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Classification and Multidimensional Analysis of Plant Communities in Mt. Moak Provincial Park, Korea

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母岳山 道立公園 植物群集의 分類와 多次元分析

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ABSTRACT

Ordination and classification techniques were used to analyze the forest communities and to examine the integration problem of community-to-ecological species group in Mt. Moak provincial park of Korea. Phytosociological classification based on floristic composition produced seven communities of *Zelkova serrata*, *Carpinus tschonoskii*, *Quercus acutissima*, *Qurcus variabilis*, *Quercus serrata*, *Quercus mongolica* and *Pinus densiflora*. These seven communities were well discriminated in the two-dimensional analyses of soil moisture, soil organic matter content and temperature(elevation),reciprocally, and in three-dimensional space of the three environmental factors also. They corresponded to seven ecological groups derived from the distribution pattern analysis of species populations in this mountain.

INTRODUCTION

Mt. Moak provincial park area(ca. 42.22 km^2), Chŏllabuk-do, Korea, is largely covered with oak(*Quercus*) forest, hornbeam(*Carpinus*) forest and pine(*Pinus*) forest.

Among them hornbeam forest was recognized as a distinct forest of cool-temperate zone in Korean vegetation system(Uyeki, 1933), that is *Carpinus tschonoskii*, *Carpinus laxiflora* and *Quercus mongolica* were clarified as character species in southern, middle and nothern part of the cool-temperate zone, respectively(Yim, 1977; Kim and Yim, 1986, 1988; Kim *et al*, 1988). In the mountain, however, the natural forests of hornbeam species are found in extremely restricted area around the temples. Therefore, phytosociological and ecological examinations on the forest vegetations in the mountain are expected to give us some information about the distribution of natural vegetations disturbed in southwestern Korea.

Classification and ordination methods represent an improvement on plant community descriptions based on leading dominants. A community is understood to be a more or less stable combination of naturally occurring species which are in an equilibrium with one another and their environment(Walter, 1971). Therefore, multidimensional analyses performed on a data base of all species are useful tools in examining relationships between plant community and environment. To clarify the integration problem for recognizing a plant grouping in phytosociological and/or ecological viewpoint as the same community, plant communities defined by classification techniques were examined by comparing with the plant groups delineated by ordination techniques.

MATERIALS AND METHODS

Source of data

The data on the floristic composition, habitat conditions and tree census, and the data on three key factors of soil condition and climate, i.e. soil moisture content, soil organic matter content and elevation, in 34 quadrats of 10m × 10m or 15m × 15m size during 1985~1988(Kim and Yim, 1992) were used for the phytosociological classification and multidimensional analyses of communities.Analytic materials(Kim and Yim, 1992; Yim and Kira, 1975, 1976) based on the climatological data to Kŭmsansa temple in the mountain and of Chŏnju meteorological station, ca. 10 km north of the mountain were referred to the analyses of distribution patterns of plant communities.

Tabulation

By tabular comparison method of Z-M school scheme(Küchler, 1967; Shimwell, 1971; Mueller-Dombois and Ellenberg, 1974; Toyohara, 1977; Suzuki *et al.*, 1985) plant communities were classified phytosociologically. To determine the vegetational units of the forest, the communities classified were compared with those of other regions(Miyawaki *et al.*, 1983; Kim and Yim, 1986, 1988; Kim *et al.*, 1988).

Multidimensional analyses of communities

To examine the relationships between plant community and its environment, the gradients ranking 1 to 10 of the three key factors, soil moisture content, soil organic matter content and elevation, were used as axes of two or three-dimensional charts for ecological classification. The communities classified ecologically were compared with the results of phytosociological classification. For examining the intergration problem of community-to-ecological species group, the stands of communities classified phytosociologically were plotted on the two-dimensional chart of elevation-moisture gradient(Kim and Yim, 1992).

RESULTS

Plant communities

The vegetation of the park area was divided into seven communities by tabular comparison method of Z-M school scheme as follows:

A. *Zelkova serrata* community(Table 1-A, Fig. 1)

This community on stony slopes of the mountain streamsides is distinguished from others by presence of the differential species group 1, 8 and 10 in Table 1. It seems to be a topographic or edaphic climax of the cool-temperate zone in Korea, as Corno-Zelkovion serratae Kim et Yim 1988 in the hierarchy of Korean forest vegetation(Kim and Yim, 1998). *Cornus controversa*, *Lindera erythrocarpa*, *Alangium platanifolium* var. *macrophyllum* and *Arisaema amurense* as character species of the association occur more abundantly in this community than in the others. The upper tree layer is chiefly composed of *Z. serrata* and *C. controversa*, which are often about 18m tall and over 35cm in DBH. The sub-tree layer is characterized by scattered maple trees, the shrub layer of 2m high by *Staphylea bumalda*, *Ligustrum obtusifolius* and *A. platanifoilum* var. *macrophyllum* and herb layer by poor species richness.

B. *Carpinus tschonoskii* community(Table 1-B, Fig. 2)

This is distinguished from other communities by the presence of the differential species group 2 but by the lack of the group 9 and 11. This community at elevation below 400m seems to be a climatic climax in southern parts of the cool-temperate zone of Korea and can be identified as Carpinetum tschonoskii Kim et Yim 1986 belonging to Carpinion laxiflorae Kim et Yim 1986 considering the character species of the association, *C. tschonoskii*, *Stephanandra incisa* and *Meliosma myriantha*, which occur abundantly in this community.

C. *Quercus acutissima* community(Table 1-C)

This is distinguished from other communities by the presence of *Q. acutissima*, the differential species. It seems to be a secondary forest developed on the lower slopes destroyed by human interferences. The forest is mixed with the other oak species, *Q. variabilis* and *Q. serrata*.

D. *Quercus variabilis* community(Table 1-D)

This community is distinguished from others by the differential species group 4. It seems to be a secondary forest which occurs on the sunny steep mountainsides and xeric hillsides. The forest is mixed with other oak species, *Q. serrata* and *Q. mongolica*. High constant species in this community are *Indigofera kirilowi* and *Lespedeza bicolor*. The community

Fig. 1. A community of *Zelkova serrata*. The zelkova forests are characterized by *Cornus controversa* and maple trees in tree layer, *Staphylea bumalda*, *Ligustrum obtusifolius* and *Alangium platanifolium* var. *macrophyllum* in shrub layer and a few herb species in herb layer in this mountain.

Fig. 2. A community of *Carpinus tschonoskii*. The hornbeam forests are characterized by *Stephanandra incisa* and *Meliosma myriantha* in this mountain.

can be closely related to Quercetum variabilis Kim et Yim 1986 belonging to Carpinion laxiflorae Kim et Yim 1986, which is a topographic or edaphic climax community in middle parts of the cool-temperate zone of Korea(Kim and Yim, 1986).

E. *Quercus serrata* community(Table 1-E)

This is distinguished from other communities by the dominance of *Q. serrata*, the differential species. It seems to be a secondary forest developed on dry middle slopes of the mountain. The forest is mixed with the other oak species, *Q. variabilis* and *Q. mongolica* as in Mt. Daedun(Kim *et al.*, 1988).

F. *Quercus mongolica* community(Table 1-F, Fig. 3)

This community is distinguished from others by the presence of the differential species group 6 and 9 but by the lack of the group 1 and 8. The community on elevations above 600 m at sea level of the mountain seems to be in a climatic climax condition in nothern parts of the cool-temperate zone of Korea. This can be identified as Rhododendro-Quercetum mongolicae Kim et Yim 1988 belonging to Acero-Quercion mongolicae Kim et Yim 1988,

Fig. 3. A community of *Quercus mongolica*. The mongolian oak forests are characterized by *Q. monglica* in tree layer, *Acer pseudo-sieboldianum* and *Rhododendron schlippenbachii* in shrub layer, and several ferns and sedges in herb layer in this mountain.

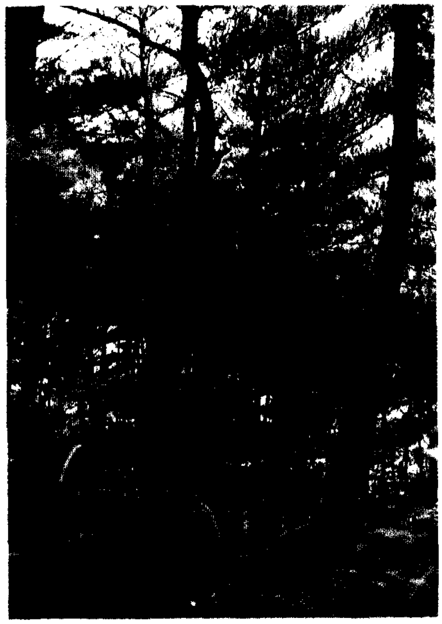

Fig. 4. A community of *Pinus densiflora*. The pine forests are characterized by *P. densiflora*, *Rhododendron mucronulatum*, *Milium effusum* and *Festuca ovina* which occur on destroyed lower parts and poor ridge lines of the mountain.

considering the character species of the association, *Q. mongolica*, *Rhododendron schlippenbachii*, *Melampyrum roseum* and *Ainsliaea acerifolia* which occur abundantly in this community(Kim and Yim, 1988). The tree layer of this community is chiefly composed of *Q. mongolica* about 13 m tall and over 17 cm in DBH, and maple trees are scattered under the tree layer. The shrub layer of 2 m high is covered with *Acer pseudo-sieboldianum* and *R. schlippenbachii* and the herb layer is dominated by several ferns and sedges.

G. *Pinus densiflira* community(Table 1-G, Fig. 4)

This is distinguished from other communities by the differential species group 7. It is similar to Rhododendro mucronulati-Pinetum densiflorae Kim et Yim 1986 belonging to Rhododendro-Pinion densiflorae Kim et Yim 1988 considering the character species of the association, *P. densiflora*, *Rhododendron mucronulatum*, *Milium effusum* and *Festuca ovina* (Kim and Yim, 1986, 1988) which occur abundantly in this community. This community occurs on the lower parts of the mountain which was destroyed by human activities, on the exposed ridge lines, and on dry and poor habitats.

Stand ordinations

34 stands were ordinated on the two-dimensional planes of soil moisture, soil organic matter content and temperature(elevation) reciprocally (Fig. 5). On the plane composed of the two axes of temperature and moisture gradient, the stands of *P. densiflora, Q. mongolica, Q. serrata, Q. variabilis, Q. acutissima, C. tschonoskii* and *Z. serrata* were clustered respectively and were separated from one another: *P. densiflora* stands on xeric-lower slopes, *Q. mongolica* stands on xeric-upper slopes, *Q. serrata* stands on xeric-upper middle slopes, *Q. variabilis* stands on xeric-middle slopes, *Q. acutissima* stands on lower slopes, *C. tschonoskii* stands on mesic-middle slopes and *Z. serrata* stands on mesic-streamsides and stony slopes. On the other plane composed of temperature and organic matter gradient, the seven clusters of stands mentioned above were also separated from one another: *P. densiflora* stands on poor-lower slopes, *Q. mongolica* stands on poor-upper slopes, *Q. serrata* stands on poor-upper middle slopes, *Q. variabilis* stands on poor-middle slopes, *Q. acutissima* stands on rich-lower slopes, *C. tschonoskii* stands on rich-middle slopes and *Z. serrata* stands on

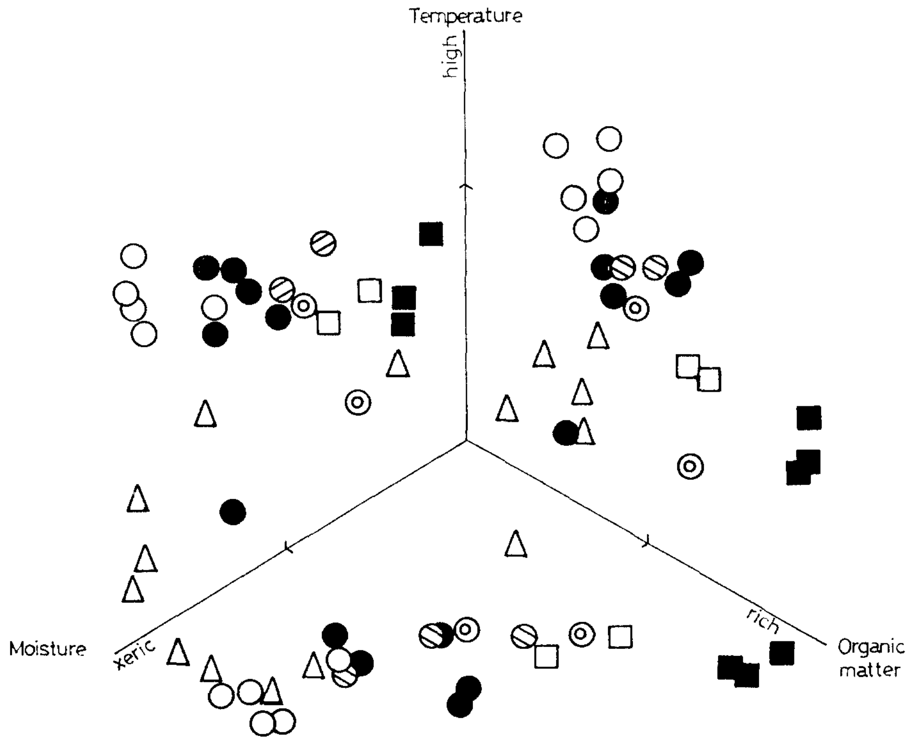

Fig. 5. Distribution patterns of 34 stands on the three two-dimensional planes. ○: *Quercus mongolica* stand, ⊘: *Q. serrata* stand, ●: *Q. variabilis* stand, ◎: *Q. acutissima* stand, □: *Carpinus tschonoskii* stand, ■: *Zelkova serrata* stand, △: *Pinus densiflora* stand.

rich-streamsides. Another two-dimensional plane of moisture and organic matter gradient also produced the seven clusters of stands: the stands of *P. densiflora* and *Q. mongolica* on xeric-poor sites, of *Q. serrata*, of *Q. variabilis* and of *Q. acutissima* on intermediate sites and of *C. tschonoskii* and of *Z. serrata* on mesic-rich sites. Among the three planes, however, the degree of clustering was more marked on the two-dimensional ordination of temperature-moisture factor pair than on those of other factor pairs.

In the three-dimensional space of temperature-moisture-organic matter (Fig. 6) the seven clusters were also discriminated well from each other. The ecological distinctions were shown among the seven clusters as follows: the stands of *P. densiflora* on xeric-poor-lower slopes, of *Q. mongolica* on xeric-poor-upper slopes, of *Q. serrata* on xeric-poor-upper middle slopes, of *Q. variabilis* on xeric-poor-middle slopes, of *Q. acutissima* on mesic-rich-lower slopes, of *C. tschonoskii* on mesic-rich-middle slopes and *Z. serrata* on mesic-rich-streamsides.

The seven clusters from the two or three-dimensional analyses corresponded to the seven communities from phytosociological classification.

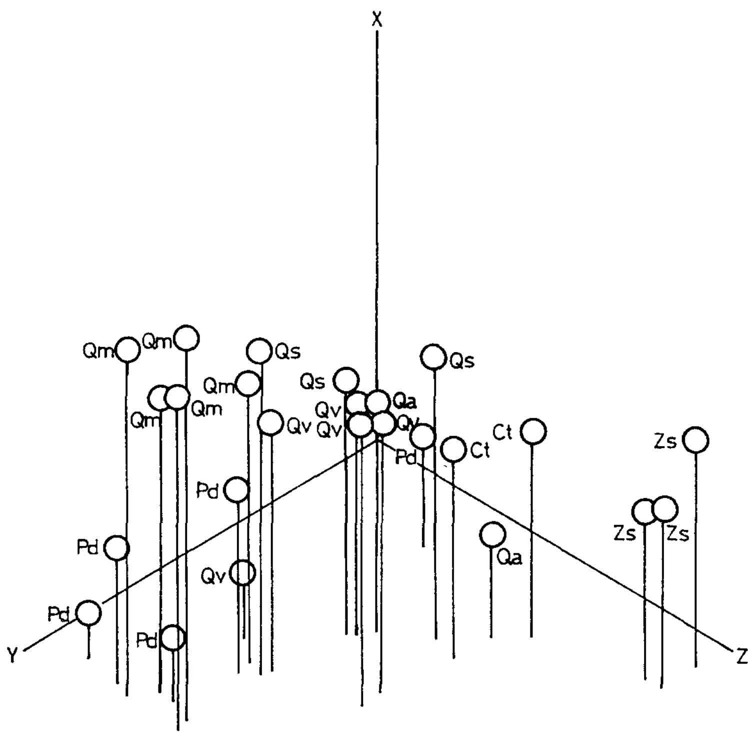

Fig. 6. Projection showing the distribution patterns of 34 stands in three-dimensional space. The axes, X, Y and Z, correspond to temperature, moisture and organic matter, respectively. Abbreviations indicate genus and species initials of dominant species in each stand: Qm: *Quercus mongolica*, Qs: *Q. serrata*, Qv: *Q. variabilis*, Qa: *Q. acutissima*, Ct: *Carpinus tschonoskii*, Zs: *Zelkova serrata* and Pd: *Pinus densiflora*.

Distribution pattern of plant communities

Plant communities classified phytosociologically were plotted on the two-dimensional chart of elevation and topographical moisture showing the distribution pattern of seven ecological species groups(Kim and Yim, 1992). The seven types derived from the two-dimensional chart were *Z. serrata, C. tschonoskii, Q. acutissima, Q. variabilis, Q. serrata, Q. mongolica* and *P. densiflora* community type. They were grouped into four vegetational patterns as follows: zelkova forest with *Z. serrata* community on ravines, hornbeam forest with *C. tschonoskii* community on mesic-middle slopes, oak forest with *Q. acutissima, Q. variabilis, Q. serrata* and *Q. mongolica* community on xeric sites and pine forest with *P. densiflora* community on dry-poor ridges(Fig. 7). The pattern of plant community distribution from stand ordination corresponded to that of ecological species group distribution from species ordination in the previous study(Kim and Yim, 1992).

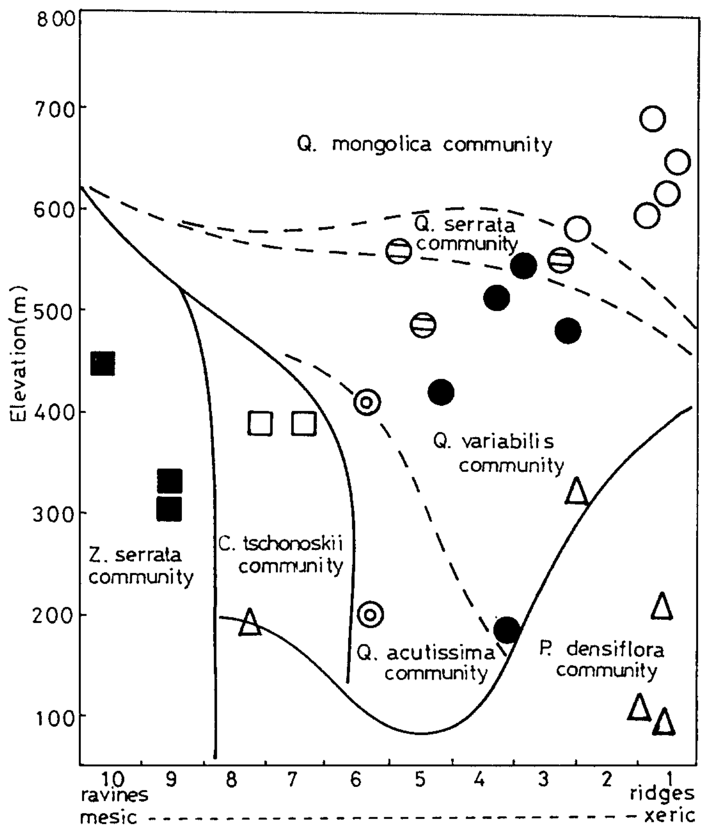

Fig. 7. A view showing the correspondence between distribution pattern of seven communities by classification and of seven ecological species groups by ordination. Stand symbols are the same as in Fig. 5.

DISCUSSION

Because classification, ordination and quantitative field analysis are mere tools to aid in an understanding of vegetation, a complete study of vegetation must include not only an establishment of the patterns of vegetation and species combinations but also an explanation of these through establishment of correlations and causes(Mueller-Dombois and Ellenberg, 1974). Vegetation types may be defined on the basis of characteristic combinations of species and can be ordered hierarchically at different levels of generalization by the classification method. The other methods for ordinations can produce the vegetation patterns by the individualistic hypothesis of plant population. To have ecological value, they must be related to habitat features(Coetzee and Weger, 1975; Dyrness and Grigel, 1979; Parker, 1982; Goldberg, 1982; Ledig and Korbobo, 1983; Austin *et al.*, 1984; Lieberman *et al.*, 1985). The idea of analyzing vegetation or distribution patterns of species populations graphically in relation to explicit environmental gradients is essentially simple, but relationships between vegetation stands and environmental factors are practically multidimensional. Multidimensional analyses performed on a data base of all species are useful approaches in examining relationship between vegetation and environment (Dooley and Collins, 1984).

Stand ordinations or multidimensional analyses of vegetation stands produced seven groups, which are the same as the seven communities from phytosociological classification(Figs. 5 and 6). They corresponded to seven ecological species groups from ordinations for distribution patterns of species populations in the previous study(Fig. 7). It seems that the classification and ordination approach for vegetation description is useful as a heuristic method for the detection of communities in nature and that the multidimensional analysis approach is effective in examining the relationships between spatial patterns of vegetation and environmental factors. Consequently, the environmental information for interpretation of vegetational pattern is important as much as the classification or ordination of vegetation is.

In short, it is clear that seven communities classified by classification method and seven ecological groups by ordination method can be recognized the same.

摘 要

母岳山 道立公園의 植物群落을 Z-M 學派의 方法으로 分類하고 多次元 分析을 通하여 群落－生態群의 一致性을 檢討하였다. 識別種群에 따라 同 地域의 植生은 느티나무群落, 개서어나무群落, 상수리나무群落, 굴참나무群落, 졸참나무群落, 신갈나무群落과 소나무群落 等 7個의 植物群落으로 類別되었다. 土壤濕度, 有機物含量과 高度의 勾配를 各各 두 軸으로 하는 二次元分析과 高度－土壤濕度－有機物含量의 三次元 空間分析에서도 이들 7個 群落들이 各各 서로 다른 分布

類型을 보여 그들의 生態的 特性을 잘 把握할 수 있었다. 또 이들 群落들의 分布類型을 7個 植物生態群의 分布類型(Kim and Yim, 1992)과 比較 檢討한 結果 이 둘이 一致하므로 種結合에 의해 分類된 植物群落과 種個體群들의 生態的 行動의 類似度를 考慮하여 묶은 生態群을 同一視할 수 있었다. 따라서 植物群落의 把握에 있어서 이들 두 分析法이 相互 補完的으로 適用될 수 있음이 立證되었다.

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Table 1. Vegetation table of forest communities on Mt. Moaksan provincial park in Chŏllabookdo, Korea

A: Zelkova serrata community
B: Carpinus tschonoskii community
C: Quercus acutissima community
D: Quercus variabilis community
E: Quercus serrata community
F: Quercus mongolica community
G: Pinus densiflora community

		A			B		C		D					E			F					G				
Serial number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Quadrat number		5	18	31	14	6	17	29	25	27	1	7	24	23	8	26	16	15	32	33	34	2	20	30	9	28
Altitude (m)		330	320	450	400	400	450	200	550	450	120	500	600	500	620	550	550	650	580	650	750	100	260	120	230	350
Slope aspect		S	S	W	N	N	S	N	SE	W	SW	NW	NW	NS	SE	N	S	S	N	NW	E	S	N	SW	N	W
Slope degree (°)		5	25	25	30	30	15	10	25	25	35	45	35	20	35	35	10	10	15	20	10	10	5	15	5	35
Topography		V	V	M	L	L	M	L	U	M	R	U	U	U	U	U	M	U	U	U	T	L	M	R	L	M
Quadrat size (m^2)		225	100	225	100	100	100	100	100	100	100	100	100	100	100	100	100	100	225	225	100	100	100	100	100	100
Height of tree-1 layer (m)		18	14	17	14	18	12	18	12	10	18	16	12	8	11	10	10	10	10	13	.	12	15	18	12	12
Coverage of tree-1 layer (%)		75	65	90	80	85	75	90	80	90	85	70	75	75	75	65	65	70	95	90	.	95	85	90	65	95
DBH of highest tree (cm)		26	30	35	24	18	23	24	23	11	33	25	24	18	23	13	17	12	17	15	.	22	25	26	20	21
Height of tree-2 layer (m)		8	8	6	8	8	6	6	6	5	10	8	6	4	6	5	6	6	6	5	.	4	6	8	6	6
Coverage of tree-2 layer (%)		70	40	65	60	70	60	60	85	75	50	65	85	65	45	85	60	75	55	60	.	50	60	45	20	65
Height of shrub layer (m)		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Coverage of shrub layer (%)		55	35	75	65	55	65	85	85	85	30	85	85	80	50	80	75	85	85	75	100	85	90	85	90	75
Height of herb layer (m)		0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.5	0.8	0.5	0.8	0.5	0.5	0.8	0.5	0.8	0.5	0.8	0.8	0.5	0.8	0.5	0.5	0.5	0.5
Coverage of herb layer (%)		20	25	70	70	95	95	80	45	55	50	85	45	55	80	50	95	45	90	70	75	60	85	60	75	75
Differential species groups																										
1 Zelkova serrata	T1:	3.3	3.3	3.3	.	.	.	.	.	.	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	T2S:	+	±	.	.	.	+	.	.	.	±	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cornus controversa	T1:	3.2	2.2	2.2	.	.	.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	T2S:	+	+	+	+ ±	+ ±	.	+	.	+ ±	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+ r
Lindera erythrocarpa	T1:	+	+	2.3	.	.	.	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	T2S:	2.2	.	2.3	+	+	+	r	r	+	.	+	.	.	.	+	.	.	+	+	.	.	±	.	.	r
Alangium platanifolium var. macrophyllum	T2:	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S:	+	.	2.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer mono	T2:	.	.	2.2	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S:	.	.	1.2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Celtis sinensis	T1T2:	±	.	.	.	.	.	1.1	.	.	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S:	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	r	.
2 Carpinus tschonoskii	T1T2:	.	.	.	3.3	3.3	+ ±	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Meliosma myriantha	T2S:	+	.	.	.	+ ±	.	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3 Quercus acutissima	T1T2:	.	.	.	.	.	3.3	3.3	.	.	+ ±	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4 Quercus variabilis	T1:	.	.	.	.	2.2	2.2	+	5.5	3.3	5.5	3.3	3.3	2.2	2.3	.	+	1.2	+	.	.	1.1	.	.	.	+
	T2:	.	.	.	.	+	1.2	+	2.2	2.2	+	.	1.2	1.1	+	.	.	1.2	.	.	.	.	.	.	.	.
	S:	.	.	.	.	.	+	+	1.2	1.1	+	1.2	+	+	+	.	.	+	.	.	+	3.3	.	1.2	1.2	.
Indigofera kirilowii	H:	.	.	.	.	+	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.
5 Quercus serrata	T1:	.	.	.	.	1.2	.	.	+	2.2	.	1.2	1.2	3.3	3.3	3.3	1.2	+	.	.	.	.	.	.	.	.
	T2:	.	.	.	.	1.2	.	+	+.1	1.1	.	+	1.2	3.3	+	.	1.2	.	.	+	.	.	.	.	.	+
	S:	.	.	.	.	.	.	+	+	1.2	.	1.2	+	1.2	+	1.2	+	.	+	+	+	1.2	+	3.3	2.2	.
6 Quercus mongolica	T1:	.	.	.	1.2	.	+	.	.	1.2	.	1.1	2.2	1.2	.	.	3.3	4.4	5.5	5.5	.	.	.	.	.	.
	T2:	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	1.2	4.5	4.4	.	.	.	.	.	.
	S:	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	+	+	2.3	2.2	4.4	.	.	.	.	.
Rhododendron schlippenbachii	S:	.	.	.	+	.	.	.	.	.	.	+	.	+	+	.	+	2.2	3.3	2.3	3.4	.	.	.	.	.
Acer pseudo-sieboldianum	T2:	.	.	.	.	.	.	+	.	1.2	.	.	+	.	.	1.2	+	+	.	.	.	.	.	.	.	.
	S:	.	.	.	+	.	.	.	+	1.2	.	.	1.2	.	.	.	.	+	+	.	+	.	.	.	+	.
Melampyrum roseum	H:	.	.	.	.	.	.	.	+	+	+	.	+	+	1.2	.	.	+	+	+	+	.	.	+	+	.
Ainsliaea acelifolia	H:	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
7 Pinus densiflora	T1:	.	.	.	.	.	.	2.2	.	.	+	+	.	+	.	.	1.2	+	.	.	.	5.5	5.5	5.5	4.4	4.4
	T2:	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	3.3	1.2	2.3	2.2	.
Rhododendron mucronulatum	S:	.	.	.	.	.	.	.	.	1.2	.	+	+	1.2	+	.	+	.	.	.	.	+	.	.	+	2.2
Juniperus rigida	T2S:	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	± +	+
Miscanthus sinensis var. purpurascens	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	2.3	+	.	.	2.2	.
Festuca ovina	H:	.	.	.	.	+	.	+	.	+	.	+	+	.	.	+	+	1.2	.	.	3.3	2.2	.	1.2	.	.
8 Oplismenus undulatifolius	H:	+	.	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arisaema thunbergii	H:	+	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ligustrum obtusifolius	S:	.	+	2.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Staphylea bumalda	S:	+	.	3.3	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Akebia quinata	H:	+	+	1.2	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hydrangea serrata for. acuminata	H:	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9 Hemerocallis fulva	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Symprocos chinensis for. pilosa	S:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1.2	.	.	.	.	.	.
Arundinella hirta	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.
Pinus thunbergii	T1:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	2.2	.	.	.
Osmunda japonica	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.
10 Sapium japonicum	T2:	2.2	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	S:	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Acer palmatum	T2:	.	1.1	.	.	.	.	.	.	.	.	1.2	.	.	+	.	.	.	.	.	.	.	.	.	.	.
	S:	+	+	.	.	.	.	+	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.
Euonymus sachalinensis	S:	.	.	+	+	+	.	.	+	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.
Carpinus laxiflora	T1T2:	.	.	.	1.1	1.2	.	.	.	.	.	.	+ ±	.	.	.	.	±	.	.	.	.	.	.	.	.
Rhus trichocarpa	T2:	.	.	.	.	.	.	.	.	.	.	1.2	.	+	+	.	+	.	.	.	.	.	.	.	.	.
	S:	.	.	.	+	+	.	+	.	.	.	+	.	+	+	.	+	.	.	.	.	.	.	.	.	.
11 Aster scaber	H:	.	.	.	.	.	.	.	.	+	.	+	.	+	+	+	.	.	.	+	+	+	+	+	+	+
Sanguisorba officinalis	H:	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.	+	+	+	+	.
Lysimachia clethroides	H:	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	+	.	.	.	+	+	.	+	.
Potentilla flagarioides var. major	H:	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	+	.	.	.	+	.

Companions																										
Disporum smilacinum	H:	.	.	+	+	+	+	1.2	1.2	1.2	+	1.2	+	+	1.2	+	+	1.2	2.3	1.2	+	.	.	.	+	2.2
Carex lanceolata	H:	.	+	+	.	+	+	+	+	+	+	+	+	+	.	+	+	.	1.3	2.3	.	+	1.2	+	+	.
Smilax china	H:	.	+	+	+	+	.	+	+	+	+	+	+	+	+	.	+	.	+	+	.	+	+	+	+	.
Lespedeza bicolor	S:	.	.	.	.	.	1.2	1.2	.	1.2	1.2	+	+	+	1.2	1.2	+	2.2	2.3	4.5	3.3	1.2	+	2.3	2.2	+
Lindera obtusiloba	T2:	+	.	.	+	.	.	.	.	.	.	+	1.2	.	.	.	+	.	.	.	.	.	.	.	.	.
	S:	+	+	.	+	+	+	+	r	+	.	+	.	+	.	+	1.2	.	+	.	.	.	.	.	.	r
Sasa borealis	H:	+	.	2.2	2.2	5.5	5.5	3.3	.	2.2	+	3.3	+	+	2.2	+	5.5	.	4.4	.	.	.	.	.	.	.
Pteridium aquilinum var. latiusculum	H:	.	.	.	2.2	+	.	+	.	.	.	+	+	+	+	1.2	.	.	+	+	+	.	+	+	+	+
Carex siderosticta	H:	.	.	.	+	+	.	2.2	.	1.2	.	1.2	1.2	2.3	+	1.2	+	+	.	1.2	.	.	2.3	+	2.2	2.2
Viola acuminata	H:	.	.	1.2	+	+	.	.	.	+	.	+	+	.	+	+	+	+	+	+	.	.	+	.	.	.
Styrax japonica	T2:	2.2	2.2	+	.	+	+	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	+
	S:	.	+	.	.	+	+	+	.	.	r	.	.	.	.	.	.	.	.	.	.	+	.	+	1.2	.
Castanea crenata	T1:	+	.	.	.	+.2	+	2.2	.	.	.	.	2.2	.	.	+	.	.	.	.	.	.	.	2.2	.	+
	T2S:	.	.	.	+	.	.	+	.	.	.	.	.	+	.	.	.	.	+ ±	+	.	+	±	±	.	.
Viola dissecta var. chaerophylloides	H:	.	.	+	.	+	.	.	+	+	.	+	+	.	+	+	+	+	+	+	.	.	+	.	.	.
Stephanandra incisa	S:	.	+	.	+	.	.	1.2	1.2	+	+	.	+	.	.	+	.	.	.	.	.	.	2.2	+	+	+
Viburnum dilatatum	S:	.	+	.	+	+	.	+	.	+	.	+	+	.	.	.	.	.	.	+	.	.	+	.	r	+
Purunus sargentii	T1T2:	.	+ ±	+	2.2	.	+	±	.	.	.	1.2	.	1.1	+ ±	1.1	+ ±	.	.	.	.	.	.	.	.	1.2
	S:	.	.	.	.	.	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	+
Artemisia sylvatica	H:	.	.	.	.	.	.	+	+	+	.	+	+	.	+	.	.	+	.	.	.	.	.	2.2	+	+
Artemisia keiskeana	H:	.	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.	+	+	+	.	.	.	+	+	+
Fraxinus rhynchophylla	T2:	+	.	.	.	.	+	.	1.2	.	.	+	.	.	1.2	.	.	.	.	.	.	.	.	.	.	.
	T1S:	.	2.1	.	.	+	1.2	.	1.2	.	.	r	+	.	+	.	.	.	.	+	.	.	.	.	.	+
Cocculus triobus	H:	.	.	.	.	.	+	+	.	.	.	.	.	+	.	.	.	.	+	+	.	+	+	.	+	.
Pueraria thunbergiana	H:	+	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	+	.
Isodon inflexus	H:	+	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	+	.	.	.	+	+	.
Albizzia julibrissin	T1T2:	.	+	.	.	.	.	.	± +	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
	S:	.	+	.	.	.	.	r	.	.	.	+	.	.	.	.	.	.	.	.	.	r	.	.	r	.
Smilax sieboldii	H:	.	.	.	.	+	.	+	.	.	.	.	+	.	.	+	.	.	.	+	.	.	.	.	+	.
Styrax obassia	T2S:	.	.	.	+ ±	±	.	+	1.2	.	.	.	+ ±	.	.	.	.	.	.	±	.	.	.	.	.	.
Platycarya strobilacea	T1:	.	.	.	.	.	+	.	.	.	.	.	+	.	.	1.1	.	.	.	.	.	.	.	.	.	1.1
	T2S:	.	.	.	.	+.1	+ ±	+	.	.	.	.	1.2	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhus verniciflua	T2S:	.	.	.	.	.	.	±	.	.	±	.	.	+ ±	.	+	.	.	.	.	.	.	+ ±	.	.	+ ±
Melica onoei	H:	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	+	+	+
Malus baccata	T1S:	.	.	.	2.2	.	.	+ ±	.	.	.	.	.	+	.	±	.	.	.	.	.	.	.	.	.	1.1
Synurus deltoides	H:	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	.	+	.	+	.	.	.
Youngia denticulata	H:	.	.	.	.	.	.	.	.	+	.	+	.	.	+	+	.	+	.	.	.	.	.	.	.	.
Chrysanthemum zawadskii var. latilobum	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	.	1.2	.	.	.	+	.
Sorbus alnifolia	S:	.	.	.	.	.	.	+	.	+	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	+
Smilax niponica	H:	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	1.2	.	.	.	+	.	.
Corylus heterophylla var. thunbergii	S:	.	.	.	.	.	.	r	r	.	.	.	+	.	.	+	.	.	.	.	.	.	.	+	+	.
Pyrola japonica	H:	.	.	.	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.
Rubus crataegifolius	H:	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	+	+	.	+	.	.	.
Arabis glabra	H:	.	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	.	.	.	.	+	+	.	.	.
Zanthoxylum schinifolium	S:	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	r	.	+	.
Rosa multiflora	S:	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solidago virga-aurea var. asiatica	H:	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Astilbe chinensis var. davidii	H:	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Davallia mariesii	H:	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Millium effusum	H:	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.
Alnus hirsuta	T1S:	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	± +	.
Vitis amurensis	H:	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.
Veratrum maackii var. japonicum	H:	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Agrimonia pilosa	H:	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Liriope platyphylla	H:	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Atractylodes japonica	H:	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.
Phyllostachys bambusoides	S:	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Sophora flavescens	H:	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Dioscolea batates	H:	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.
Quercus dentata	T2S:	.	.	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	+	.	.	.	.	.	.	.
Quercus aliena	S:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.
Aster yomena	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	+	.
Lastrea thelypteris	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.
Tilia taquetii	T2S:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.2	.	.	.	±	.	.	.	.	.	.
Ostericum sieboldii	H:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.
Thalictrum filamentosum	H:	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.

Rare species: Cephalotaxus koreana (1:S-+), Actinidia arguta (1:H-+), Polystichum tripteron (1:H-+), Boehmeria tricuspis (2:S-+), Securinega suffruticosa (2:S-+), Poligonatum odoratum var. pluriflorum (2:H-+), Cayratia japonica (2:H-+), Euonymus alatus for. ciliato-dentatus (3:S-+), Vicia unijuga (3:H-+), Pseudostellaria palibiniana (3:H-+), Clematis apiifolia (3:H-+), Geum japonicum (3:H-+), Crataegus pinnatifida (4:T2-2.2, S-1.2), Adenocaulon himalaicum (4:H-+), Lilium cernum (14:H-+), Peucedanum terebinthaceum (9:H-+), Kalopanax pictus (10:S-+), Trachelospermum asiaticum var. intermedium (10:H-3.3), Asparagus schoberioides (10:H-+), Liliope spicata (10:H-+), Rubia akane (12:H-+), Grewia biloba var. parviflora (14:S-+), Lastrea laxa (13:H-+), Adiantum pedatum (13:H-+), Coniogramme intermedia (13:H-+), Carex ciliato-marginata (18:H-+), Pedicularis resupinata (18:H-+), Codonopsis lanceolata (19:H-+), Spodiopogon cotulifer (19:H-+), Artemisia stolonifera (19:H-+), Rosa Wichuraiana (20:S-+), Artemisia japonica (20:H-+), Cymbopogon tortilis var. goeringii (20:H-+), Potentilla dickinsii (20:H-+), Themeda triandra var. japonica (20:H-+), Hosta longipes (20:H-+), Fraxinus sieboldiana (21:S-r), Adenophora triphylla var. hirsuta (21:H-+), Platycodon grandiflorum (21:H-+), Asplenium incisum (22:H-+), Lonicera japonica (22:H-+), Arthraxon hispidus (22:H-+), Dryopteris crassirhizoma (22:H-+), Athyrium squamigerum (22:H-+), Patrinia villosa (23:H-+), Patrinia scabiosaefolia (24:H-+), Lilium tsingtauense (24:H-+).

Date of survey: Quadrat No. 1-8; Oct. 1, 1985, No. 9-18; Oct. 3, 1985, No. 19-30; Oct. 27, 1985, No. 31-34; Oct. 2, 1988.

Simbols: V; valley, L; lower part of slope, M; middle part of slope, U; upper part of slope, R; ridge, T; top.