16)
Qv	0.9518^b (0.7854-1.1182)	13.50^a (10.55-16.45)	3086.24^a (1628.37-4544.11)
Cl	0.7628 (0.6135-0.9121)	10.80 (5.58-16.02)	4169.45 (2710.72-5628.18)
Pd	0.8193 (0.6782-0.9604)	11.50 (6.75-16.25)	5963.14^b (2683.82-9242.46)
MB	0.7431^a (0.6686-0.8176)	8.23^b (6.38-10.07)	2996.34^a (2358.34-3634.34)

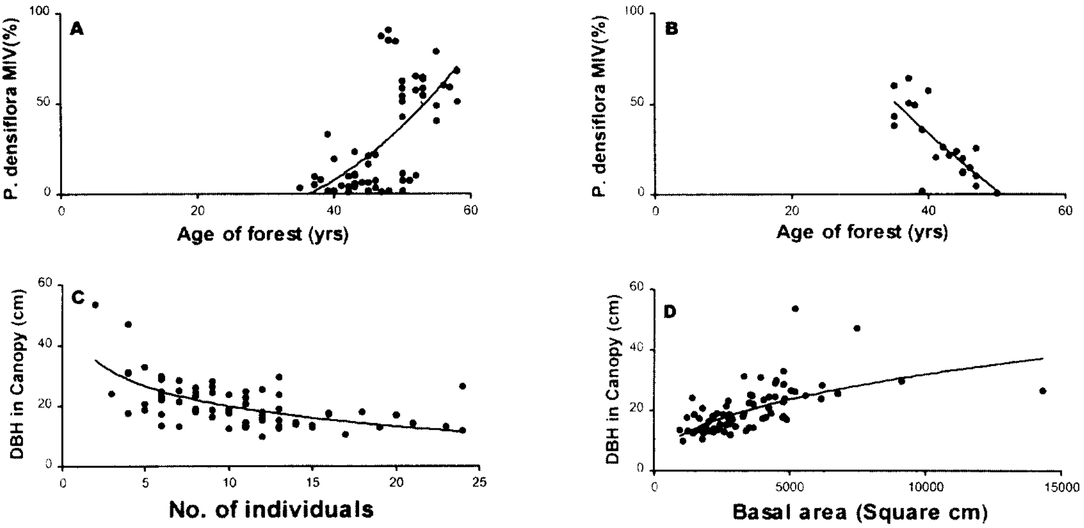

Figure 3. The scatter plot and trend line between major variables. (A) is relation of between I.V. of mixed broad-leaf community and the age of forest, (B) is I.V. of *P. densiflora* and the age of forest, (C) is DBH and number of individuals, and (D) is DBH and basal area.

Therefore, although *C. laxiflora* and mixed broad-leaf forest were assessed climax stage, they have had lower indices of diversities and number of individuals (Lee *et al.*, 1992; Choi *et al.*, 1997).

Analysis between major variables showed significant non-linear regressions (Table 4, Figure 3). The analysis of between I.V. of the mixed broad-leaf community and age of forest revealed significant quadratic relationship. The age of forest increased with the importance value of mixed broad-leaf community. On the contrary, in the analysis of between I.V. of *P. densiflora* and age of forest, I.V. of *P. densiflora* decreased with the age of forest. DBH and number of individuals revealed a negative natural logarithmic curve relationship and the relationship between DBH and basal area fit the simple power curve. According to the succession dynamics, Figure 3 showed that I.V. of *P. densiflora* (B) decreased through the inter-species competition with time, while on the contrary, I.V. of mixed broad-leaf species (A) was increased. This reveal changes in the relative density of the species.

Table 4. The regression model equations of major variables

Variable		Regression	R^2
Dependent	Independent		
I.V. of *P. densiflora*	Age of forest	$\hat{y}= 0.0235X^2-5.2641X+206.34$	0.615
I.V. of Mixed forest	Age of forest	$\hat{y}= 0.0612X^2-2.5472X+11.866$	0.417
DBH in canopy layer	No. of individuals	$\hat{y}= -9.6041 \ln(X) + 42.022$	0.410
DBH in canopy layer	Basal area	$\hat{y}= 0.5734 X^{0.498}$	0.452

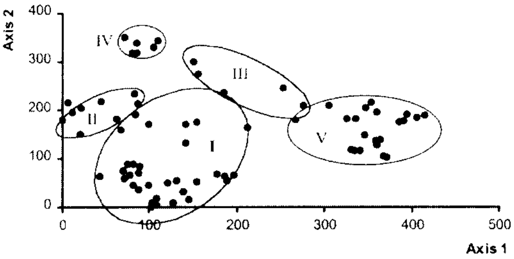

Figure 4. DCA diagram of seventy three plots

2. Ordination

The detrended correspondence analysis (DCA) was applied to PDAP data, which contain mean importance values (M.I.V.) of each species as plot and presence-absence data on seventies three plots. The first two axes explained 73.0% of the cumulative variance. The results were plotted with the vegetation groups obtained from clustering of DCA scores followed by vegetation characteristics (Figure 4). There was a vegetation discontinuum among communities except between *Q. mongolica* and *Q. variabilis.*

3. Factor analysis

For the factor analysis, twenty seven variables was trimmed to thirteen, focusing on those that were generally well-correlated. The method of principal components was used, and varimax rotation was applied. The principal components approach is simple and solves the communality problem, and it can be directly computed to get the factor scores since it assumes common variance. Varimax rotation makes less ambiguous with variables. An eigenvalues of 1.0 was adopted as the cut-off points. Of the thirteen factors, five factors have eigenvalues exceeding 1.0. The five accounted for 84.7 per cent of the varables in the data set (Table 5). Factor 1 was comprised of Shannon' s diversity, number of species and Simpson' s diversity index were highly positively loaded. Factor 2 contained four variables: basal area and average DBH in canopy and understory layers respectively. The highly related variables in factor 3 were the number of individuals in canopy and understory layers respectively. Age of forest and depth of organic matters were highly related variables in factor 4, and elevation (altitude) and slope were in factor 5. Factor 1 is termed the species richness; factor 2, biomass; factor 3, density; factor 4, time; factor 5, geography.

Table 5. Factor loadings for vegetation and geographic variables (varimax rotation)

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
SHANNON	.96008	-.00381	-.02469	.00516	-.05027
N_SPEC	.93318	.03442	.18702	-.03782	-.03681
SIMPSON	.89425	-.01251	-.16290	.02869	-.02839
BA_C	-.01438	.96972	.07596	-.12869	-.07047
BA_T	.01048	.96612	.14068	-.13250	-.03623
DBH_C	.17256	.71134	-.55542	.10661	.07368
DBH_T	-.50512	.61035	-.32668	-.15201	-.18209
INDI_C	-.22189	.09773	.86965	-.17077	-.04638
INDI_T	.35912	-.06193	.83871	-.06784	.09483
OM	-.21311	-.24596	-.00958	.88929	.09758
AGE_F	.20162	-.04101	-.25750	.86131	-.08874
ALTI	-.00192	.03578	.01376	.20687	.82517
SLOPE	-.08427	-.17066	.00708	-.35231	.63906

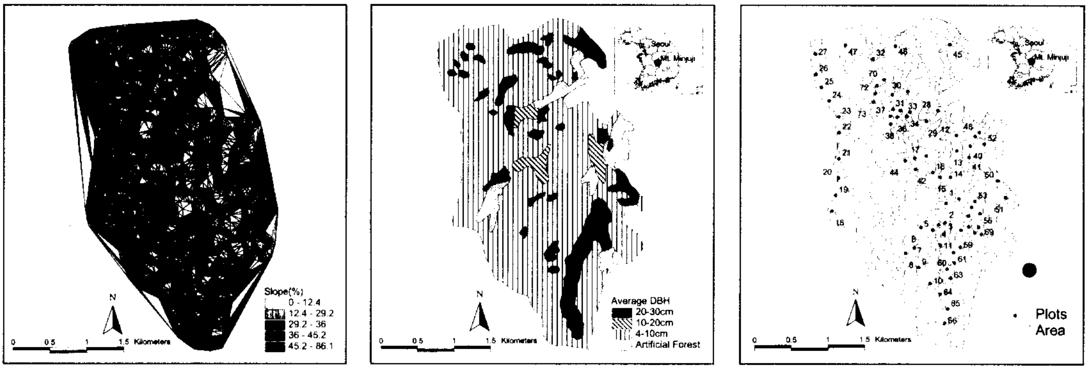

Figure 5. The results of GIS analysis and thematic map of Mt. Minjuji

4. GIS application

Others, spatial attributes of the region were considered in the factor analysis. Elevation data for altitude and terrain configuration (slope, aspect) were developed. GIS was also used to display the level of attributes for factors for each forest stand type. Figure 4 shows the results of GIS slope analysis and a thematic map of DBH of Mt. Minjuji. Factor scores provide a measure of the relationship between each observation and the new factors. Factor scores also can give the advantages of simplifying the original variables into a smaller number of factors, and be mapped out in geographical space (Shaw & Wheeler, 1994). Table 6 showed the factor scores calculated using SPSS system. Each factor was obtained by the calculation like the regression equation. At this time, each variable itself loads heavily on each factor. All variables were used so that standardized values could be made. Therefore each factor score reflected the combined influence of those high-scoring variables (Shaw & Wheeler, 1994). Figure 5 shows the spatial results for the Mt. Minjuji study area.

Factor 1 (richness) corresponds with areas dominated by *Q. variabilis*. In the successional dynamics in Korean, although mixed broad-leaf and *C. laxiflora* community are climax stage, *Q. variabilis* and *P. densiflora* was highly scored. The reason was that high-

Table 6. Factor score for the natureness of Mt. Minjuji

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
SHANNON	.30721	.00471	-.03654	-.02572	-.02537
SIMPSON	.28938	-.00701	-.10821	-.03392	-.00496
INDI_C	-.08883	.08743	.46516	.05927	-.05714
INDI_T	.09639	.05451	.43389	.08674	.06653
N_SPEC	.29497	.03387	.07652	-.01077	-.01580
BA_C	.00737	.36203	.10764	.05147	.01659
BA_T	.01439	.36911	.14098	.05959	.04544
DBH_U	.07719	.24909	-.23045	.05646	.14111
DBH_T	-.14570	.16793	-.13539	-.06691	-.11308
SLOPE	-.00830	-.05664	-.08362	-.23411	.54125
ALTI	.01032	.11050	.02921	.14777	.73016
AGE_F	.04775	.06318	.00028	.49105	-.06211
OM	-.09116	.01948	.13025	.53867	.07138

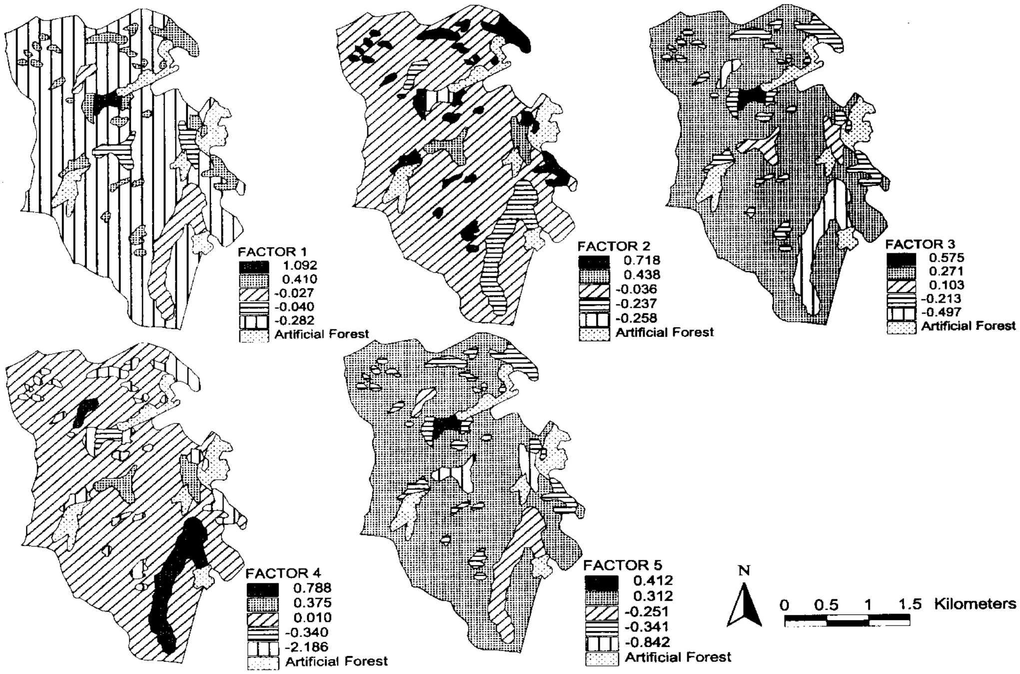

Figure 6. Maps of five factor scores. Factor 1 accounts for 25.6%, factor 2 22.6%, factor 3 18.6%, factor 4 9.4% and factor 5 8.5% of the data variance.

er diversity is achieved when there is a severe competition between populations or the disturbances are intermediate in frequency and intensity (Coombs, 1976; Connell, 1978; Choi, 1992). On the contrary, *Q. variabilis* has a low factor score in biomass factor, factor 2. Instead, *P. densiflora* and *C. laxiflora* communities showed higher rank. In terms of factor 3, density factor, *Q. variabilis* and *Q. mongolica* communities were recorded higher value, while mixed broad-leaf and *C. laxiflora* have lower ones. Usually during a primary stage in successional dynamics, many species would be introduced (Lee *et al.*, 1994). The mixed broad-leaf and *C. laxiflora* communities, climax stage in Korea(Choi *et al.*, 1997), were rated high in factor 4 (age of forest). The dominance of the mixed broad-leaf community indicates that the forest community is currently stable in terms of ecological succession. The last factor, geography, consisting of altitude and slope variables, showed *Quercus* spp. communities rated high.

5. Multiple regression analysis

For the purpose of demonstration, we assumed forest age to be an adequate substitute measure of importance (Table 4). To find out the maturity function between variables in Mt. Minjuji of Korea, multiple regression analysis was applied using SPSS. Stepwise regression was adopted to select variables. That regression is to combine the efficiency of forward inclusion and backward elimination with the throughness of all possible regression(Shaw & Wheeler, 1994). Dependent variable was age of forest, and thirteen independent variables were entered into the model. The results of the regression analysis gave the following equation.

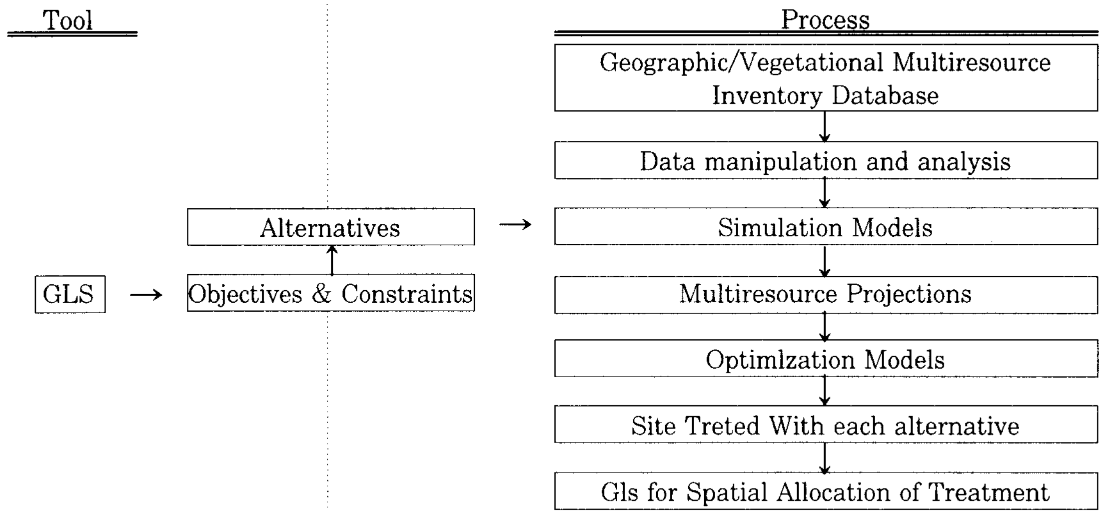

Figure 7. The process of decision support system(This flowchart was modified from Covington et al. (1988))

$$\hat{Y} = 16.9216 + 0.9358\,X_1 + 9.4272X_2 + 0.2145\,X_3 - 0.0056X_4\ (R^2 = 71.0\%),$$

where X_1 is depth of organic matters, X_2 is index of Shannon' s diversity, X_3 is DBH in canopy layer and X_4 is altitude.

These partial regression coefficients are unstandardized and, therefore, direct comparisons are difficult (Shaw & Wheeler, 1994). So, a relative importance can be determined from the beta weights of the variables. Thus, the beta values of X_1 was 0.8188, X_2 was 0.3266, X_3 was 0.2897 and X_4 was -0.1503. From this regression equation, therefore, depth of organic matter produced the most rapid change in the dependent variables, the age of forest.

In the study of simulation of organic matter accumulation, Kellomäki & Kolström(1992) showed that the accumulation of organic matter is precipitously increased by *c.* 50 to 100 years. Comparing that with the range of the age of forest in study area which is *c.* 37 years in *P. densiflora* to 52 years in mixed broad-leaf forest, the maturity function was well explained by depth of organic matter even though it has times limitation.

In the study of criteria for forest nature reserves, Goldsmith (1987) has selected four criteria which are number of plant species, number of rarities, area and diameter of the largest trees, and those criteria were quantified and then ranked. In the maturity equation, index of Shannon' s diversity and DBH in canopy layer were the similar criteria with Goldsmith' s ones.

In order to assess the statistical significance of the model, Table 7 was prepared, from which it is concluded that the model is valid and the null hypothesis of no explanation is rejected.

Table 7. ANOVA table of regression model for maturity of Mt. Minjuji (four predictors)

Source	Sum of Squares	df	Mean Square	*F* ratio	Sig. *F*
Regression	1623.671	4	405.918	41.554	.0000
Residual	664.247	68	9.768		
Total	2287.918	72			

$R^2 = 0.709$; critical $F(.95{:}4,68) = 2.51$

6. Management options

The management of forest resource must be driven by an objective or set of objective, and management alternatives must be evaluated (Covington *et al*, 1988). Johnson (1986) suggested that one way to accomplish forest management would be through the analysis of feasible actions on individual sites. Figure 6 is a process for decision support system to fit the vegetation in Korea. The flowchart was modified from the TEAMS (Terrestrial Ecosystem Analysis and Modeling) decision support system. Actually, this model is proposed for planners and foresters to remove the gap between strategic planning and implementation. Since graphic results are obtained, this model is helpful to specify how each stand should be treated. Using the graphic results, the managers can compare to goal, standard, and guidelines (Covington *et al.*, 1988).

CONCLUSIONS

At this early stage of the study in the Mt. Minjuji region, the emphasis reported here is on the development of descriptive models to relate observed variables to the rarity and uniqueness (Importance Value) index of the various forest habitat types. Based on the regression model defined in Table 6, management objectives might focus on managing species diversity, and three size and maturity. Simulation models of forest stand structure that focus on tree growth and interspecies competition (Voinov *et al.*, 1997) could conceivabely be used by to assess various management options and their predicted outcomes with respect to maintaining the importance of the forest resource. It is also conceivable that optimization models could be constructed for spatial allocation of management activities although it shoud be recognized that these would be best used as points of departure for management plans, rather than be construed as a plan in and of themselves. Given the spatial properties of the forest features GIS can be used to make various management alternatives and perform evaluations.

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