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Minimal Areas and Community Structures of *Pinus densiflora* Forests and *Quercus mongolica* Forests

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소나무림 및 신갈나무림의 최소면적과 군락구조

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ABSTRACT

A comparative study on the minimal areas and the community structures in pine (*Pinus densiflora*) and oak (*Quercus mongolica*) forests was carried out. Basic tools used in the present study were species diversity and classical syntaxonomy (Z.–M. School) of the phytocoenosis. Total 120 nest-quadrats in 40 stands situated at the syngeographical region of the Lindero-Quercion mongolicae were investigated. Each stand was classified on the basis of species combination, and species abundance was computed with net contribution degree (NCD). Composition ratio of plant-form and rate of actual species diversity (ASD) to syntaxa were computed for better interpretation of the minimal areas. Four syntaxa were structured: Saso-Quercetum mongolicae, *Viola albida-Quercus mongolica* community, *Carex humilis-Pinus densiflora* community and *Juniperus rigida-Pinus densiflora* community. Their minimal areas were determined as 305, 196, 169, and 81 m^2, respectively. A consistent regularity between species composition ratio and community structure in the multi-layered plant community was hardly found. The minimal areas increased linearly with increasing rate of ASD, and a phytocoenosis developed by diverse arboreta in the understory and shrub-layer should be investigated with larger sampling sizes.

Key words: Actual species diversity, Life-form, Minimal area, Net contribution degree (NCD)

INTRODUCTION

In the Zürich-Montpellier School, the relevé selection is the most important task in the beginning stage of syntaxonomical research (Barkman 1968). Because a classified vegetation unit depends on relevé information by species composition such as homogeneity, representativeness and species pool to which ecologists have paid attention (Westhoff and van der Maarel 1978).

Thus establishment of relevé site has been emphasized as follows: a relevé size possibly comprising the species pool, a uniform environmental condition of habitat, and a homogeneous vegetation cover (Moravec 1973, Mueller-Dombois and Ellenberg 1974). Size and shape of a relevé are generally based on vegetation physiognomy and/or species composition (Becking 1957). Specifically, a size of the relevé area might be diverse due to different species pool depending on various vegetation types (Knapp 1984). In this respect, determination of minimal area to respective phytocoenosis is the most significant task in the syntaxonomy.

On the other hand, methodology for determining the minimal area has been historically developed in Europe and Russia, which is spontaneously considered in the central European's vegetation science (Sobolev and Utekhin 1984). Five methods are recognized: species-area (incl. relevé number) curve by Braun-Blanquet and Jenny (1926) and Kylin (1926), frequency-area curve by Du Rietz *et al.* (1921), statistical procedures by Chouard (1932), qualitative minimal area by Moravec (1973), and similarity level of phytocoenosis by Dietvorst *et al.* (1982). Some American reviews to minimal area determination were also found mostly concerning species-area curves (Cain 1938, Rice and Kelting 1955, Vestal 1949).

The present study was carried out with species-area curves and aimed to clarify the minimal area of two vegetation types canopied by *Quercus mongolica* and *Pinus densiflora.* In south Korea, no research has been done on minimal areas, although there are many syntaxonomical works (Kim *et al.* 1994).

MATERIALS AND METHODS

Study sites

The study was carried out in the mongolian oak (*Quercus mongolica*) and red pine (*Pinus densiflora*) forests which are widespread in central and southern parts of the Korean peninsula. Stands were randomly selected in the region of the alliance Lindero-Quercion mongolicae (Kim 1990). They are located at areas of siliceous soil on Imdong-myon, Andong-gun (36° 33′ N 128°55′E) in Kyungpook province, Mt. Palgong (36° 00′ N 128° 41′ E) in Taegu, and Mt. Kaya, Hapch'on-gun (35° 47′ N 128° 06′ E) in Kyungnam province. The areas have relatively small mean annual rainfall of 1094±130 mm, the coldest month mean temperature of −1.4±0.9 ℃, and an annual mean temperature of 12.7±0.8 ℃, which implies the Youngnam-type climate in Korea (*sensu* Kim, unpublished) characterized by physiologically and physically unfavorable water condition to plants. Particularly, the study sites of Andong-gun with shale bedrock have been subject to edaphic drought, and contained sparse woodlands dominated by dwarf red pines and junipers (*Juniperus rigida*).

Data collection and floristic analysis

Four vegetation types were investigated: two mongolian oak (*Quercus mongolica*) forests dominated by either dwarf bamboos or several forbs and grasses in the forest floor, and two red pine (*Pinus densiflora*) forests with either a matured canopy or not. We analyzed total 40 stands with ten stands for each type in terms of the Braun-Blanquet School's method (Braun-Blanquet 1964). Structured syntaxonomical tables were produced by [TWINSPAN] (Hill 1979) and hand-sorting method (Becking 1957). All species were recorded using a transformed Braun-Blanquet scale for cover abundance (Westhoff and van der Maarel 1978) in tree, shrub and herb-layers. Net contribution degree (NCD) and relative net contribution degree (R-NCD) of species to each syntaxon were computed by using the computer program [SYNOPTIC1] (*vide* Kim and Manyko 1994). Finally, synthesized table was prepared with synoptic values such as R-NCD and constancy degree (I～V).

In the species-area analysis, 10 stands have been regarded as a minimum quadrat number (Hanson and Churchill 1961). Presence/absence data of species for species-area curve were obtained by Numata's square-meter nest-quadrat method (Numata 1957) in each stand and stratum. Total 120 nest-quadrats were investigated. Subsequently, species diversity and composition ratios of life-form (Raunkiaer 1934) of syntaxa were so determined as to assist the interpretation of relationship between community structure and minimal area. The actual species diversity (ASD) was determined as the rate of the number of accidental species (≤ 0.6 in R-NCD) to total species number in each syntaxon. The life-form's composition ratio of syntaxon was calculated by the following formula: $n/\Sigma N_i \times n/N_i$, where n is the number of relevant species to each life-form and N_i is total number of species in syntaxon i.

Drawing of species-area curve

Minimal area to each syntaxon could be determined through logistic growth curve based on species number and quadrat size (Brewer and McCann 1982). The general form of the equation for the logistic growth curve is:

$$y = \frac{k}{1 + ((k - n_0)/n_0 e^{-rt})}$$

where y is the species number recorded in a quadrat with size t. Three parameters k, n_0, and r were estimated by [SAS] package (SAS institute Inc. 1991) in consideration of actual data y and t. k is the height of the horizontal asymptote (the expected value of y for very large t), n_0 is the expected value of y at size t = 0, and r is a measure of growth rate. The minimal area size was assumed to be adequate when a given increase rate in sample size produces less than the same increase rate in the number of species (Fig. 1).

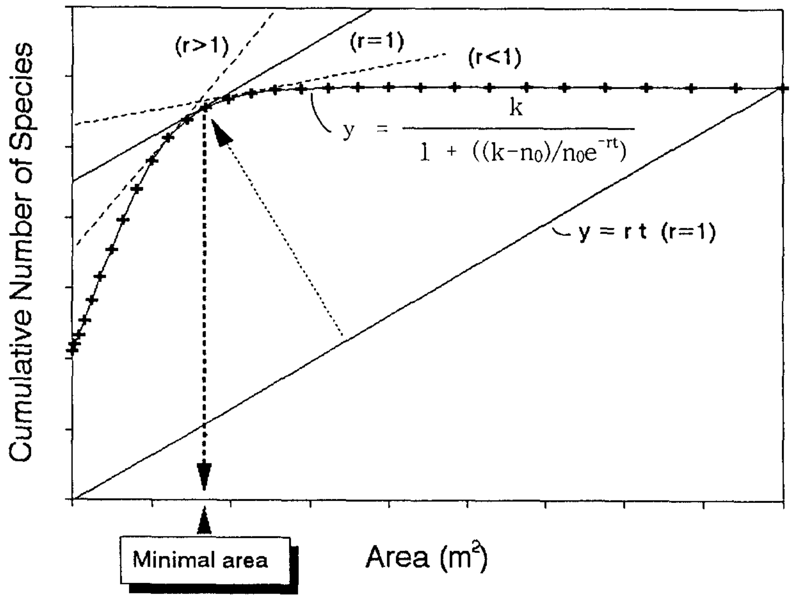

Fig. 1. Model of a species-area curve (slightly modified from Brewer and McCann 1982).

RESULTS

Syntaxa

Syntaxonomically, four vegetation types could be recognized: Saso-Quercetum mongolicae Kim 1990 (sasa-oak forest), *Viola albida-Quercus mongolica* community (violet-oak forest), *Carex humilis-Pinus densiflora* community (sedge-pine forest), *Juniperus rigida-Pinus densiflora* community (juniper-pine forest) (Table 1).

The Saso-Quercetum mongolicae was determinated by *Sasa borealis* and *Quercus mongolica* of transgressive character species to its higher syntaxa (Kim 1990). This association is one of the typical types of the Lindero-Quercion mongolicae representative to the cool-temperate forests in Korea (Kim 1992). *Sasa borealis*, monocarpic and guerilla plant, dominates the forest floor. Vernal arboreta such as *Lindera obtusiloba, Styrax obassia, Magnolia sieboldii, Symplocos chinensis* for. *pilosa* occurred in high NCD, which constitute understory and shrub layers.

The *Viola albida-Quercus mongolica* community is distinctively characterized by the high NCD value of diagnostic species to the Rhododendro-Quercion mongolicae. Typical arboreta to the Callicarpo-Quercion serratae such as *Callicarpa japonica, Lindera erythrocarpa* and *Lindera glauca* occurred in the community. Differing from the above association, this community was differentiated by many hemicryptophytes and geophytes such as *Viola albida, Polygonatum flacatum, Ainsliaea acerifolia,* and so on (Table 1).

Table 1. Vegetation table described by synoptic degree of species.
A : Saso-Quercetum mongolicae
B : *Viloa albida-Quercus mongolica* community
C : *Carex humilis-Pinus densiflora* community
D : *Juniperus rigida-Pinus densiflora* community

Vegetation units :	A		B		C		D		
Altitude (m, $\overline{x} \pm \sigma$) :	807 ± 81		840 ± 134		495 ± 177		250 ± 30		Life-
Synoptic values :	CD	R-NCD	CD	R-NCD	CD	R-NCD	CD	R-NCD	form
Diagnostic species group of association and communities :									
Sasa borealis	V	100.0	I	0.1		.		.	H
Acer mono	IV	16.7	I	1.1	I	0.1		.	Ph
Viola albida	I	0.1	V	22.5	II	3.4		.	H
Polygonatum falcatum	I	0.1	V	19.7	III	9.3		.	G
Athyrium vidalii	III	2.8	V	21.1	II	4.5		.	H
Astilbe chinensis var. *davidii*	I	0.5	IV	14.6	IV	9.9		.	H
Hosta longipes		.	IV	13.4	II	1.7		.	H
Pseudostellaria palibiniana	I	0.5	IV	10.8		.		.	H
Pinus densiflora	III	10.9	II	6.2	V	100.0	V	100.0	Ph
Carex humilis	IV	9.1	IV	22.5	V	34.2	III	23.6	H
Rhododendron mucronulatum var. *ciliatum*	I	0.3	II	3.0	V	33.8	II	2.7	Ph
Lespedeza x *tomentella*	III	6.8	V	15.2	V	22.5		.	Ph
Carex okamotoi	I	0.1		.	III	6.8		.	H
Juniperus rigida		.		.	IV	7.9	V	59.1	Ph
Miscanthus sinensis var. *purpurascence*		.	III	3.5	III	8.5	V	42.4	H
Atractylodes japonica		.	I	0.6	IV	15.8	V	28.6	H
Lespedeza cyrtobotrya		.	I	0.1	III	3.5	V	24.5	Ph
Zanthoxylum schinifolium	I	0.1	I	0.1	III	5.6	IV	21.8	Ph
Patrinia villosa		.	I	0.1	I	0.1	V	28.8	H
Sanguisorba officinalis		.		.	II	1.3	V	30.3	H
Quercus dentata		.		.	I	0.4	IV	18.2	Ph
Quercus variabilis		.	I	1.7	II	4.5	III	12.7	Ph
Festuca ovina		.	I	0.8		.	IV	29.7	H
Platycodon grandiflorum		.	I	0.1		.	V	19.1	Ph
Rhapontica uniflora		.		.		.	V	13.6	H
Diagnostic species group of the Lindero-Quercion mongolicae :									
Quercus mongolica	V	71.6	V	100.0	III	11.0	I	1.2	Ph
Symplocos chinensis for. *pilosa*	V	45.5	V	34.2	IV	11.8	II	2.3	Ph
Fraxinus rhynchophylla	V	34.1	V	23.7	III	8.5	I	0.2	Ph
Acer pseudosieboldianum	V	61.4	V	73.2	IV	16.9		.	Ph
Lindera obtusiloba	V	30.7	V	47.9	V	35.2		.	Ph
Corylus heterophylla var. *thunbergii*	V	24.6	III	13.5	IV	12.4		.	Ph
Styrax obassia	IV	21.1	II	8.5	III	11.8		.	Ph
Stephanandra incisa	IV	8.2	IV	7.9	IV	19.7		.	Ph
Callicarpa japonica	IV	24.6		.	II	1.7	I	0.2	Ph
Quercus serrata	IV	18.3	I	0.8	V	27.9	V	54.9	Ph
Lindera erythrocarpa	IV	16.7	I	1.1	IV	12.8		.	Ph
Magnolia sieboldii	III	12.3	II	3.0	I	0.3		.	Ph
Maackia amurensis var. *buergeri*	III	5.7	I	0.1	I	0.1	I	0.2	Ph
Asarum sieboldii	I	0.1	IV	13.5	II	2.3		.	G
Fraxinus sieboldiana	I	0.3	IV	30.4	V	25.4		.	Ph
Carpinus cordata	I	0.9	I	1.7	I	1.4		.	Ph
Ainsliaea acerifolia		.	III	13.5	III	9.2		.	H
Sorbus alnifolia		.	III	13.5	III	10.1		.	Ph
Carex siderosticta		.	III	7.7	III	9.9	I	0.9	H
Rhododendron schlippenbachii	I	0.1	III	9.2	V	27.9	I	0.5	Ph
Pyrola japonica	I	0.5	IV	8.9	IV	19.2	I	0.9	H
Prunus leveilleana	II	3.1	I	1.1	V	16.5	II	3.2	Ph
Cornus controversa	I	0.1	I	0.4	II	1.3	I	0.3	Ph

Table 1. Continued

Vegetation units : Altitude (m, $\bar{x} \pm \sigma$) : Synoptic values :	A 807 ± 81 CD	 R-NCD	B 840 ± 134 CD	 R-NCD	C 495 ± 177 CD	 R-NCD	D 250 ± 30 CD	 R-NCD	Life-form
Styrax japonica		.	I	0.4	III	3.5	I	0.2	Ph
Carpinus laxiflora		.		.	II	3.8		.	Ph
Lindera glauca		.		.	I	0.6		.	Ph
Companions :									
Isodon inflexus	IV	8.2	V	21.5	IV	8.9	IV	9.7	H
Rhus trichocarpa	III	5.7	IV	13.8	V	46.5	III	7.3	Ph
Smilax nipponica	III	4.1	V	18.3	IV	11.3	II	2.4	G
Viola collina	III	2.8	V	19.0	III	6.8	III	5.5	H
Weigela subsessilis	II	4.1	V	27.9	III	11.1	I	0.6	Ph
Ampelopsis brevipedunclata var. *heterophylla*	II	2.8	III	5.9	III	5.9	I	0.2	Ph
Aster scaber	I	0.1	V	17.7	V	19.7	IV	8.5	H

Notes: CD - constancy degree, R-NCD - Relative net contribution degree.
Refer complete vegetation data in the Tables 2, 3, 4 and 5 of Lee 1994.

The *Carex humilis-Pinus densiflora* community showed the highest number of 164 species among the four plant communities. There were some indicative species to logging and fire, which are clonal plants with rhizome or stolon such as *Carex humilis*, *Rhododendron mucronulatum* var. *ciliatum*, *Lespedeza* × *tomentella*, *L. cyrtobotrya* and *Miscanthus sinensis* var. *purpurascence*. The community contained several diagnostic species of the Lindero-Quercion mongolicae as well. This suggests that the community is on seral phase from the pine forest to the deciduous forest.

The community architecture of *Juniperus rigida-Pinus densiflora* community is divisive, which seems to be closely related to the soil moisture in terms of edaphic condition. The community appeared two-layered dwarf structure, but three other communities had more or less distinct 3~4 layers. The community formed sparse stands around the Imha-Dam where shale bedrocks prevail throughout the region.

Floristic characteristics

The sasa-oak forest showed the lowest number of species per stand (ca. 33 species) and the lowest composition rate (0.85) of herb-layer species, but higher values in mean species' NCD (0.56). Especially this forest was extremely low in hemicryptophyte abundance (0.0297) (Table 2), but three other forests ranged from 0.089 to 0. 096 in hemicryptophyte abundance. This is probably due to community architecture with dwarf bamboo *Sasa* forming a dense but a little shallow jungle in the forest floor from clonal root system with thick and long-lasting modules.

In the sasa-oak forest, the composition ratio of species with low R-NCD value (≤0.6) regarded as an accidental species was the highest 52.0%. That of the juniper-pine forest was the lowest 40.8%, probably due to a less-developed A1-soil layer and an exposed rock physically unfavorable for plants to utilize water. Except *Quercus serrata*, no diagnostic species to the Callicarpo-Quercenion serratae were found, and a few indicative species to open canopied forests were frequent with high NCD values. They are ***Festuca ovina, Juniperus rigida, Lespedeza cyrtobotrya, Miscanthus sinensis*** var. ***purpurascence, Patrinia villosa, Platycodon grandiflorum*** and ***Sanguisorba officinalis.*** Among them, the NCD value of rhizomatous hemicryptophytes steadily increased in this community.

Composition ratio in the shrub-layer species and the herb-layer species of the sedge-pine forest was extremely high as 0.95 and 0.59, respectively. In contrast, the juniper-pine forest showed the highest composition ratio (0.97) in the herb-layer species but the lowest in the shrub-layer species (0.15) (Table 2). Therefore, relationship between species composition ratio in the multilayered plant community varied remarkably, suggesting that there

Table 2. Statistics of the species diversity in each syntaxon

Syntaxon		Saso-Quercetum mongolicae		*Viola albida-Quercus mongolica* community		*Carex humilis-Pinus densiflora* community		*Juniperus rigida -Pinus densiflora* community	
① Total no. species (N_i)		98		145		164		98	
② Mean no. species / relevé		$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ	$\overline{x}$	σ
		32.6	8.6	49.3	9.0	57.3	8.7	37.5	5.9
③ Mean NCD of species ($\Sigma NCD / \Sigma N_i$)		0.56	1.34	0.41	0.89	0.39	0.77	0.48	0.97
④ Composition ratio of herb-layer species against total no. species		0.85		0.92		0.95		0.97	
⑤ Composition ratio of shrub-layer species against total no. species		0.36		0.16		0.59		0.15	
⑥ No. of accidental species		51		75		82		40	
⑦ Rate of ASD: ⑥÷①×100 (%)		52.0		51.7		50.0		40.8	
⑧ Composition ratio	Th	0.00016		0.0018		0.0012		0.0008	
of Life-form	G	0.0040		0.0135		0.0150		0.0024	
($n / \Sigma N_i \times n / N_i$)	H	0.0297		0.0960		0.0925		0.0893	
	Ch	0		0.00004		0.00004		0.00004	
	Ph	0.1525		0.0897		0.1290		0.0640	

$\overline{x}$-mean, σ - standard deviation, NCD - Net contribution degree, ASD - Actual species diversity, n - number of relevant species to each life-form, N_i - total number of species in syntaxon i, Th -Therophyte, G- Geophyte, H - Hemicryptophyte, Ch - Chamaephyte, Ph - Phanerophyte.

was no consistent regularity between the species diversity and the community structure.

Minimal area

The calculated minimal area was 305 m^2 of the sasa-oak forest, 81 m^2 of the juniper-pine forest, 196 m^2 of the violet-oak forest, and 169 m^2 of the sedge-pine forest (Table 3). These differences in the minimal areas were clearly due to different species composition according to phytocoenosis.

The sasa-oak forest had the biggest investigated areas, but the lowest species composition rate in the herb-layer (Table 2), suggesting that various vernal arboreta species with high composition ratio were admixed in the upper layers, and every arboretum covers wide areas and possesses infiltration strategy (*sensu* Wilson and Lee 1989) or phalanx growth form (*sensu* Lovett Doust and Lovett Doust 1982). The minimal area of the violet-oak forest was slightly bigger than that of the sedge-pine forest. This is merely a reflection of bigger rate of ASD of the former forest, even though the number of accidental species in the latter forest was the most (82 species).

The number of species to quadrat size of the juniper-pine forest rapidly increased with r=0.052 in a measure of growth rate, and then slightly decreased at 81 m^2 and reached a steady state at 100 m^2 (Table 3). It was due to the smallest richness of canopy tree (1 taxon) and shrub-layer species (9 taxa) found in this forest and to the restricted species pool due to a highly sparse vegetation cover as a result of poor soil condition combined with the Youngnam-climate type.

Table 3. Species-area curve equation computed in each syntaxon

Syntaxon	Saso-Quercetum mongolicae			*Viola albida-Quercus mongolica* community			*Carex humilis-Pinus densiflora* community			*Juniperus rigida-Pinus densiflora* community		
Parameter	Value	ACI		Value	ACI		Value	ACI		Value	ACI	
		lower	upper		lower	upper		lower	upper		lower	upper
k	34.17	32.69	35.65	47.4	45.83	48.97	58.84	57.06	60.61	36.4	35.70	37.08
n_0	10.8	9.46	12.13	16.71	14.05	19.38	20.7	17.4	24.0	14.96	12.95	16.96
r	0.008	0.006	0.009	0.018	0.013	0.02	0.021	0.016	0.027	0.052	0.039	0.064
Equation	$y=\frac{34.17}{1+2.6e^{-0.008t}}$			$y=\frac{47.4}{1+1.84e^{-0.018t}}$			$y=\frac{58.8}{1+1.84^{-0.021t}}$			$y=\frac{36.39}{1+1.43e^{-rt}}$		
Minimal Area (m^2)	305			196			169			81		

k - the expected value of y for very large t, n_0 - the expected value of y at time t=0, r - a measure of growth rate, y - number of species, t - areas, e - exponential value, ACI - Asymptotic 95% confidence interval.

DISCUSSION

The size of minimal area of a phytocoenosis is a matter of species composition. The concept of minimal area produced by species-area curve might be directly correlated with vegetation type, *i. e.* minimal area as a sampling unit (relevé size) in syntaxonomical works indicates enough size possessing the possible component species of the considered vegetation type. Such minimal area information enables us to save time and costs for field investigation (Hanson and Churchill 1961, van der Maarel 1970).

Generally, it has been recognized that the smaller size of minimal area needed in such cases of phytocoenosis covered by a few dominants or a varied species in the forest floor. In the present study, such general recognition was not always applicable. Being dominated by *Quercus mongolica* in the canopy, and densely occupied by *Sasa borealis* in the forest floor and underground, the size of minimal area of the sasa-oak forest was the biggest among the four forest types. In fact, although the sedge-pine forest showed the higher values on the criteria of the species diversity such as the total number of species, composition ratio of shrub- and herb-layer species, and the number of accidental species, its actual species diversity (ASD) was lower than that of the sasa-oak forest. It can be understood that a phytocoenosis developed by diverse arboreta in the understory and shrub-layer should be investigated with the larger relevé sizes.

The rate of ASD was closely related to the minimal area. The minimal areas increased linearly with increasing ASD ($r^2=0.71$). This is caused by the ASD property strongly based on the varied species pool to every different vegetation type. The phytocoenosis possessing the larger species pool should be investigated with larger sampling sizes, too.

Zechmeister and Mucina (1995) noted that one of the most serious problems was the apparent poor compatibility of sampling scales in a syntaxonomic revision. In Korea, syntaxonomical studies have steadily appeared, but minimal areas have hardly been regarded (Kim *et al.* 1994, Yim and Baik 1984). Preliminary studies on the optimal relevé size to the different vegetation types in Korea are necessary for comparing and synthesizing vegetation data obtained from previous syntaxonomical works with various quality and for biodiversity monitoring (Kim 1993).

적 요

소나무림 및 신갈나무림의 최소면적과 군락구조에 대한 비교연구가 이루어졌다. 본 연구의 수단은 식물군락에 대한 식물종 다양성 및 군락분류 (Z.－M. School)에 있다. 우리나라 냉온대의 신갈나무-생강나무군단역에 위치하는 40 개의 조사지에서 총 120 개의 중첩방형구에 대하여 종조성과 식물종의 순기여도 (net contribution degree)를 분석하였다. 최소면적의 해석을 위하여 단위식생의 식물형 구성비 (composition ratio of plant-form) 및 종다양성율 (rate of actual

species diversity)이 산출되었다. 군락분류학적으로 4 개의 식생형이 구분되었다: 신갈나무-조릿대군집, 신갈나무-태백제비꽃군락, 소나무-산거울군락, 소나무-노간주나무군락. 이들 군락들의 최소면적은 각각 305 m^2, 196 m^2, 169 m^2, 81 m^2 로 나타났다. 다층을 형성하는 식물군락에 있어서 식물종 구성비와 군락구조와의 사이에 일정한 규칙성은 관찰되지 않았다. 최소면적은 종다양성율 (ASD)의 증가에 따라 비례적으로 증가하였으며, 다양한 관목층 및 아교목층 식물종으로 이루어진 식분 (植分)은 보다 넓은 면적으로 식생조사가 이루어져야 함이 밝혀졌다.

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