한국환경생태학회지 25(4) : 540~561. 2011
Kor. J. Env. Eco. 25(4) : 540~561. 2011

Study of Analysis of Vegetation Structure and Species Diversity for Vegetation Management on Shrine Forest of Miwhang-sa, Korea[1]

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식생구조 관리를 위한 한국 미황사 사찰림의 식생구조 및 종다양성 분석 연구[1]

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ABSTRACT

We carried out a study for ecological management and ideal vegetation structure selection on the shrine forest of 'Miwhang-sa' considering the species diversity and the vegetation structure analysis associated with global warming. We carried out the analyses of phytosociological vegetation structure, correlation between vegetation units and environmental variables, life form, species diversity, and species evenness. This study identified the vegetation units as 3 communities. The identified vegetation units are as follows: *Quercus acuta* community(DQ), *Quercus serrata*-*Quercus variabilis* community(QQ) and *Celtis sinensis* community(CS). According to the basis on the environmental variables; Ca, Mg and P, *Celtis sinensis* community and other communities were classified. *Quecus serrata*-*Quercus variabilis* comm. and *Quercus acuta* comm. were classified, according to the basis on the environmental variables; organic matter(OM), Ni and Zn. *Sasa borealis* as life form R1-2, dominated the herb layer and will dominate the herb and shrub layers. Species simplification is formed on herb layer and will be formed on shrub layer. The species diversity of *Quercus serrata*-*Quercus variabilis* community is higher than the one of *Quercus acuta* community, and the species diversity of shrine forest around Miwhang-sa was higher than the shrine forest around Nameun-sa where evergreen broad-leaved forests dominate. It is essential that the long-term vegetation management considering the vegetation units by phytosociological analysis, the species simplification problem of low layers by *S. borealis* and the species diversity and evenness in the shrine forest, Miwhang-sa.

KEY WORDS: PHYTOSOCIOLOGY, EVERGREEN BROAD-LEAVED FOREST, CLIMATE CHANGE, LIFE FORM, SPECIES COMPOSITION, TEMPLE

요 약

지구온난화에 따른 한반도 식생구조의 변화에 맞추어 미황사 사찰림의 현 식생구조분석과 종다양성을 고려한 사찰림의 식생학적 구조분석과 적합한 식생구조 선정 및 관리를 위한 연구를 실시하였다. 본 연구는 식물사회학적 식생구조분석, 식생단위와 환경변수와의 상관관계, 생활형구조분석, 종다양성 분석 등을 실시하였다. 현 사찰림은 식물사회학적

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1 접수 2010년 8월 27일, 수정(1차: 2010년 12월 27일, 최종: 2011년 8월 11일), 게재확정 2011년 8월 12일
Received 27 August 2010; Revised(1st: 27 December 2010, Final: 11 August 2011); Accepted 12 August 2011
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식생구조 분석결과 졸참나무-굴참나무 군락, 붉가시나무군락, 팽나무군락의 식생단위로 구분되었으며, 환경변수 Ca, Mg, P 의 기준에 따라서 팽나무군락과 나머지 군락들(졸참나무-굴참나무군락과 붉가시나무군락)의 두 영역으로 분포하였다. 또한 환경변수 유기물(OM), Ni, Zn 에 따라서 졸참나무-굴참나무군락과 붉가시나무군락의 분포와 상관성이 있는 것으로 나타났다. 졸참나무-굴참나무 군락과는 양의 상관관계를 붉가시나무군락과는 음의 상관관계를 가지는 것으로 나타났다. 생활형 R1-2 식물인 조릿대가 관목층 이하에서 우점하고 있으며, 저층부의 종의 단순화를 이루고 있다. 종다양성은 졸참나무-굴참나무 군락이 붉가시나무 군락에 비하여 더 높게 나타났으며, 상록활엽수림으로 이루어진 남은사에 비해서 본 미황사 사찰림의 종다양성이 높게 나타났다. 식물사회학적 분석결과를 통한 식생군락, 조릿대에 의한 저층부 이하의 종의 단순화, 종다양성 및 종균재도를 고려한 미황사 사찰림의 장기적 식생관리가 필요하다 사료된다.

주요어: 식물사회학, 상록활엽수림, 기후변화, 생활형, 종조성, 사찰

INTRODUCTION

An shrine forest consists of variable spaces such as natural forests or preserved forests by artificial management (Lim, 1999). This forest is also the space that artificial and natural influences coexist with each other, and the important space that people can experience the nature easily and naturally. This is the space with higher naturalness in comparison with village groves.

There were very a few ecological studies about the shrine forest even though the shrine forest has been located significantly in the vegetation viewpoint and the society.

The studies of Japanese shrine forest have been started to study the vegetation of temple and shrine forest throughout the country. All of shrine forests were investigated: the vegetation structure analysis by the phytosociological method, the environmental condition of habitats, the history of shrine, the characteristics of shrine forests, the vegetation maps and the conservation, and the utility conditions of shrine forest (Ryokuchikenkyukai, 1984). Since 2000’s, it was carried out that the studies on the role of shrine wood to a local residential area, and on an adaptation of the focal species approach for conserving the woody plant species diversity in fragmented shrine forests in urban or suburban landscapes(Hayashi *et al*., 2005; Murakami *et al*., 2009).

The vegetation distribution in Korea is so variable by the influence of average maximum temperatures on warmest months and coldest months, precipitation and seasonal distribution of precipitation. Annual average precipitation is relatively much as about 1,200mm and concentrated in summer. The vegetation distribution is affected by temperature compared to precipitation(In *et al*., 2006).

Global warming means an increase in the average temperature of Earth's surface. Average temperature in the Korean Peninsula will rise an additional 3 to 4℃ by about 2100(NASA, 2010). Since last 50 years, the average temperature in the Korean Peninsula has increased 0.23 ℃ per 10 years(Jung *et al*., 2002).

In other words, the average temperature in the Korean Peninsula will be increased additionally compared to the average temperature increase all over the earth. The climate zone in the Korean Peninsula will go northward because of the global warming. According to this change of climate zone, the vegetation distribution in the Korean Peninsula will be also altered. The vegetation in present warm-temperate zone will migrate to the position in southern part of present cool-temperate zone. Therefore a vegetation structure analysis on evergreen broad-leaved forest has to be carried out for the reason that the evergreen broad-leaved forest is the most representative vegetation in the warm-temperate zone. Especially, the vegetation of the area where the warm-temperate zone coexists with the cool-temperate climate zone can be changed most easily by the influence of global warming. Therefore, the investigation about this area is very significant. The shrine forest around Miwhang-sa(shrine) is located in Mt. Dalma. The forest of Mt. Dalma is composed of the evergreen broad-leaved forest and the deciduous broad-leaved forest. This forest is affiliated with the climate zone where the warm-temperate forests are developed(Kwon *et al*., 2007).

The vegetation management of shrine forest is essential with the consideration about potential natural vegetation, succession and vegetation structure change by the global warming. Especially, the species diversity and the stable vegetation structure of forest should be considered mainly.

As the purpose of this study, we identified what kinds of vegetation is the most suitable for long-term vegetation management, according to the phytosociological and life form perspectives about the present shrine forest vegetation and species diversity analysis.

METHOD

1. Study sites

This study was carried out on the forests around Miwhang-sa as the traditional shrine on southern part of South Korea(Figure 1).

Miwhang-sa was established in the year 749. Since 749, nothing about the shrine had come down, but Monk Man-sun reconstructed the shrine in the year 1598 after destruction of the shrine by aggression of Japan in the year 1597. And then, Sung-gan and Deok-su were reconstructed in the year 1660 and 1754(Encyber, 2010). Mt. Dalma which encloses the shrine is at altitude 489m and consists of the typical Evergreen Broad-Leaved Forests(EBLF) and the Deciduous Broad-Leaved Forests(DBLF) containing the vegetation elements of evergreen broad-leaved forest.

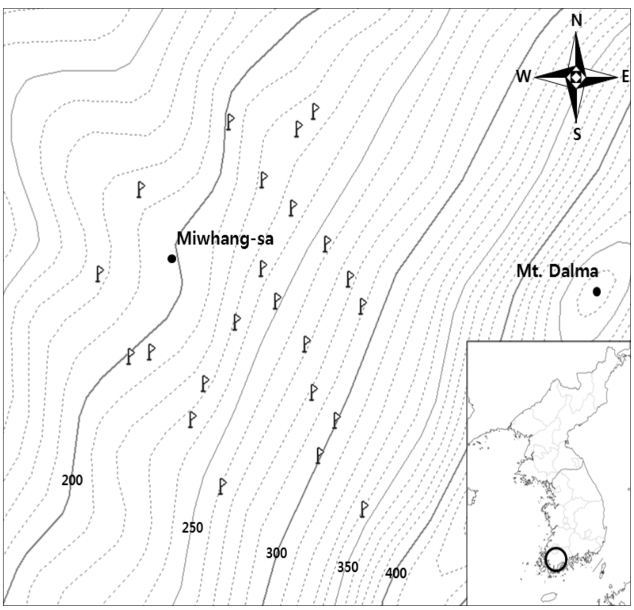

Figure 1. Location of study stands around Miwhang-sa (topographic map: KOTM v3.1; elevation error range: 0~30m)

2. Field study

The vegetation field research was carried out from July to October, 2009. We established twenty three quadrate stands on the shrine forest and investigated the dominance and sociability of each of all appearance species in each stand through the phytosociological vegetation research method (Braun-Blanquet, 1964). The quadrate is set up as 10X15 to 20X15m, based on the minimum extent which representativeness is represented in the each vegetation type of study areas, and we also investigated dominance and sociability of appearance species in each study stand (Braun-Blanquet, 1964).

3. Temperature change for 37 years

The change of annual mean temperature in the study area(average altitude: 235.83m) for 37 years from 1973 to 2009 was confirmed after applying the air temperature lapse rate(-0.55℃/100m) by Kira(1948) to the annual mean temperature data of Haenam weather station(Korea meteorological administration, 2010). We also confirmed the changes of Warmth Index(WI) and Coldness Index(CI) in the study area for 37 years.

The evergreen broad-leaved forest and the southern part of deciduous broad-leaved forest are usually placed in the area of forest on CI over -10℃, and in the one of forest on WI from 90℃ to 105(100)℃ in the warm-temperate zone(Yim and Kira, 1975).

4. Analysis of vegetation structure

For the analysis of vegetation structure on the shrine forest, We applied two basic data: the vegetation structure system of Korean evergreen broad-leaved forest by authors and vegetation structure analysis on the evergreen broad-leaved temple forest in southern part of Korea(Lee *et al.*, 2009a; 2010).

We analyzed the vegetation structure of shrine forests through a table manipulation method by Ellenberg(1956), with applying the two basic data. The basis on scientific name was arranged on the Lee(1985), Lee(1996) and Korean plant names index(2010).

We carried out the analyses of Bray-Curtis(BC) ordination meaning correlation among study stands, and BC ordination meaning the correlation among vegetation units for the confirmation of more accurate vegetation structures. We also carried out the analysis of CCA ordination between study stands and environmental variables for the correlation between the community formation and the environmental variables. We should consider the environmental conditions of high interrelationship with each vegetation structure for vegetation management of Shrine forest. The environmental variables are as follow: slope degree(°), slope aspect, altitude(m), general soil analysis data(H_2SO_4, T.N., pH, organic matter(OM; g/kg), available phosphate (P; mg/kg), exchangeable base ($cmol^+$/kg; K, Ca, Mg, Na), Electrical conductivity(EC; dS/m) and the heavy metals in soil(Cd, Cu, As, Hg, Pb, Cr, Zn, Ni). The study stand 'DM8' was analyzed except for the CCA ordination because of the soil sampling impossible(Table 1).

We utilized the vegetation analysis program 'PC-ord 4.41' for the ordination and cluster analyses based on the result of Quantified dominance and sociability(Mccune and Grace, 2002). The conversion of dominance and synthetic indices for the quantification is as follow: 5.5(dominance. sociability) → 87.50, 5.4/4.5 → 75.00, 4.4 → 62.50, 4.3/3.4 → 50.00, 3.3 → 37.50, 3.2/2.3 → 26.25, 2.2 → 15.00, 2.1/1.2 → 8.75, 1.1 → 2.50, +.2 → 0.5, + → 0.1.

5. Life form analysis

We analyzed the structure of Numata's life form about species(Numata and Asano, 1969; 1970; LEE, 1996). Especially, we applied the quantification data of species instead of presence of species. For analyzing substantive dominance structure of life form on the present vegetation, the analysis based on the quantification data at each layer is more significant and effective than the one based on number of species at each layer utilized at previous studies.

We carried out the analysis of life form classified by layers. In case of the classification by layers, all of appearance species at each layer were quantified at each layer. In other words, we quantified the species separately at each layer if the same species appear at each layer. This is possible to interpret an effective dominance extent of life form on present vegetation structure of shrine forest. We also carried out the analysis of life form classified by species types. In case of the classification by species types, we utilized the highest dominance and sociability at any layer without the presence of species at each layer.

According to the life form analyses classified by layers and species types, we can recognize the present life form composition of species appeared and estimate the life form composition and dominance extent of that the species composing the vegetation of the future such as the vegetation change and the maturity of forest etc. since now. We can therefore take measures about long-term vegetation management on the shrine forest.

6. Species diversity analysis

It was analyzed that the indices of species diversity and evenness utilizing Shannon-Wiener diversity index(H') and Pielou's evenness index(J')(Kent and Coker, 2002).

The indices were utilized for long-term vegetation management considering species diversity. Species diversity and evenness of shrine forest were analyzed on the two ways. First method is the analysis after dividing into two forests, EBLF and DBLF, and the second method is the comparison of species diversity and evenness between this shrine forest and the other shrine forest around Nameun-sa(Lee, Unpublished data) where the typical evergreen broad-leaved forests dominate. It was investigated that the ideal vegetation types considering the species diversity and evenness of shrine forest.

Eventually, it is possible that the ideal vegetation structure selection and ecological management considering the forest stability and species diversity, through the analyses of the species diversity, life form and phytosociological vegetation structures.

RESULT and DISCUSSION

1. Temperature change in study area for 37 years

The annual mean temperature in study area for 37 years increased about 0.51℃, and will increase continually according to the growth data of linear trendline(Figure 2).

WI(Figure 3) which is highly correlated with the distribution of deciduous broad-leaved forest in the warm-temperate zone was the most of conditions between 90 and 107℃ for 37 years, that the southern part of deciduous

Table 1. Chemical properties of the soil in the study areas

Study areas	H_2SO_4	T.N.	pH (1:5)	OM	P	Exchangeable base				EC	Heavy metals in soil							
						K	Ca	Mg	Na		Cd	Cu	As	Hg	Pb	Cr	Zn	Ni
DM1	6.50	0.44	4.20	68.00	24.00	0.11	0.10	0.10	0.45	1.03	0.03	0.09	0.03	0.16	0.03	0.03	46.88	15.60
DM2	7.50	0.51	4.50	68.00	9.00	0.26	0.10	0.10	0.58	0.58	0.02	0.09	0.00	0.24	0.62	0.04	62.66	18.93
DM3	10.05	0.69	4.30	69.00	16.00	0.24	0.60	0.70	0.54	1.59	0.05	0.10	0.01	0.20	0.39	0.04	59.32	13.97
DM4	10.05	0.69	4.30	69.00	16.00	0.24	0.60	0.70	0.54	1.59	0.05	0.10	0.01	0.20	0.39	0.04	59.32	13.97
DM5	8.22	0.56	4.50	66.00	11.00	0.20	0.40	0.30	0.58	0.96	0.02	0.12	0.01	0.21	0.56	0.06	67.17	17.35
DM6	5.63	0.38	4.20	67.00	8.00	0.13	0.10	0.04	0.56	0.65	0.02	0.08	0.05	0.14	0.76	0.04	59.49	14.25
DM7	5.16	0.35	4.70	69.00	7.00	0.11	0.10	0.01	0.52	0.38	0.01	0.05	0.00	0.12	0.49	0.06	52.31	21.24
DM9	9.39	0.64	4.00	70.00	35.00	0.34	1.40	0.50	0.65	1.38	0.04	0.29	0.15	0.37	0.60	0.05	84.63	19.87
DM10	2.45	0.16	4.50	48.00	4.00	0.11	0.40	0.10	0.62	0.30	0.00	0.07	0.00	0.04	0.74	0.03	25.14	9.92
DM11	4.54	0.30	5.00	67.00	8.00	0.13	0.20	0.01	0.65	0.28	0.02	0.19	0.01	0.10	0.72	0.05	44.70	13.46
DM12	4.55	0.31	4.70	69.00	6.00	0.21	0.10	0.20	0.62	0.33	0.01	0.11	0.00	0.11	1.10	0.07	50.93	20.11
DM13	5.31	0.36	4.50	68.00	6.00	0.22	0.20	0.10	0.60	0.51	0.02	0.11	0.00	0.13	0.64	0.06	79.80	26.06
DM14	5.05	0.34	4.40	67.00	7.00	0.15	0.50	0.10	0.57	0.69	0.02	0.55	0.00	0.14	0.94	0.03	60.89	18.60
DM15	6.29	0.43	4.40	68.00	21.00	0.20	1.30	0.60	0.58	1.25	0.04	0.27	0.08	0.13	0.56	0.03	67.69	20.54
DM16	4.46	0.30	4.70	71.00	6.00	0.11	0.10	0.50	0.65	0.34	0.01	0.12	0.00	0.12	1.04	0.07	51.70	19.49
DM17	3.29	0.22	4.50	57.00	5.00	0.15	0.10	0.40	0.61	0.58	0.01	0.05	0.05	0.10	1.07	0.08	71.29	17.18
DM18	3.36	0.22	4.40	67.00	8.00	0.19	0.20	0.20	0.69	0.47	0.01	0.07	0.03	0.07	0.86	0.03	42.52	12.44
DM19	8.93	0.61	4.10	69.00	16.00	0.32	0.40	0.30	0.66	1.33	0.03	0.18	0.15	0.24	0.43	0.04	83.32	24.56
DM20	5.82	0.39	4.50	68.00	8.00	0.23	0.20	0.20	0.59	0.52	0.02	0.11	0.00	0.14	0.64	0.06	76.80	22.94
DM21	7.59	0.52	4.40	68.00	31.00	0.40	2.50	0.70	0.68	1.59	0.03	0.30	0.07	0.17	0.07	0.04	78.53	25.24
DM22	5.05	0.34	4.70	68.00	6.00	0.17	0.10	0.10	0.55	0.38	0.01	0.09	0.01	0.10	0.96	0.04	82.71	20.10
DM23	5.31	0.36	4.50	70.00	35.00	0.25	3.80	1.20	0.65	1.34	0.02	0.16	0.12	0.13	0.50	0.02	64.24	21.28

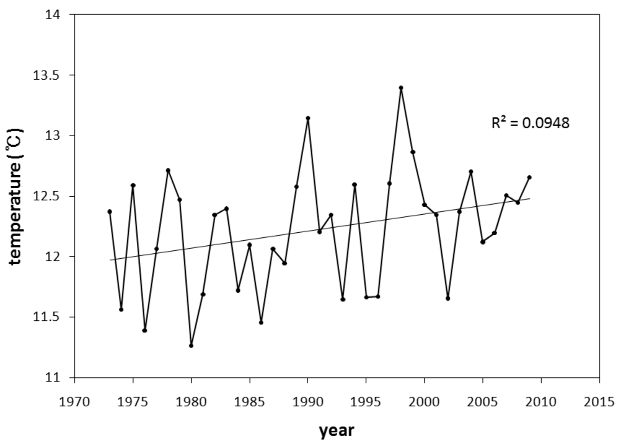

Figure 2. Mean temperature change for 37 years in the study area
* Altitude of study area (average 235.83m)

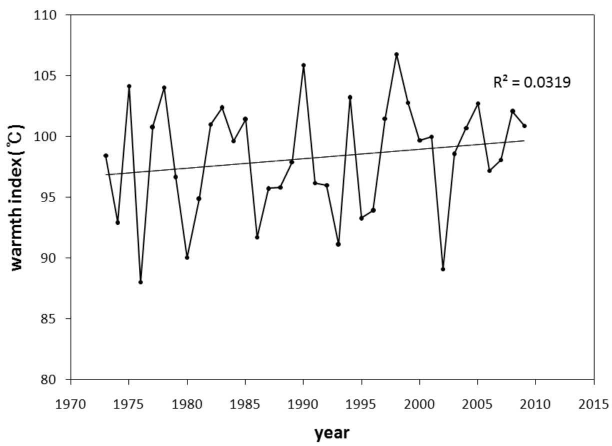

Figure 3. Warmth Index(WI) change for 37 years in the study area

broad-leaved forest in the warm-temperate zone can be distributed, except for the cases under WI 90℃(1976 and 2002). WI will increase continually through the growth data of the annual mean temperature and the linear trendline.

CI(Figure 4) which is highly correlated with the distribution of evergreen broad-leaved forest in the warm-temperate zone recently came in the condition over -10℃ that the evergreen broad-leaved forest in the warm-temperate zone can be distributed according to the data of linear trendline, and will also increase continually in the future.

This study area belongs to the southern part of deciduous broad-leaved forest in the warm-temperate zone and recently began to come in the condition of evergreen

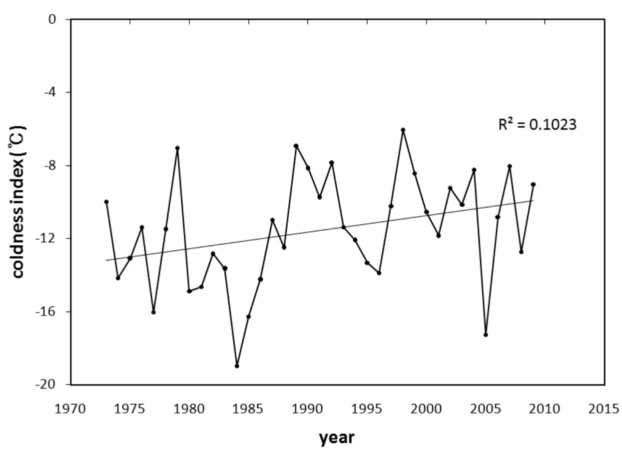

Figure 4. Coldness index(CI) change for 37 years in the study area

broad-leaved forest in the warm-temperate zone. This result means, some of the study area will be continued to change in gradually from the deciduous broad-leaved forest to the evergreen broad-leaved forest in the long term because of the temperature increase by global warming. Therefore, it is necessary that the vegetation management considering the vegetation structure alteration toward evergreen broad- leaved forest in the long-term vegetation management.

2. Analysis of vegetation structure

Total of 143 species were recorded on the 23 quadrates of the shrine forest. Average appearance species was 31.96 species from minimum 18 species to maximum 56 species. The altitude was recorded from 155m to 312m. The slope aspect was recorded from flatland to 40°. As a result of the average height at each layer, average height 14.64m from 12m to 20m was recorded at tree layer(T-1). The height of sub-tree layer(T-2) was average 10.29m from 9m to 12m. The one of shrub layer(S) was recorded as average 5.59m from 5m to 7m. The average height 0.65m from 0.5m to 1m was recorded at herb layer(H). As a result of the average coverage rate at each layer, the average coverage rate 79.55% from 65% to 85% was recorded at tree layer(T-1). The coverage rate of sub-tree layer(T-2) was average 22.94% from 10% to 30%. The one of shrub layer(S) was recorded as average 30% from 15% to 40%. The average coverage rate 37.96% from 15% to 40% was recorded at herb layer(H)(Table 2).

Table 2. Phytosociological table on the shrine forest of Miwhang-sa

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
Study stands	DM 13	DM 8	DM 16	DM 9	DM 2	DM 12	DM 20	DM 19	DM 3	DM 11	DM 14	DM 22	DM 21	DM 15	DM 1	DM 17	DM 7	DM 4	DM 18	DM 5	DM 10	DM 6	DM 23
T-1(m)	12	13	13	12	14	12	14	12	14	14	16	14	15	16	13	15	13	14	18	18	15	20	18
T-1(%)	75	80	80	75	80	75	80	85	75	85	75	75	65	80	75	85	80	80	85	85	85	85	85
T-2(m)	-	-	-	-	10	-	10	-	10	10	10	9	10	12	10	10	10	10	10	12	11	10	11
T-2(%)	-	-	-	-	30	-	20	-	20	30	35	20	10	30	30	15	25	20	30	20	20	15	20
S(m)	6	6	7	7	5	6	5	7	5	5	5	5	5	6	5	5	5	5	5	6	7	6	5
S(%)	35	20	30	35	20	30	30	15	30	35	40	30	35	25	30	15	35	30	30	30	35	35	30
H(m)	0.8	1	0.7	1	0.8	0.8	0.7	0.8	0.8	0.5	0.5	0.5	0.5	0.7	0.5	0.5	0.5	0.7	0.5	0.5	0.7	0.7	0.5
H(%)	65	70	50	60	70	60	45	45	60	15	10	60	40	60	10	30	15	60	10	5	5	10	50
Slope aspect	N 48 W	S 54 W	N 38 W	N 18 W	N 60 W	S 82 W	N 42 W	N 62 W	N 80 W	N 18 W	N 20 E	N 42 W	N 42 W	N 32 W	N 32 W	N 70 W	N 74 W	N 54 W	N 82 W	N 52 W	N 70 W	N 18 W	N 56 W
Slope degree(°)	20	32	23	20	22	35	20	25	23	26	20	13	12	18	17	17	25	20	40	20	17	25	20
Elevation(m)	212	262	230	257	249	170	240	312	294	178	210	201	207	220	221	226	274	289	217	286	249	265	155
Releve size	15 X 20	15 X 10	15 X 15	10 X 15	15 X 15	15 X 15	15 X 15	15 X 15	15 X 10	10 X 15	20 X 15	15 X 15	15 X 10	20 X 15	15 X 15	15 X 15	10 X 15	15 X 15	15 X 10	15 X 20	15 X 15	15 X 20	15 X 15
No. of species	22	19	18	19	39	39	33	39	27	28	31	20	45	46	56	27	26	28	23	29	33	23	52
Units	A*															B							C
Subunits(1)	a-1			a-2						a-3		a-4				b-1			b-2			b-3	
Subunits(2)												a-41			a-42	b-11		b-12					
Character and differential species of *Quercus acuta* comm.																							
Quercus acuta for. *acuta*	·	1.1	3.3	2.1	1.2	1.1	1.2	+	2.2	1.1	2.2	1.1	1.2	·	2.2	4.4	3.3	4.3	4.4	4.4	4.4	4.4	1.1
Machilus japonica	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2.1	2.2	3.2	·
Neolitsea aciculata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Character and differential species of *Q. serrata-Q. variabilis* comm.																							
Quercus serrata	3.3	4.3	2.2	4.3	4.3	4.3	3.3	4.4	3.3	2.2	2.1	3.2	2.1	1.1	3.3	2.1	3.2	2.2	1.1	1.1	1.1	·	2.1
Quercus variabilis	2.3	·	1.1	·	1.1	+	3.2	·	1.1	1.1	1.1	2.1	1.1	·	2.2	·	·	1.1	·	·	·	·	1.1
Vaccinium oldhamii	3.2	2.1	+.2	2.2	+.2	1.1	2.2	+.2	+.2	2.2	·	3.2	2.2	+.2	+	+	+	1.1	·	+	+	·	·
Ilex macropoda	1.2	2.2	1.1	1.1	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.1	·	1.1	·	1.1	2.1	1.1	·	·	1.1	·
Differential species of subcomm.																							
Pinus densiflora	1.1	1.1	2.2	1.1	1.1	1.1	1.1	+	1.1	3.3	3.3	1.1	1.1	1.1	1.1	1.1	·	·	1.1	·	+	·	·
Fraxinus sieboldiana	1.2	+	1.2	1.1	+	2.2	·	+	+	+.2	+	+.2	+	·	+	·	·	·	·	·	·	·	·
Rhododendron mucronulatum var. *mucronulatum*	1.1	+	·	1.1	·	·	+	+.2	+	+.2	+.2	+	+.2	·	+.2	·	·	·	·	·	·	·	·
Differential species of group																							
Quercus acutissima	·	·	1.1	1.1	·	1.1	·	·	·	·	+	3.2	3.3	3.3	·	·	·	·	·	·	·	·	2.2
Ligustrum obtusifolium	·	·	·	·	+	·	·	·	·	·	·	·	+.2	+.2	·	·	·	·	·	·	·	·	+.2
Carex humilis var.*nana*	·	·	·	·	·	+	·	·	+	·	·	·	+	+	·	·	+	·	·	·	·	·	·

Table 2. (Continued)

Differential species of group																							
Parthenocissus tricuspidata	·	·	·	·	·	·	·	+.2	·	·	·	·	+	+	+.2	·	·	+	·	+	+.2	·	+.2
Lemmaphyllum microphyllum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	·	+.2	+	+	+	+	·
Torreya nucifera	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·	·	+.2	·	·	+
Acer palmatum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+.2	+	+.2	+	1.1	+
Aphananthe aspera	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1	+
Acer mono	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1	1.1
Differential species of *C. sinensis* comm.																							
Celtis sinensis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3.3
Cornus controversa	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3.3
Cyrtomium fortunei	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.2
Dryopteris lacera	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+.2
Rhamnella franguloides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+.2
Staphylea bumalda	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+.2
Cornus macrophylla	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1
Achyranthes japonica	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+.2
Rosa multiflora var.*multiflora*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2.2
Character species of Camellietea japonicae																							
Eurya japonica	+.2	1.1	2.1	2.2	+.2	1.1	1.1	+.2	+.2	2.2	3.3	1.2	+	+.2	1.1	1.1	3.2	1.1	1.1	1.1	·	·	·
Machilus thunbergii	·	·	·	·	+	+	+	+	·	+	+	+.2	+	·	2.2	+	+	+	+.2	+.2	2.2	1.1	1.1
Camellia japonica	·	·	·	+	·	·	1.1	+	1.1	+.2	·	+.2	3.2	·	1.1	2.2	2.2	2.2	3.2	3.3	3.2	2.2	2.2
Ardisia japonica	·	·	·	·	+	·	·	+.2	+.2	1.1	+.2	·	+.2	+	+.2	1.1	2.1	2.1	2.1	1.1	+.2	+.2	·
Ligustrum japonicum var. *japonicum*	·	+	·	+	+	+	+.2	·	+.2	·	+.2	·	·	+	+.2	1.2	+.2	·	3.2	2.2	1.2	1.1	1.2
Trachelospermum asiaticum var. *asiaticum*	·	·	·	·	·	+	+.2	·	·	·	+.2	·	+.2	+	+.2	+	·	·	1.1	+	+	+	2.2
Ophiopogon japonicus	·	·	·	·	+	+	+	+.2	·	·	+	·	+	·	·	+	·	+	+	+	+		+.2
Kadsura japonica	·	·	·	·	·	·	+		·	·	+	·	+.2	+.2	+.2	+.2	·	·	+.2	+	+.2	+.2	3.3
Dryopteris bissetiana	·	·	·	·	·	·	+	+	·	·	·	·	+	+	+.2	·	·	+	+.2	+	+	·	·
Quercus salicina	·	·	·	·	·	1.1	·	·	·	1.2	·	1.1	+	+	·	·	·	·	·	·	·	·	+
Actinodaphne lancifolia	·	·	·	·	1.1	·	+	·	·	·	·	·	·	·	1.2	+	+	+	·	1.1	1.1	1.2	·
Cinnamomum japonicum	·	·	·	·	+	·	·	·	·	+	·	·	·	+	+	·	·	·	·	1.2	+.2	+	1.1
Liriope platyphylla	·	·	·	·	·	+	·	·	·	·	+	·	·	·	+	·	·	·	·	+	+	·	1.1
Hedera rhombea	·	·	·	·	·	·	+	·	·	·	·	·	·	+.2	·	·	·	+	·	·	+	·	2.2
Akebia quinata	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	+
Dryopteris erythrosora	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	1.1	1.1	·	+.2	·
Neolitsea sericea	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.2	·	2.2	+.2
Aucuba japonica	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2.2	·

Table 2. (Continued)

Differential species of *Q. serrata-Q. variabilis* forest (Warm-temperate deciduous broad-leaved forest)																							
Viburnum erosum	2.2	+.2	1.1	1.1	1.1	1.1	2.1	2.1	2.1	2.1	+.2	2.2	2.2	+	3.3	1.1	+	1.1	1.1	+	+.2	·	·
Styrax japonicus	1.2	2.2	2.2	2.1	2.2	2.1	2.2	2.2	2.2	1.1	2.2	2.1	1.1	3.2	3.2	2.1	1.2	2.2	·	1.1	2.1	·	1.1
Smilax china	+	+	+	+	+	+	·	+	+	+	+	+	+	+	+	+	+	+	+	·	+	·	·
Lindera obtusiloba var. *obtusiloba*	+.2	+	+.2	+	+.2	+	+.2	1.1	+.2	+.2	+.2	·	+.2	·	1.2	·	·	·	+	·	·	·	·
Lindera erythrocarpa	·	·	+	·	+	·	+	+.2	·	+	+	+	+.2	+.2	+.2	+	+	+	·	·	·	·	·
Sapium japonicum	·	·	·	·	+	·	·	2.1	+	·	·	·	+	·	2.2	+	+.2	1.1	+	1.1	1.1	·	1.1
Carpinus tschonoskii var. *eximia*	·	1.1	·	·	+	·	2.1	1.1	1.1	·	·	·	·	1.1	1.1	·	·	·	2.1	1.1	1.1	1.1	2.2
Euonymus oxyphyllus	·	·	·	·	+	·	+	+	·	·	·	·	·	+	+	+	·	+	·	+	+	·	·
Pourthiaea villosa var. *villosa*	+	·	+	·	·	+		+	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·
Rhus tricocarpa	·	·		·	+	·	+	·	·	·	·	·	·	+	·	·	·	+	·	·	·	·	1.1
Cornus kousa	·	·	+	·	+	·	·	·	·	·	·	·	+	1.1	1.1	·	·	·	·	·	·	·	·
Viburnum dilatatum	·	·	·	·	+	·	·	·	·	·	·	·	+	+	+.2	·	·	·	·	·	·	·	·
Stephanandra incisa var. *incisa*	·	·	·	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+.2
Corylus sieboldiana var. *sieboldiana*	·	·	·	·	·	·	·	+	·	·	·	·	+.2	·	+.2	·	·	·	·	·	·	·	·
Carpinus laxiflora var. laxiflora	·	·	·	·	1.1	·	·	·	·	·	·	·	·	·	·	·	1.1	·	·	·	·	·	·
Companions																							
Sasa borealis	4.3	4.4	3.3	4.3	4.4	4.3	3.3	3.2	4.3	1.1	+	4.3	3.3	3.4	+.2	3.2	1.1	1.1	·	·	+	·	·
Acer pseudosieboldianum	1.1	+	2.1	+	1.2	+	·	2.1	1.1	·	+.2	+.2	·	·	+	+	+	·	·	·	·	·	·
Sorbus alnifolia	+	+	·	1.1	+	1.1	·	+	1.1	+	·	·	·	+	+	·	+	·	·	·	·	·	·
Symplocos chinensis for. pilosa	·	·	·	·	+	+.2	+.2	+.2	·	+	·	+	·	+	+.2	·	·	·	·	·	·	·	·
Lindera glauca var. glauca	·	·	·	·	+	·	·	+	·	·	+	·	·	+	+	·	·	·	·	·	·	·	·
Oplismenus undulatifolius var. *undulatifolius*	·	·	·	·	·	·	+	+	·	·	+	·	+	+	+.2	·	+	+	·	·	·	·	+.2
Rhus verniciflua	·	·	·	·	+	+	+	·	+	·	·	·	+	+	+	·	·	·	·	+	·	·	·
Dryopteris chinensis	·	·	·	·	·	·	·	+	·	·	+	·	+	·	·	+	+	+	·	·	·	·	·
Callicarpa mollis	·	·	·	·	·	·	·	+	·	·	·	·	·	·	1.1	·	·	+	+.2	·	+	·	·
Symplocos tanakana	·	·	·	·	·	+	·	·	·	·	·	·	·	2.1	·	·	·	·	·	·	·	·	·
Persicaria filiformis	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	+.2
Prunus sargentii	·	+	·	·	+	·	·	·	1.1	·	·	·	+	·	1.2	·	·	·	·	·	·	·	·
Platycarya strobilacea var. *strobilacea* for. *strobilacea*	·	·	·	·	·	1.1	·	·	·	·	·	·	·	2.2	+	+	·	·	·	·	·	·	·
Meliosma oldhamii	·	·	·	·	+	·	·	1.2	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·
Elaeagnus macrophylla	·	·	·	·		·	·	·	+	·	·	·	·	·	·	·	+	·	·	·	·	+	+
Mallotus japonicus	·	·	·	·	+	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1
Pteridium aquilinum var. latiusculum	+	·	·	·	·	+	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·
Lespedeza maximowiczii	·	·	·	·	·	+	+	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·
Callicarpa japonica	·	·	·	·	·	·	·	·	·	·	+	·	·	2.1	+	·	·	·	·	·	·	·	+
Rhododendron schlippenbachii	+.2	·	·	·	·	·	·	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Dioscorea quinqueloba	·	·	·	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·	+	·
Weigela subsessilis	·	·	·	·	·	·	+.2	·	·	·	·	·	·	·	+	+		·	·	·	·	·	·

Table 2. (Continued)

Ampelopsis brevipedunculata for.*citrulloides*	·	·	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·	·	·	·	+	·	·
Albizia julibrissin	·	1.1	·	·	·	·	1.1	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	1.1
Pyrola japonica	+	·	·	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Zelkova serrata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1.1	·	·
Alangium platanifolium var. *trilobum*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	·
Meliosma myriantha	·	·	·	·	·	·	·	+	·	·	·	·	·	·	1.1	·	·	·	·	·	·	·	·
Disporum smilacinum	·	·	·	·	·	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·
Corylus heterophylla var. *thunbergii*	·	·	·	·	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·
Idesia polycarpa	·	·	·	·	·	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	·	·
Arisaema ringens	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·
Euscaphis japonica	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	+
Robinia pseudoacacia	+	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Ainsliaea acerifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	+	·	·	·	·
Styrax obassia		·	·	·	·	·	·	+	1.1	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Fraxinus rhynchophylla	·	·	·	+.2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

* Vegetation units:

A(*Quercus serrata*-*Quercus variabilis* community, QQ); B(*Quercus acuta* community, QA); C(*Celtis sinensis* community, CS); a-1(*Pinus densiflora* typical subcommunity, QQ-Ts1); a-2(*Pinus densiflora* typical subcommunity, QQ-Ts2); a-3(*Pinus densiflora* typical subcommunity, QQ-Ts3); a-4(*Pinus densiflora* subcommunity, QQ-Ts4); a-41(*Quercus acutissima* group, Ts4-Qa); a-42(*Torreya nucifera* group, Ts4-Tn); b-1(*Quercus serrata* subcommunity, QA-Qs); b-11(Typical group, Qs-Tg); b-12(*Acer palmatum* group, Qs-Ap); b-2(Typical subcommunity and *Acer palmatum* group, QA-Ap1); b-3(Typical subcommunity and *Acer palmatum* group, QA-Ap2)

Species (+ and one time) of companions in study areas:

DM1: *Zanthoxylum schinifolium, Polygonatum odoratum* var. *pluriflorum, Dioscorea tenuipes, Panicum miliaceum* DM2: *Davallia mariesii, Symplocos coreana* DM7: *Melica onoei* DM10: *Dryopteris saxifrage, Vitis flexuosa* DM11: *Mitchella undulate, Rhododendron mucronulatum* var. *ciliatum* DM12: *Diospyros kaki, Juniperus rigida, Rhododendron yedoense* for. *poukhanense, Spodiopogon cotulifer, Poa sphondylodes* DM13: *Lophatherum gracile, Vaccinium bracteatum* DM14: *Carpinus turczaninovii, Ainsliaea apiculata* DM15: *Thelypteris japonica* var. *japonica, Phryma leptostachya* var. *asiatica, Gynostemma pentaphyllum, Cocculus trilobus, Clematis apiifolia, Lonicera fragrantissima, Circaea mollis* DM17: *Morus bombycis* var. *bombycis* DM19: *Elaeagnus glabra* DM20: *Carex ciliatomarginata, Ampelopsis brevipedunculata* DM21: *Paederia scandens* var. *scandens, Impatiens textori* var. *textori, Boehmeria nivea, Viola selkirkii* for. *Selkirkii, Leersia sayanuka* DM23: *Desmodium podocarpum* var. *oxyphyllum, Smilax sieboldii* for. *sieboldii, Lilium distichum, Euonymus alatus* for. *ciliatodentatus, Boehmeria spicata, Euonymus japonicus, Commelina communis, Cudrania tricuspidata, Persicaria longiseta*

1) Phytosociological community structure analysis

The shrine forest around Miwhang-sa was classified into the three vegetation units: *Quercus serrata-Quercus variabilis* community(QQ), *Quercus acuta* community(QA) and *Celtis sinensis* community(CS)(Table 2). *Q. serrata- Q. variabilis* comm. was classified one more into the subunits as typical group of *Pinus densiflora* typical subcomm.(QQ-Ts1, QQ-Ts2 and QQ-Ts3), *Quercus acutissima* group(Ts4-Qa) and *Torreya nucifera* group(Ts4-Tn). *Q. acuta* comm. was classified one more into the subunits as *Q. serrata* subcomm.(QA-Qs) and typical subcomm.(QA-Ap1 and Qa-Ap2), and *Q. serrata* subcomm. was classified one more into the subunits as typical group(Qs-Tg) and *Acer palmatum* group(Qs-Ap). According to this phytosociological community structure analysis, we identified that the evergreen broad-leaved forest and the deciduous broad-leavd forest were coexisted, and the vegetation elements of evegreen broad-leaved forest (Character species of *Camellietaea japonicae*) demonstrated the high appearace rate in *Q. serrata-Q. variabilis* comm. The vegetation elements of warm-temperate deciduous broad-leaved forest(differential species of *Q. serrata-Q. variabilis* forest) demonstrated the high appearace rate in *Q. acuta* comm..

P. densiflora typical subcomm. of *Q. serrata-Q. variabilis* comm. was classified into three types: QQ-Ts1 (a-1), QQ-Ts2(a-2) and QQ-Ts3(a-3). 'QQ-Ts1' consisting of study stands DM8, DM13 and DM16 is the typical group that the vegetation elements of evergreen broad-leaved forest do not appear practically, and 'QQ-Ts2' consisting of study stands DM2, DM3, DM9, DM12, DM19, and DM20 is the typical group that the vegetation elements of evergreen broad-leaved forest do appear. 'QQ-Ts3' consisting of study stands DM11 and DM14 is the typical group that the vegetation elements of evergreen broad-leaved forest do appear, and the dominance of *Sasa borealis* is low compared to other typical groups.

The group QQ-Ts1 is only *P. densiflora* typical subcomm. falling under typical deciduous broad-leaved secondary forest that the vegetation elements of evergreen broad-leaved forest do not exist practically among all of vegetation communities classified. Even if *Q. acuta* existed as high dominance at some study stands, the study stands were affiliated to the evergreen broad-leaved forest according to the phytosociological community classification concentrated to the presence and dominance of character and differential species. The decrease in dominance of *Q. acuta* and the increase in dominance of the character and differential species of *Q. serrata-Q. variabilis* comm. are estimated to come up at this 'QQ-Ts1'. Especially, *S. borealis* had the high dominance at this group.

The group QQ-Ts2 is the typical group of *P. densiflora* typical subcomm. that the vegetation elements of evergreen and deciduous broad-leaved forests were appeared. This group is affiliated to the intermediate region between evergreen broad-leaved forest and deciduous broad-leaved forest, and has the characteristics of relatively high dominance and appearance rate of the vegetation elements of deciduous broad-leaved forest in comparison with the elements of evergreen broad-leaved forest. This result means that this typical group was identified closer to the deciduous broad-leaved forest, even though this group was affiliated to the intermediate region. By the character and differential species of *Q. serrata-Q. variabilis* comm., this group was identified close to the deciduous broad-leaved forest one more.

The group QQ-Ts3 is the typical group of *P. densiflora* typical subcomm., having the characteristics of the vegetation elements of evergreen and deciduous broad-leaved forests, high dominance of differential species of *P. densiflora* typical subcomm., and relatively low dominance of *S. borealis*. This typical group was comprised of the character and differential species of relatively low dominance in *Q. serrata-Q. variabilis* comm., the differential species of relatively high dominance on *P. densiflora* typical subcomm., and *S. borealis* practically no exited. Both of vegetation elements of deciduous and evergreen broad-leaved forests upspringed, and numerical value of evergreen broad-leaved forest was higher than the one of deciduous broad-leaved forest. 'QQ-Ts3' can be defined as the deciduous broad-leaved forest with the high dominance of *P. densiflora* forest in warm-temperate zone, because of the factors that we mentioned above and the high dominance of only *Eurya japonica* among the vegetation elements of evergreen broad-leaved forest. This vegetation will fall behind in the future by the high appearance rate of character and differential species of *Q. serrata-Q. variabilis* comm., low dominances of other species except for *P. densiflora* among differential species of *P. densiflora* subcomm.. The present shrub and herb layers that *S. borealis* of low dominance is distributed will be dominated as *S. borealis* by invasion of *S. borealis* from other *P. densiflora* typical subcomm. (QQ-Ts1 and QQ-Ts2).

The character and differential species of *Q. serrata*-*Q. variabilis* comm. upspringed highly at the *Q. acutissima* group(Ts4-Qa) and T. nucifera group(Ts4-Tn) of *P. densiflora* subcomm.. High dominance of *Q. acutissima* was identified as similar as the one of character and differential species of *Q. serrata*-*Q. variabilis* comm. at *Q. acutissima* group. In other words, this vegetation was developed close to the deciduous broad-leaved mixed forest dominated mainly by *Q. acutissima* and *Q. serrata* instead of the dominance of *Q. serrata* or *Q. variabilis*. The vegetation elements of evergreen and deciduous broad-leaved forests, high dominance of *S. borealis*, and relatively low dominance of differential species of *P. densiflora* subcomm. demonstrated. However, the character and differential species of *Q. serrata*-*Q. variabilis* comm. had the high dominance index at T. nucifera group. Especially, *T. nucifera* and *Lemmaphyllum microphyllum* upspringed in only this group in comparison with other *P. densiflora* subcomm.. *S. borealis* also had the low dominance.

Only *Q. acuta* among the character and differential species of *Q. acuta* comm. upspringed as high dominance at *Q. serrata* subcomm.(QA-Qs) of *Q. acuta* comm., and *Q. serrata* had the next high dominance. The dominance of vegetation elements of evergreen broad-leaved forest was higher than the one of deciduous broad-leavd forest. This result means that the canopy of this subcomm. is dominated by evergreen broad-leaved species such as *Q. acuta* and vegetation elements of evergreen broad-leaved forest, even though vegetation elements of evergreen and deciduous broad-leaved forests are mixed up. Especially, this subcomm. is the evergreen broad-leaved forest of the intermediate region which is different with the deciduous broad-leaved forest(QQ-Ts2) mentioned above. According to the relatively low vegetation elements of evergreen broad-leaved forest and the high dominance index of some study stand(DM17) of typical group in this subcomm., the vegetation of shrub and herb layers have been impenetrated and dominated by *S. borealis*, and this vegetation structure will fall behind. On the contrary to this, another study stand(DM7) was composed of high vegetation elements of evergreen broad-leaved forest and low dominance of *S. borealis*, and vegetation condition of present evergreen broad-leaved forest or the rate of vegetation elements of evergreen broad-leaved forest will be maintained or increase. Especially, *A. palmatum* group of this subcomm. was composed of high dominance of *Q. acuta*, relatively low vegetation elements of evergreen and deciduous broad-leaved forests and low dominance of *S. borealis*. Many character and differential species of *Q. serrata* subcomm. upspringed, but the dominance indices of those species were not high. *A. pamlatum* also upspringed otherwise typical group.

The typical subcomm. of *Q. acuta* comm. was classified into two subunits according to the composition of appearance species: *A. palmatum* group that the vegetation elements of deciduous broad-leaved forest upsprings(QA-Ap1; DM5, DM10 and DM18) and *A. palmatum* group that the vegetation elements of deciduous broad-leaved forest do not practically upspring(QA-Ap2; DM6).

'QA-Ap1' was identified as low vegetation elements of deciduous broad-leaved forest in comparison with the one of evergreen broad-leaved forest, even though deciduous broad-leaved forest upspringed. Especially, the dominance of character and differential species of *Q. serrata*-*Q. variabilis* comm. was identified as very low in comparison with *Q. serrata* subcomm.. *S. borealis* did not upspring except for the dominance '+' of DM10. This result means that this group is relatively similar with typical and pure evergreen broad-leaved forest in comparison with *Q. serrata* subcomm..

'QA-Ap2' was identified as no character and differential species of *Q. serrata*-*Q. variabilis* comm. except for the dominance/sociability '1.1' of Ilex macropoda. Espcially, *S. borealis* and vegetation elements of deciduous broad-leaved forest did not upspring except for *Carpinus tschonoskii*(1.1). This result means that this group is the most similar to the typical and pure evergreen broad-leaved forest among all of vegetation units.

C. sinensis comm.(CS) was dominated by *Q. serrata*, *Q. variabilis*, *Q. acutissima* and differential species of *C. sinensis* comm. The dominance/sociability of *C. sinensis* and Cornus controversa was the highest as '3.3'. Especially, the appearance rate and dominance of vegetation elements of evergreen broad-leaved forest were higher than the one of deciduous broad-leaved forest. This result means that this comm. is composed close to mixed stand forest of evergreen and deciduous broad-leaved forests according to the vegetation elements for only this comm.(differential species of *C. sinensis* comm. and *Q. acutissima* group etc.) and vegetation elements of evergreen broad-leaved forest. This is also located beside road. This comm. can be therefore altered easily by artificial influence in comparison with other vegetations.

2) BC ordination analysis

The result of BC ordination analysis was almost similar as the one of phytosociological community classification (Table 2 and Figure 5).

Q. serrata subcomm.(b-1) of *Q. acuta* comm. was located relatively near *Q. serrata*-Q. variablilis comm. in comparison with other subcomm.. High dominances of character and differential species of *Q. serrata* subcomm. and the high appearance rate of *S. borealis* compared to subcomm. of *Q. acuta* comm. are the major cause of This result. According to the position of study stands, the study stand DM6 located uttermost from *Q. serrata*-*Q. variablilis* comm. was close to the typical and pure evergreen broad-leaved forest alike aforementioned phytosociological vegetation classification results(QA-Ap2). We could therefore identify that the result of BC ordination analysis is also located uttermost from study stands of deciduous broad-leaved forest.

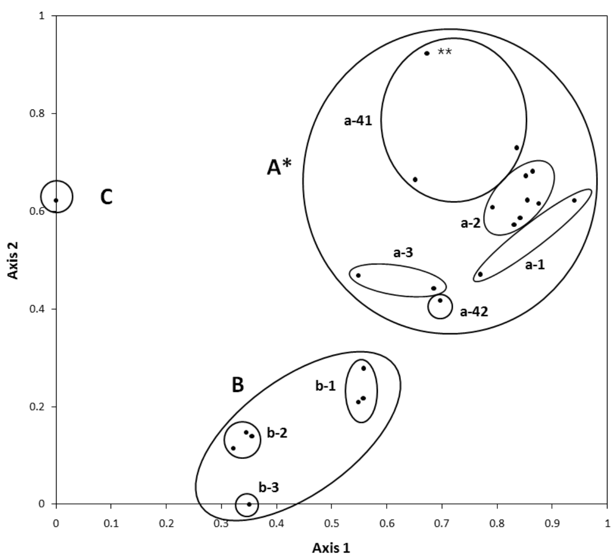

Figure 5. Diagram of BC ordination

*A, B, C, a-1, a-2, a-3, a-41, a-42, b-1, b-2, b-3: vegetation units and subunits(refer to Table 2)

**●: study stands(refer to Table 2)

Q. serrata-*Q. variablilis* comm.(QQ; A) as deciduous broad-leaved forest was classified from one subunits to three subunits like the result of phytosociological community classification, and the subunits could be classified into and distributed as five types according to the species composition. In case of ‘a-1(QQ-Ts1)’ and ‘a-2(QQ-Ts2)’ of *P. densiflora* typical subcomm., the study stand DM8 was located in the ‘a-2’. The vegetation of DM8 is the most similar with the one of DM12. This result can be analogized from that the dominance index of species of DM8 is relatively more similar with the one of DM12 than DM13 and DM16 of same *P. densiflora* typical subcomm., in the result of phytosociological community classification. The study stand DM8 is therefore affiliated to the *P. densiflora* typical subcomm. that both of the vegetation elements of evergreen broad-leaved forest and deciduous broad-leaved forest upspring, even though the vegetation elements of evergreen broad-leaved forest do not practically upspring in this study stand.

The study stands of ‘a-2(QQ-Ts2)’ as *P. densiflora* typical subcomm. had the highest similarity at each other in *Q. serrata*-*Q. variabilis* comm.. According to the relatively high dominance and appearace rate of vegetation elements of evergreen broad-leaved forest in comparison with deciduous broad-leaved forest, low dominance of *S. borealis* and high dominance of *P. densiflora* typical subcomm., ‘a-3(QQ-Ts3)’ will be intergraded to the evergreen broad-leaved forest by the natural succession and the environmental change etc., even though the present vegetation is deciduous broad-leaved forest near *P. densiflora* forest. It supports that ‘a-3’ is relatively located nearby to evergreen broad-leaved forest in comparison with the other communities of deciduous broad-leaved forest in Figure 5.

The study stands of *Q. acutissima* group(a-41) were located far apart at each other. That is, the similarity is low at each other, because of the difference in the character and differential species of *Q. serrata*-*Q. variabilis* comm., and the dominance index of the vegetation elements and presence of species in evergreen and deciduous broad- leaved forests. However, this vegetation unit was dominated by *Q. serrata*, *Q. acutissima* and the character and differential species of *Q. serrata*-*Q. variabilis* comm.. it is appropriated that the study stands were designated as one subunit and group(a-41) even though the similarity among the stands is low.

C. sinensis comm.(CS; C) was located far apart from and was the lowest similarity with other communities alike the result of phytosociological community classification. Especially, it was possible to explain that the correlationship and the vegetation change according to the presence and dominance index of species between Q. serrata-*Q. variabilis* comm. and *Q. acuta* comm., but it is impossible to explain that this community has the correlationship with other communities. This cause is that the community is located in mixed stand forest and beside road, and there is the highest artificial influence in comparison with other communities. This vegetation unit can be intergraded easily to other vegetation structures by and artificial influence, and the artificial management instead of natural succession is essential.

3) Correlation between vegetation units and environmental variables

As a result of CCA ordination analysis for the correlation between vegetation units and environmental variables, the shrine forest around Miwhang-sa is closely correlated to the environmental variables: Ca, Mg, P, OM, Ni and Zn(Figure 6).

According to the basis by environmental variables Ca, Mg and P, the shrine forest was distributed separately between *C. sinensis* comm.(C) and the other comm.(A and B). According to the basis by the environmental variables OM, Ni and Zn, the environmental variables had the close correlation with the distribution between *Q. serrata*-*Q. variabilis* comm.(A) and *Q. acuta* comm.(B). *Q. serrata*-*Q. variabilis* comm. had the positive correlation with the environmental variables and *Q. acuta* comm. had the negative correlation. This result is almost similar as the result of BC ordination distributed separately by the similarity of the presence and dominance extent of species. However, Some study stands(DM11) emigrated from the position near deciduous forest as same as BC ordination to the position near evergreen broad-leaved forest by the environmental variables. Given the succession in vegetation from deciduous broad-leaved forest to evergreen broad-leaved forest according to the climate change by global warming, we should observe closely N, P, K as constituents of plant growth and the change of OM, Ni and Zn comparing with other soil conditions at the vegetation management of shrine forest.

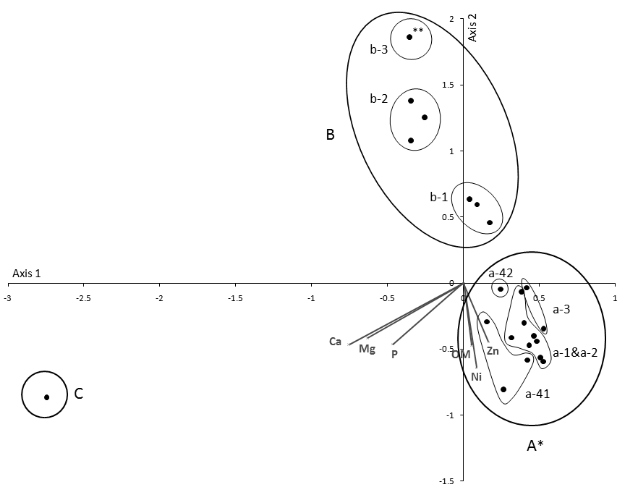

Figure 6. Diagram of CCA ordination with environmental variables

*A, B, C, a-1, a-2, a-3, a-41, a-42, b-1, b-2, b-3: vegetation units and subunits(refer to Table 2)

**● : study stands(refer to Table 2)

3. Life form analysis

We carried out the analysis and comparison of life form classified by species types and layers(Table 3). As a result of life form structure classified by layers(Figure 7), megaphanerophytes(MM) as tree species dominated dormancy form mainly as 61.29%. ‘MM’ species covered 36.10% at tree layer, and microphanerophytes(M) as sub-tree species covered 15.49% at sub-tree layer as the highest rate at each layer. However, various species were distributed as ‘MM’ species(8.72%), ‘M’ species(6.98%) and nanophanerophytes(N) as shrub species(10.76%) at shrub layer. ‘N’ species as shrub species compared to herb species occupied 15.38% at herb layer among all of radicoid form at all layers, and dominated most of herb layer as 82.32% among all of radicoid form at only herb layer. This result means the two cases: herb layer dominated various species and herb layer dominated a few or one species.

In accordance with the analysis of radicoid form, monophyte(R5) dominated at tree, sub-tree and shrub layers(total ‘R5’ species: 80.89%, tree layer: 36.33%, sub-tree layer: 18.52%, shrub layer: 26.04%). However at herb layer, ‘R1-2’ species occupied 13.81% among total radicoid form at all layers, and dominated most of herb

Table 3. Numata life form and Quantification at each layer

Scientific name	Life form*				Quantification at each layer**			
	Dormancy form	Propagation form		Growth form	T-1	T-2	S	H
		Radicoid form	Disseminule form					
Acer mono	MM	R5	D1	e	2.50	2.50	2.50	·
Acer palmatum	MM	R5	D1	e	·	3.00	0.90	·
Acer pseudosieboldianum	MM	R5	D1	e	·	2.60	24.60	0.70
Achyranthes japonica	H	R5	D2	e	·	·	·	0.50
Actinodaphne lancifolia	MM	R5	D2	e	2.50	7.50	5.70	0.90
Ainsliaea acerifolia	G	R3	D1	e	·	·	·	0.20
Ainsliaea apiculata	H	R3	D1	ps	·	·	·	0.10
Akebia quinata	N	R3	D2	l	·	·	·	0.20
Alangium platanifolium var. *trilobum*	N	R5	D2	e	·	·	0.20	·
Albizia julibrissin	M	R5	D4	e	7.50	·	·	0.10
Ampelopsis brevipedunculata	N	R3	D4,2	l	·	·	·	0.10
Ampelopsis brevipedunculata for. *citrulloides*	N	R3	D4,2	l	·	·	·	0.30
Aphananthe aspera	MM	R5	D2	e	2.50	2.60	·	·
Ardisia japonica	Ch	R2-3	D2	e	·	·	·	37.45
Arisaema ringens	G	R5(c)	D4	e	·	·	·	0.20
Aucuba japonica	N	R5	D2,4	e	·	·	15.00	0.50
Boehmeria nivea	Ch	R3	D4	e	·	·	·	0.10
Boehmeria spicata	Ch	R3	D4	e	·	·	·	0.10
Callicarpa japonica	M	R5	D2	e	·	·	8.95	0.10
Callicarpa mollis	N	R5	D2	e	·	·	3.20	0.10
Camellia japonica	M	R5	D4	e	·	95.10	158.60	2.30
Carex ciliatomarginata	H	R2-3	D4	pr	·	·	·	0.10
Carex humilis var. *nana*	H	R3	D4	t	·	·	·	0.50
Carpinus laxiflora var. *laxiflora*	MM	R5	D1	e	·	5.00	·	·
Carpinus tschonoskii var. *eximia*	MM	R5	D1	e	37.50	31.35	0.20	·
Carpinus turczaninovii	M	R5	D1	e	·	·	0.10	·
Celtis sinensis	MM	R5	D2	e	37.50	8.75	·	·
Cinnamomum japonicum	MM	R5	D2	e	·	2.50	3.20	1.30
Circaea mollis	G	R2-3	D2	e	·	·	·	0.10
Clematis apiifolia	N	R5	D1	l	·	·	·	0.10
Cocculus trilobus	N	2-3	D1	l	·	·	·	0.10
Commelina communis	Th	R5	D4	b-p	·	·	·	0.10
Cornus controversa	MM	R5	D2,4	e	37.50	·	0.10	·
Cornus kousa	M	R5	D2,4	e	·	5.00	0.40	0.10
Cornus macrophylla	MM	R5	D2,4	e	·	2.50	·	·
Corylus heterophylla var. *thunbergii*	M	R5	D4	e	·	·	0.10	0.10
Corylus sieboldiana var. *sieboldiana*	M	R5	D4	e	·	·	1.10	·
Cudrania tricuspidata	M	R5	D2	e	·	·	0.10	·
Cyrtomium fortunei	H	R(t)	D1	t	·	·	·	8.75
Davallia mariesii	E	R4	D1	e	·	·	·	0.10
Desmodium podocarpum var. *oxyphyllum*	H	R3	D2	e	·	·	·	0.10
Dioscorea quinqueloba	G	R3(s)	D1	l	·	·	·	0.30
Dioscorea tenuipes	G	R3(S)	D1	l	·	·	·	0.10
Diospyros kaki	MM	R5	D2	e	·	·	·	·
Disporum smilacinum	G	R5	D2	e	·	·	·	0.20
Dryopteris bissetiana	Ch	R(o)	D1	t	·	·	·	1.70
Dryopteris chinensis	H	R(o)	D1	t	·	·	·	0.60
Dryopteris erythrosora	Ch	R3	D1	t	·	·	·	5.60
Dryopteris lacera	H	R3	D1	t	·	·	·	0.50
Dryopteris saxifraga	Ch	R(o)	D1	t	·	·	·	0.10
Elaeagnus glabra	M	R5	D2	l	·	·	·	0.10
Elaeagnus macrophylla	M	R5	D2	l	·	·	0.40	·

Table 3. (continued)

Scientific name	Life form*				Quantification at each layer**			
	Dormancy form	Propagation form		Growth form	T-1	T-2	S	H
		Radicoid form	Disseminule form					
Pyrola japonica	Ch	R3	D1,4	r	·	·	·	0.30
Quercus acuta for. *acuta*	MM	R5	D4	e	502.50	127.50	42.90	20.70
Quercus acutissima	MM	R5	D4	e	123.75	7.50	2.60	·
Quercus salicina	MM	R5	D4	e	5.00	2.50	2.80	0.70
Quercus serrata	MM	R5	D4	e	525.00	205.10	52.05	0.40
Quercus variabilis	MM	R5	D4	e	86.25	47.50	0.70	0.20
Rhamnella franguloides	M	R5	D4	e	·	·	0.50	0.10
Rhododendron mucronulatum var. *ciliatum*	N	R5	D4	e	·	·	0.10	0.10
Rhododendron mucronulatum var. *mucronulatum*	N	R5	D4	e	·	·	5.40	0.30
Rhododendron schlippenbachii	M	R5	D4	e	·	·	0.70	·
Rhododendron yedoense for. *poukhanense*	N	R5	D4	e	·	·	0.10	0.10
Rhus tricocarpa	M	R5	D4	e	2.50	·	0.20	0.30
Rhus verniciflua	MM	R5	D4	e	·	·	0.70	0.10
Robinia pseudoacacia	MM	R5	D3	e	·	·	·	0.20
Rosa multiflora var. multiflora	N	R3	D2	e	·	·	15.00	·
Sapium japonicum	M	R5	D4	e	·	22.50	21.00	0.60
Sasa borealis	N	R1-2	D4	e	·	·	·	598.20
Smilax china	N	R3(s)	D2,4	l	·	·	3.00	2.20
Smilax sieboldii for. *sieboldii*	N	R5	D2	l	·	·	·	0.10
Sorbus alnifolia	MM	R5	D2	e	·	2.60	5.80	0.20
Spodiopogon cotulifer	H	R3	D4	t	·	·	·	0.10
Staphylea bumalda	M	R5	D4	e	·	·	0.50	0.10
Stephanandra incisa var. *incisa*	N	R5	D4	e,b	·	·	0.70	·
Styrax japonicus	MM	R5	D4	e	20.00	121.25	123.25	0.70
Styrax obassia	MM	R5	D4	e	·	2.50	0.10	·
Symplocos chinensis for. *pilosa*	N	R5	D4	e	·	·	2.40	·
Symplocos coreana	N	R5	D4	e	·	·	0.10	·
Symplocos tanakana	M	R5	D4	e	·	·	8.85	·
Thelypteris japonica var. *japonica*	G	R2-3	D1	e	·	·	·	0.10
Torreya nucifera	MM	R5	D2	e	·	·	0.80	0.10
Trachelospermum asiaticum var. *asiaticum*	M	R5	D1	p-l	·	·	0.20	20.00
Vaccinium bracteatum	N	R5	D2,4	e	·	·	·	0.10
Vaccinium oldhamii	N	R5	D2,4	e	·	·	129.15	0.50
Viburnum dilatatum	M	R5	D2	e	·	·	0.80	·
Viburnum erosum	N	R5	D2	e	·	·	136.70	4.30
Viola selkirkii for. *selkirkii*	H	R3(v)	D3	r	·	·	·	0.10
Vitis flexuosa	M	R3	D2	l	·	·	0.10	·
Weigela subsessilis	N	R5	D4	e	·	·	0.60	0.10
Zanthoxylum schinifolium	M	R5	D4	e	·	·	·	0.10
Zelkova serrata	MM	R5	D1	e	2.50	·	·	·

layer as 73.88% of total radicoid form at only herb layer. The 'R1-2' species are *Sasa borealis* and *Pteridium aquilinum* var. *latiusculum*. The numerical value of Quantification of *P. aquilinum* var. *latiusculum* is 0.4, and the value of Quantification of *S. borealis* is 598.2. We can therefore identify that *S. borealis* dominates most of herb layer. We also confirmed that herb layer is dominated by one species at the result of dormancy form.

The light condition of dominant vegetation by *S. borealis* is very low in understory vegetation. Distribution of surface species, therefore, is not almost composed of and the artificial management through the clearcutting against *S. borealis* is required. The surface vegetation will be dominated by and changed to other vegetations except for *S. borealis* in 3~4 years after clearcutting(Yuruki *et al*., 1977). Especially, July and October have the

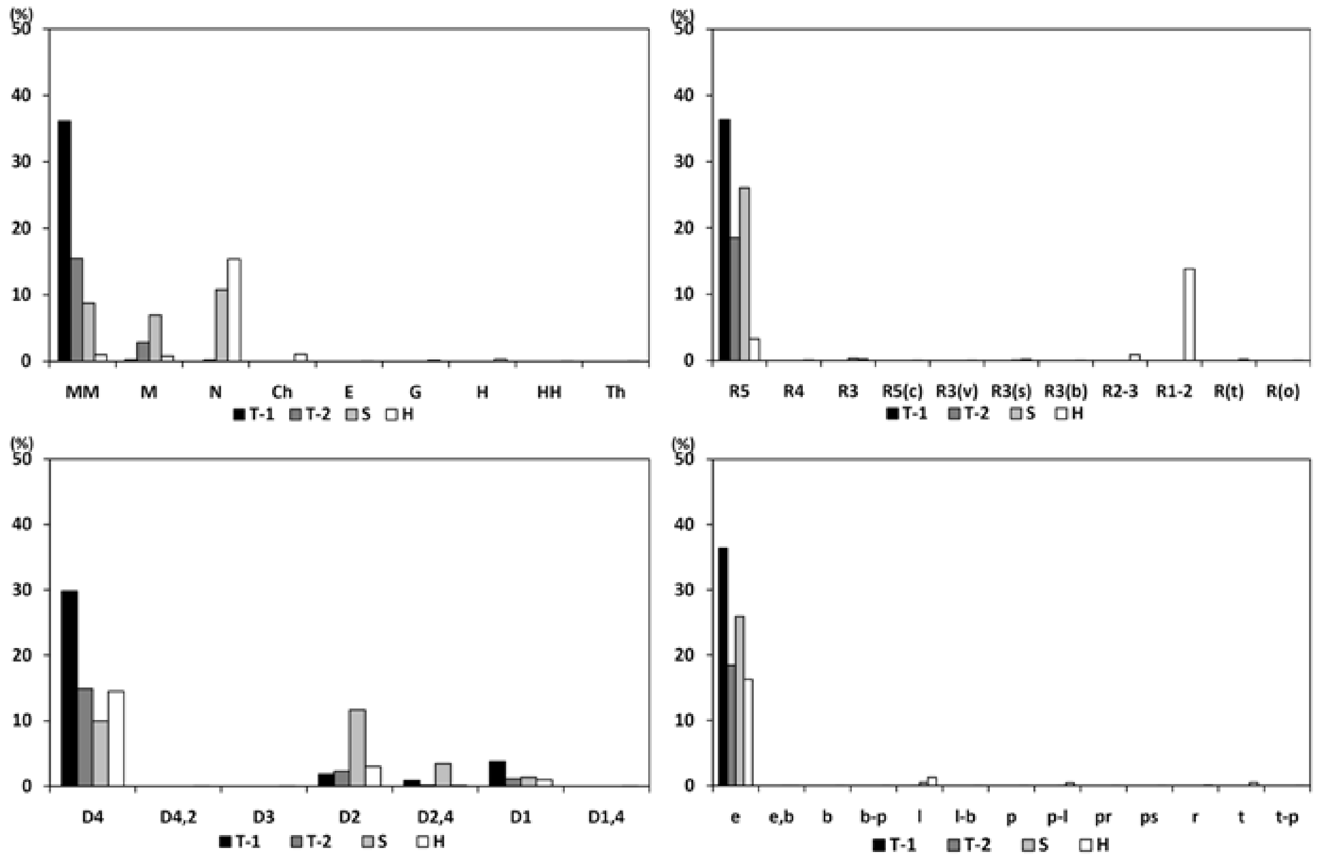

Figure 7. Life form of the classification of layers(Life form: refer to Table 3)

advantage in comparison with January and April on the clearcutting period for management through the annual change of living culms and new culms on *S. borealis* stands for 11 years. *S. borealis* done clearcutting on January and April is kept up on the high level after increasing highly, while those of *S. borealis* done clearcutting on July and October is kept up on that level or decreased without great change. In case of new culms, this species on July and October cuttings is kept up or changes without great change from next year the research initiated, while this species on January and April cuttings supervene massively until the end of research compared to other two month cuttings, even new culms usually decrease(Yuruki and Aragami, 1984).

High dominance of *S. borealis* on this study, therefore, means low species diversity of surface and understory vegetation, and it is necessary that radical measures such as periodical July and October cuttings against dominance of the species devise for the vegetation management for high species diversity on the shrine forest.

The alterations of climate zone and vegetation associated with global warming will have an effect on the distribution of *S. borealis* except for the artificial management. *S. borealis* usually emerges on the cool-temperate zone compared to warm-temperate zone. In case of Japan, *S. borealis* distributes at only high mountains of Kyusyu and Shikoku on warm-temperate zone, even the species distributes throughout the country(Yuruki *et al*., 1977). *S. borealis* also does not emerge almost all at the typical evergreen broad-leaved forest on the warm-temperate zone in Korea such as Japan(Kim, 1986; Ministry of Environment, 2000). Similar species(*Sasa quelpaertensis*) of same life form distributes on some relatively high elevation, and *S. borealis* emerges on the portion of areas where evergreen and deciduous broad-leaved forests mixed up such as this study(Kim, 2002; Shim, 2006; Lee *et al*., 2009b). It, therefore, is necessary that the climate change on the Korean peninsula should be considered for the long-term vegetation management of *S. borealis*, not short-term management.

As a result of disseminule form analysis, ‘D4’ species dominated 69.18%, and the species at tree species occupied 29.81% as the highest rate. ‘D4’ species also dominated most of sub-tree and herb layers. ‘D4’ species of sub-tree layer occupied 14.89%, and ‘D4’ of herb layer occupied 14.49% among all layers. On the other hand, at shrub layer, ‘D4’ species dominated 80.39% at only sub-tree layer, and dominated 77.55% at only herb layer. However ‘D4’ species occupied 9.99%, ‘D2’ species occupied 11.66%, and ‘D2,4’ species occupied 3.44%. As a result of growth form analysis, ‘e’ species dominated most of all layers as 97.03%. The species dominated 36.33% at tree layer, 18.46% at sub-tree layer, 25.93% at shrub layer, and 16.31% at herb layer.

As a result of life form structure classified by species types(Figure 8), Megaphanerophtes(MM) dominated 56.05% of dormancy form as the highest rate. The remarkable point is that Nanophanerophytes(N) dominated 21.17% as second highest rate. According to the analysis of radicoid form, monophyte(R5) dominated 65.60% of radicoid form as the highest rate, and the ‘R1-2’ species at shrub layer covered 15.92% as second highest rate among total radicoid form. This result is the dominating rate among radicoid form of all appearance species at all layers. On the other hand, ‘R1-2’ species dominated the most of shrub layer as 70.46% at only shrub layer. As a result of disseminule form analysis, ‘D4’ species at tree layer dominated 48.22% of desseminule form as the highest rate, and ‘R5’ species at shrub layer covered 16.25% as second highest rate. ‘e’ species dominated most of growth form as 97.07%, and the ‘e’ species of tree layer occupied 65.52% among all of ‘e’ species.

We can analogize the life form of species composing vegetation intergraded in the future such as maturity of forest and vegetation change etc., according to the result of life form structure classified by species types, as

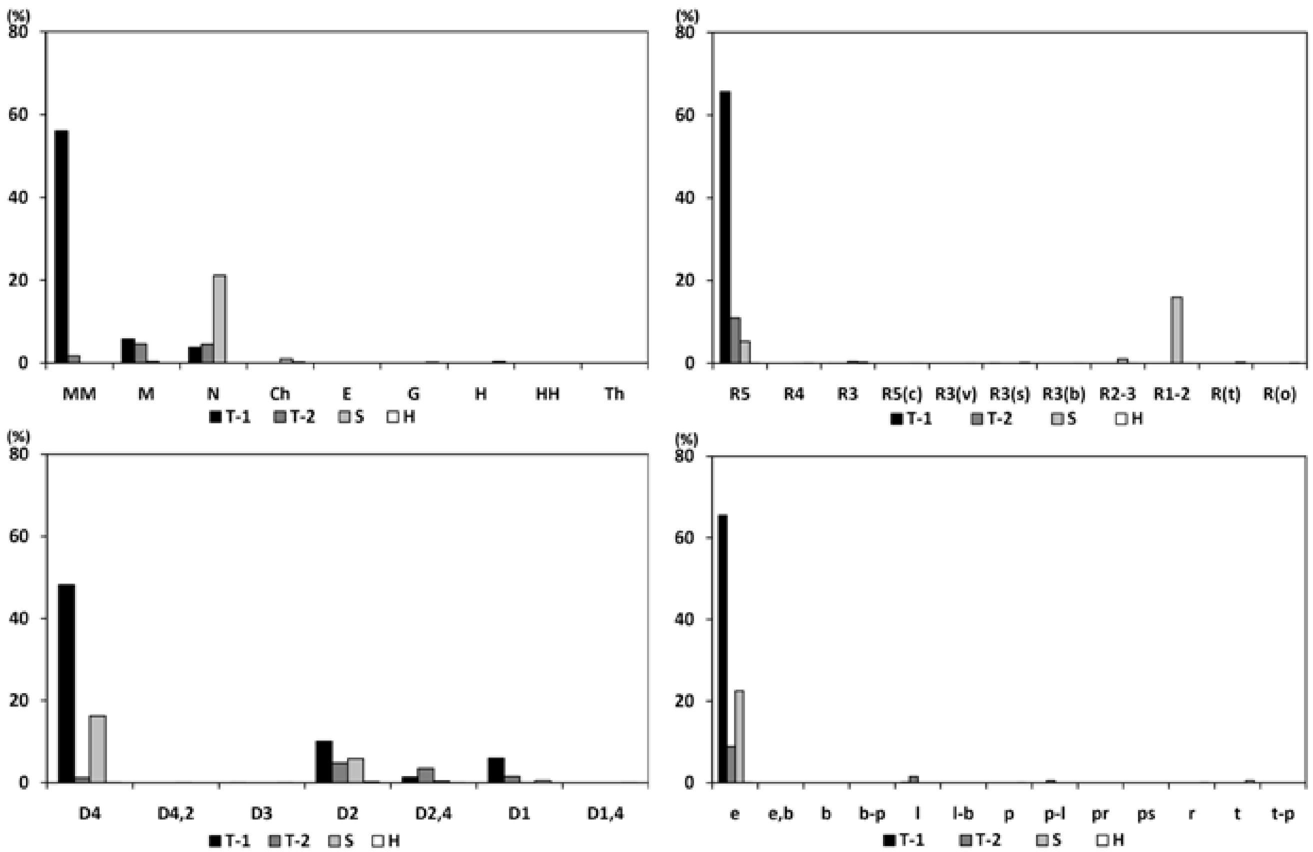

Figure 8. Life form of the classification of species types(Life form: refer to Table 3)

different as that the life form structure classified by layers represents the effective life form structure of present shrine forest. Therefore the species of radicoid form R1-2 as *S. borealis* will develop until shrub layer, and then will dominate the shrub and herb layers.

4. Species diversity analysis and vegetation management methodology

As a result of the species diversity analysis, the species diversity was distributed from minimum 1.69(DM8) to maximum over 2.6(DM1 and DM23), and species evenness index was also distributed from 0.51(DM2) to 0.75(DM16) extensively. The result of species diversity and evenness of the shrine forest around Miwhang-sa was relatively higher than the result of the shrine forest around Nameun-sa. For the reason that the shrine forest around Miwhang-sa was composed with two types of forest: deciduous and evergreen broad-leaved forests, and the shrine forest around Nameun-sa was composed with only evergreen broad-leaved forest, the higher species diversity and evenness of shrine forest around Miwhang-sa is a natural result(Figure 9).

The shrine forest will do the succession to the evergreen broad-leaved forest according to the considerations of potential natural vegetation, natural succession, species diversity and vegetation change by global warming.

In common with this study, the study about the succession and competitive exclusion relation among forests mutually in the study about the mixed forest where the evergreen broad-leaved forest and the deciduous broad-leaved forest coexist, means the natural selection of deciduous broad-leaved forest and the substitution to evergreen broad-leaved forest(Oh and Choi, 1993; Oh and Cho, 1996). This result has something in common with the expectation of this study.

These studies however did not make reference to the species diversity, life form and species(*S. borealis* etc.) having an influence on vegetation structure in the succession. This only means the anticipation of vegetation transition simply, but we can not apply directly to the points where the artificial management considering various conditions such as shrine forest is necessary.

In the analysis result of this study, therefore, even the succession of vegetation structure of the shrine forest and species diversity is considered, the most ideal and suitable vegetation structures are the vegetation structure of the study stands which are the intersection of two trendlines or the points around near the intersection(Figure 10).

The two trendlines are as follow: deciduous broad-leaved forest(*Q. serrata-Q. valiabilis* comm.; A) and evergreen broad-leaved forest(*Q. acuta* comm.; B). The

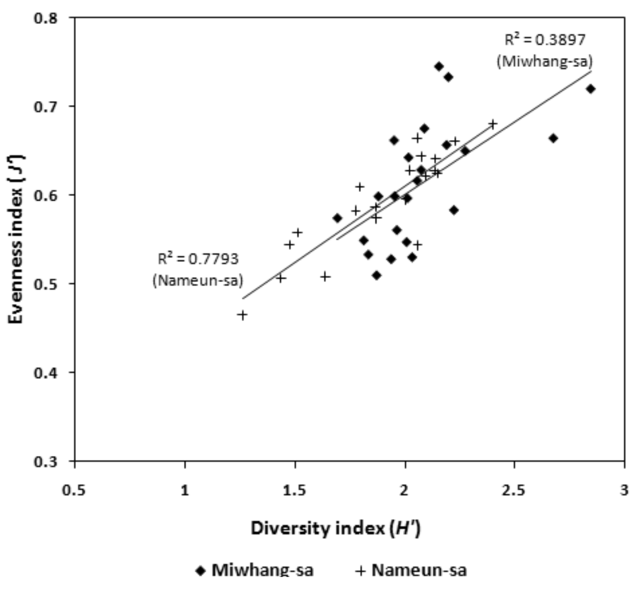

Figure 9. Species diversity and evenness of shrine forests(1)

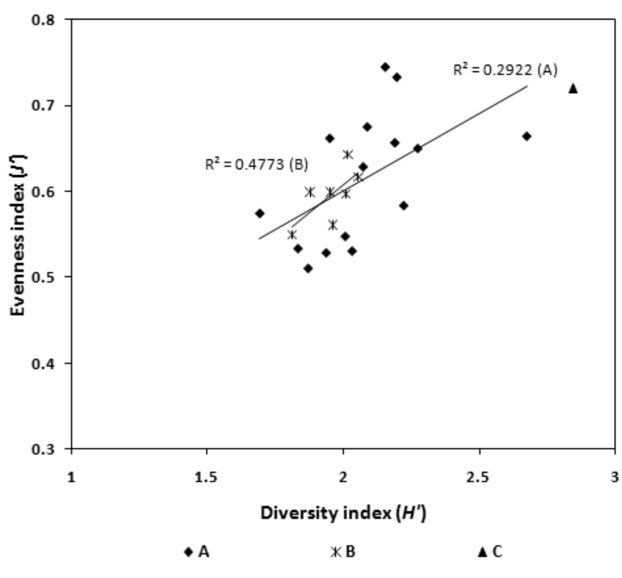

Figure 10. Species diversity and evenness of shrine forests(2)

(◆ A, *B, ▲C: vegetation units(refer to Table 2)) meaning of high species diversity is that the vegetation elements of evergreen broad-leaved forest and deciduous broad-leaved forest are mixed up(succession stage; Huston, 1994), as mentioned above. Especially, the meaning of high species evenness not only species diversity is that the vegetation elements of both forests are mixed up as similar rates, not to be dominated by one forest. The analysis of species diversity by Jang and Song(1997) also underpins that the those vegetations maintain stable species diversity and evenness. Artificial introduction of species from other vegetation is only method to make species diversity and evenness high over that extent of species diversity and evenness. The present vegetation structure of shrine forest will be intergraded by the succession, potential natural vegetation and temperate change by global warming. It is therefore suitable to manage the vegetations long-termly to the level of species diversity and the evenness of evergreen broad-leaved forest.

According to the result of study that simplification in Quercus zone is influenced preferentially by the insufficiency of non-evergreen broad-leaved species(elements) (Ishida *et al*., 2005), the vegetation elements of deciduous broad- leaved forest in the present vegetation not only the species diversity and evenness of evergreen broad-leaved forest should be considered for vegetation management of shrine forest.

The vegetation change by temperate change according to global warming does not mean the sharp change of present vegetation. Especially, the vegetation elements of warm-temperate deciduous broad-leaved forest will be intergraded to the level of regression of dominance and appearance rate of the species. As a result to identify the study stands which are the intersection of two trendlines or the points around near the intersection, the study stands as DM5, DM7 and DM18 are the nearest points. The vegetation structures of three points are the typical group (DM7) of *Q. serrata* subcomm.(Figure 10).

ABSTRACT

As a result of the vegetation structure analysis of shrine forest around Miwhang-sa by the phytosociological vegetation structure analysis, three community units and seven subunits(*Q. serrata*-*Q. variabilis* community: four subunits, *Q. acuta* comm.: three subunits) were classified. This structure composed with the evergreen broad-leaved forest and the warm-temperate deciduous broad-leaved forest. As a result of the life form analysis classified by layers and species types, *S. borealis* as R1-2 species dominated the present herb layer, and it is estimated that the species will also dominate the shrub layer. The species diversity at this shrine forest was higher than the one at the shrine forest where the typical evergreen bread-leaved forest dominates, and it was confirmed that the deciduous broad-leaved forest is higher according to the comparison of species diversity and evenness between the evergreen broad-leaved forest and the deciduous broad-leaved forest in this shrine forest.

For the long-term vegetation management for the ideal and suitable vegetation structure with the consideration of potential natural vegetation, succession and the temperate change by global warming, the long-term vegetation management should be carried out with the results of life form structure of vegetation, phytosociological vegetation structure data, and species diversity and evenness we analyzed. Especially, we should consider the stable species diversity and the evergreen broad-leaved forest that the forest will be succession to according to the climate change for the vegetation management of shrine forest. The maintenance management of non-evergreen broad-leaved species in the evergreen broad-leaved forest deserves consideration in Quercus forest of this study as the evergreen broad-leaved forest on account of having an effect on the maintenance and alteration of species diversity. It is necessary that the artificial management about *S. borealis* for species diversity of understory vegetation will be also accomplished sustainedly.

ACKNOWLEDGEMENT

We would like to express our gratitude to Global COE Program, "Eco-Risk Management from Asian Viewpoints" supported by Ministry of Education, Culture, Sports, Science and Technology of Japan, and to Ying-hua JIN and Kyung-mee LEE in Graduate school of Chung-Ang University in Korea to assist the field survey.

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