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The Ecological Characteristics of Classified Forest Cover Types in the Natural Forest of Sobaeksan

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Abstract

This study was conducted to evaluate the ecological characteristics of forest cover types which were classified by cluster analysis in the natural forest of Sobaeksan on the basis of the vegetation data from the point-quarter sampling method. Recognized forest cover types were 1) Mixed mesophytic forest, 2) *Taxus cuspidata* forest, 3) *Fraxinus rhynchophylla-Quercus mongolica* forest, 4) *Betula ermanii* forest, 5) *Pinus densiflora* forest, 6) *Quercus mongolica* mixed forest, and 7) *Quercus mongolica* pure forest. For those of classified types, the species composition was expressed by importance value (*IV*) to describe the community floristically. The species diversity was quantified using the Shannon's diversity index. The results showed that the forest cover types were characteristically different from one another in growing species and compositional rates, depending upon the type which was formed by a number of similar vegetational sample points. Species diversity indices (*H'*) of total and overstory both were the highest in the mixed mesophytic forest (3.530 and 2.880, respectively), and lowest in the *Q. mongolica* pure forest (2.122 and 0.000, respectively) with only one canopy species. The highest species diversity in the mixed mesophytic forest may due to the relatively high species richness and evenness in the forest cover types. The description on ecological characteristics were suggested to understand the formation and development of forest cover types in this study area.

Key Words: cluster analysis, forest cover type, importance value, species diversity, sobaeksan

Introduction

Given the diversity and complexity of forest ecosystems, classification is an attempt to create order from disorder, to explain the unknown, and to predict conditions in the future. Forest classification is launched to improve our ability to understand every kind of information on the management of any particular forest stand. One might decide that the most useful approach to classification of forests is one that provides all possible information desired by forest related stakeholders. However, Kimmins (2004) noted that the best classification is generally a compromising between the need for simplicity and the need for sufficient detail to make the classification effective.

Vegetation classification methods generally reflect the overall ecological characteristics of a site more faithfully than are possible with other approaches such as climatic, physiographic, or edaphic classifications. The classification of vegetation approach also gives the current level of ecological understanding and ability to measure the environment. The concepts have been on the basis of the idea of Daubenmire (1976) that the biota constitutes the best

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measurement and integration of the total physical and biotic environment.

Forest cover type classification is one practical application of the vegetation classification methods, defined by Eyre (1980) as "a descriptive classification of forestland based on present occupancy of an area by tree species." Kimmins (2004) has also noted that forest cover type is a category of forest characterized by the trees presently occupying the area, no implication being conveyed as to whether it is temporary or permanent. Emphasis is given to composition rather than development, and the classification is based on existing tree cover.

The objectives of this study was to classify the natural forests of Sobaeksan National Park area into appropriate number of forest cover types by cluster analysis and to describe ecological characteristics for each forest type, including species composition and species diversity. The descriptions would give recognition on ecological factors influencing the formation and development of forest cover types in study area.

Data and Methods

Study Area

The study was conducted in the areas of Sobaeksan, located in the course of Baekdudaegan (Fig. 1). Sobaeksan designated as the 18th national park in Korea, 1987. It is 322,383 km^2 in area and is the third largest mountainous national park in Korea next to Jirisan and Seoraksan. Sobaeksan has many peaks beginning with Birobong which stands at 1,439 m to Gungmangbong (1,420 m), Yeonhwabong (1,383 m), and Dosolbong (1,314 m). The mountain extends over some portion of Yeongju-si of Gyeongsangbuk-do, Danyang-gun of Chungcheongbuk-do, and Yeongwol-gun of Gangwon-do (Korea National Park Service 2014).

The vegetation data for this study were collected mainly from valley, ridge, and mid-slope where situated in Yeonhwabong and Birong of Sobaeksan (Fig. 1).

The mean annual temperature at the nearest Yeoungju weather station of study area for the last 30 years was 11.3°C, and annual precipitation was 1,290.9 mm. Mean temperature of the warmest and coldest month were 24.2°C in August and −2.9°C in January, respectively. Seventy percent of annual precipitation have occurred during the summer season, June to September (Fig. 2) (Korea Meteorological Administration 2014).

In this national park, Korean Association for Conservation of Nature (1995) conducted the scientific survey on geology, plants and vegetation, animals and insects, and mycoflora in 1994.

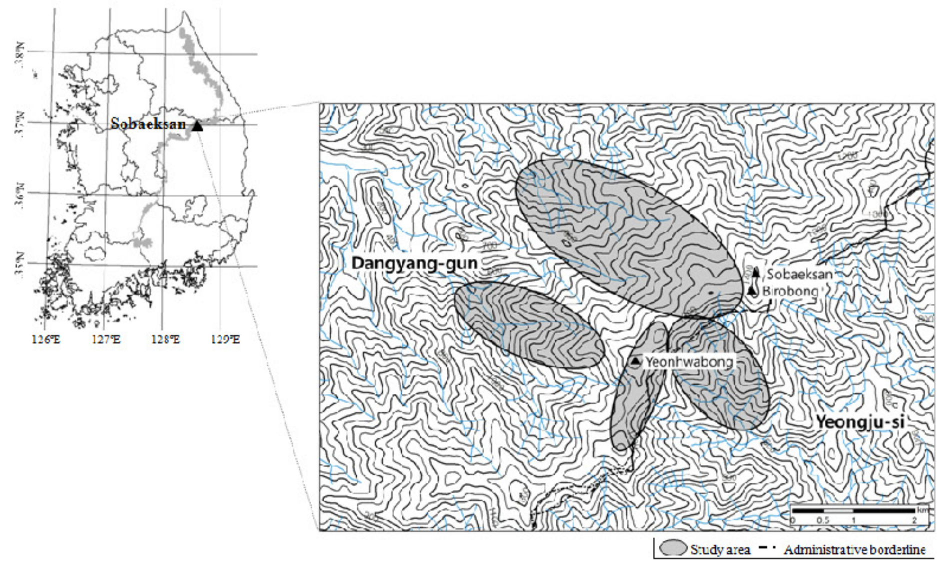
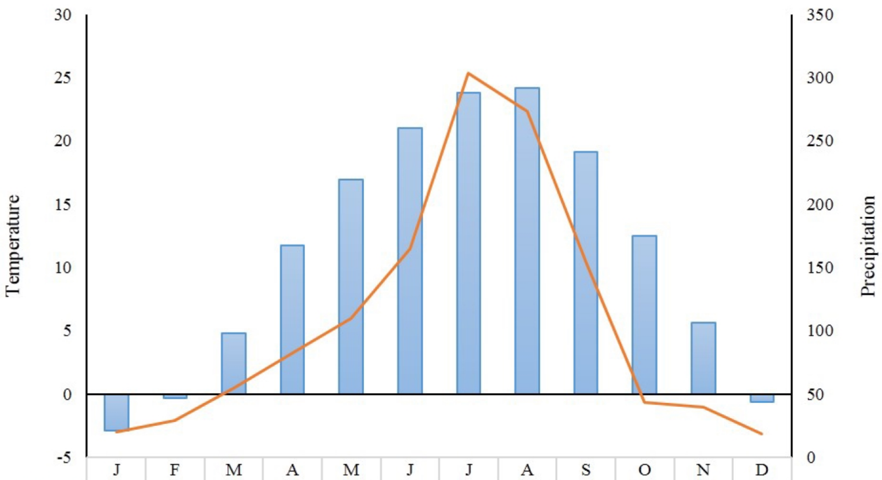


Fig. 1. The location and study boundary in Sobaeksan.



	J	F	M	A	M	J	J	A	S	O	N	D
Temperature	-2.9	-0.3	4.8	11.7	16.9	21	23.8	24.2	19.1	12.5	5.6	-0.6
precipitation	19.8	28.8	54.3	82.9	109.9	164.6	303.6	273.1	153.2	43.2	39.3	18.3

Fig. 2. Mean monthly temperature and precipitation (1981∼2010).

Collection of data

Since the study area was rather extensive, the point-quarter sampling method was adopted to collect vegetation data to reduce labor and time but not to sacrifice the information and accuracy obtainable from plot or line sampling method (Brower and Zar 1977). On the randomly selected sample point P, four compass directions (N, S, E, and W) were divided into four quadrants. In each quadrant, all woody plants closest from the point were tallied by three vertical strata (overstory, midstory, and understory), identified by the species level, and measured for diameter, height, and distance from the point P (Fig. 3).

The taxonomy of woody plant species was referred to Lee (2003). The interval between points was given more than 50 m and the areas of forest plantation and gap were excluded to eliminate biased vegetation data. The total of 246 sample points temporarily established by topographic position and aspect throughout the study area.

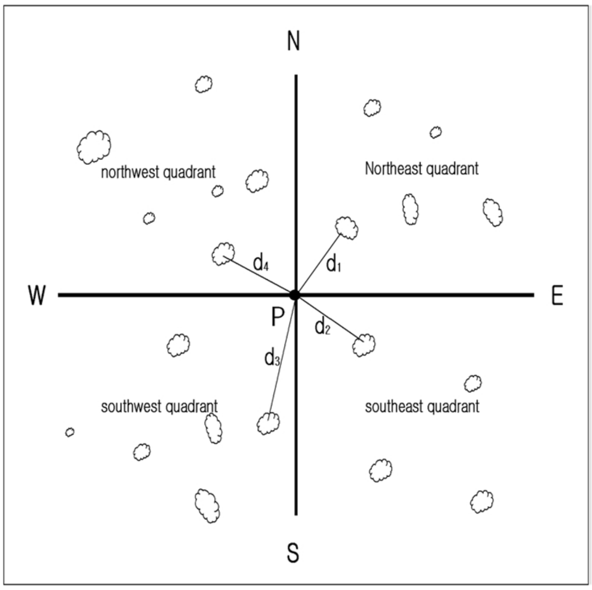


Fig. 3. The diagram of point-quarter sampling method.

Arrangement and analysis of data

The collected vegetation data from 246 sample points were subjected to the cluster analysis to make all points classify into similar group according to the species composition in overstory. The sample points were grouped by Ward's method of hierarchical clustering. Ward's method, also known as a minimum variance clustering, has widely used by ecologists for grouping purpose (Orloci 1967; Everitt 1973; Hartigan 1975). This method has great intuitive appeal because it is based on the simple underlying principle that at each stage of clustering the variance within clusters is minimized with respect to the variance between clusters (Ludwig and Reynolds 1988). Also it is effective when the intent is to minimize information loss associated with any interactive step in cluster formation (Lattin et al. 2003). The SPSS Statistics 17.0 (SPSS, Inc.) software was employed to implement the analysis.

The species composition was expressed by importance value designed by Curtis and McIntosh (1951) to describe the community floristically. The importance value gives an overall estimate of the influence or importance of a plant species in the community (Brower and Zar 1977). The three relative measures for species i are considered as the importance value (IV_i) of the species by following equation;

$$IV = (RD + RF + RC)/3$$

where RD is the relative density, RF is the relative frequency, and RC is the relative coverage of basal area.

Species diversity is measured by species richness (the number of species present in sample of a particular community) and species evenness (the relative abundance of the different species). Shannon-Wiener diversity index would be a useful index for the community of which two or three species were dominant such as in the natural deciduous forest of Korea (Kim et al. 2011). Shannon-Wiener diversity index is appropriate when you have a random sample of species abundances from a larger aggregation, say a random sample of an entire community (Brower and Zar 1977).

The species diversity in each cluster were quantified using (1) the Shannon's diversity index (H'), (2) the Maximum diversity (H_{max}), (3) the Evenness (J'), and (4) the Dominance ($1\text{-}J'$). The species diversity were calculated as;

$$H' = (N \log N - \sum n_i \log n_i)/\mathrm{N},\ H_{max} = \log s,\ J' = H'/H_{max}.$$

where N is the total number of individuals, and n_i is the number of species i in each cluster. For this calculation, we used logarithmic base e.

Results

Classification of forest cover types

The procedure of cluster analysis of vegetation data (Fig. 4) brought 244 out of 246 sample points of which two were sampling outliers, resulted in seven distinctive forest cover types. The determination of cluster numbers and naming of forest types were referred to Lee et al. (2014). Recognized

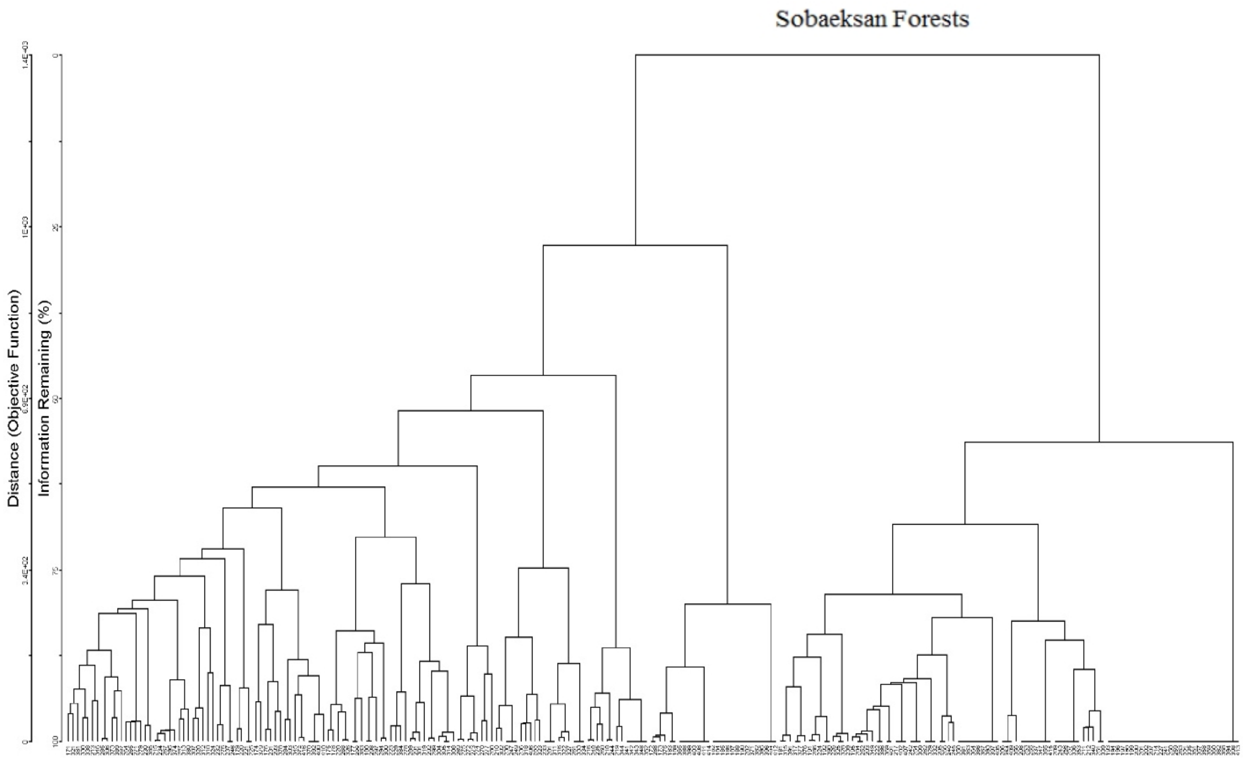


Fig. 4. Dendrogram from hierarchical cluster analysis of a species in each sample point using the Euclidean distance measure and the Ward's method.

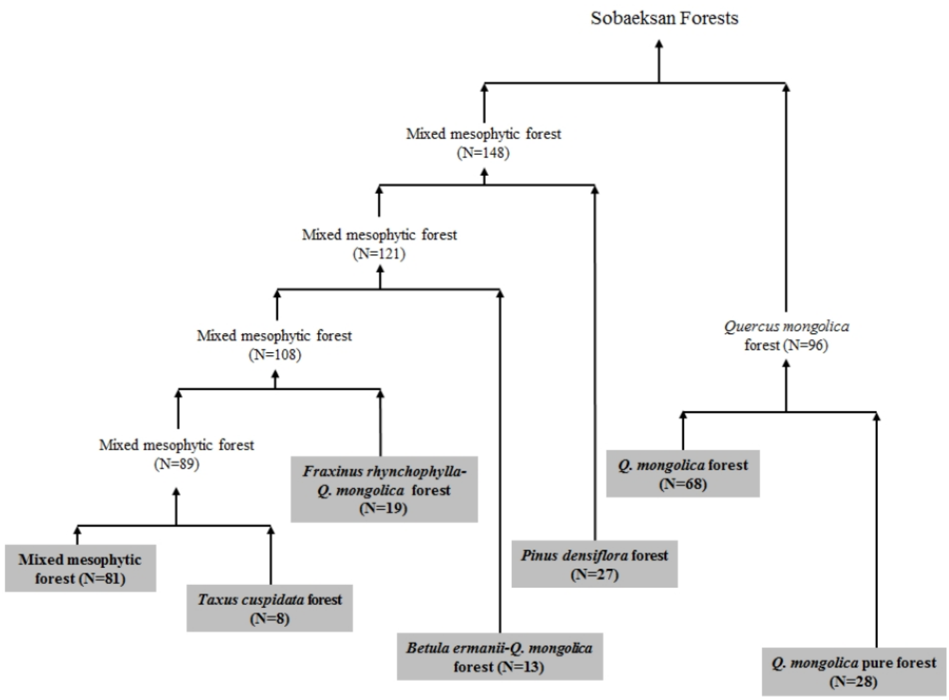


Fig. 5. The forest cover types in the Sobaeksan (N; number of sample points).

forest cover types were 1) Mixed mesophytic forest, 2) *Taxus cuspidata* forest, 3) *Fraxinus rhynchophylla-Quercus mongolica* forest, 4) *Betula ermanii* forest, 5) *Pinus densiflora* forest, 6) *Quercus mongolica* mixed forest, and 7) *Quercus mongolica* pure forest (Fig. 5).

It was noticed that the classification analysis revealed *Q. mongolica* to be most abundant species in the study areas, marking dominance or co-dominance in four forest cover types. Several studies reported that the species has been most nation-widely distributed in the natural deciduous forest (Lee et al. 1990; Korea Forestry Research Institute 1996; Lee et al. 1998; Yun et al. 2011). Other research (Chung 1998; Jo et al. 2004; Lee et al. 2014) conducted in Baekdudaegan also noted that *Q. mongolica* was predominant in many forest types, occupying large areas, similar to the results of this study.

Species composition

Because types of forests are defined on a floristic basis, the species composition plays an important role to grasp fundamental ecological estimation and information for a specific forest cover type. The abundance, distribution, or dominance of species can be expressed numerically, so that different forest cover types can be compared on the basis of species differences.

The species composition expressed by importance values of overstory tree species for 7 classified forest cover types was presented in Table 1. The results showed that growing species and compositional rates were characteristically different from one another, depending upon the forest cover type which was formed by a number of similar vegetational sample points.

Species diversity

Species diversity is a characteristic expression of the structural attributes in a forest. A forest community is said to have a high species diversity if many equally or nearly equally abundant species are present. On the other hand, if a community is composed of a very few species, or if only a few species are abundant, species diversity is low (Brower and Zar 1977).

The species diversity can provide useful information for understanding various kinds of attributes in the forest community. High species diversity indicates a highly complex community because a greater variety of species allows for more variety of species interactions. Also the species diversity could play a role in measuring the stability and maturity of the community. Presumably, the stability of the for-

Table 1. Species composition expressed by importance values for 7 classified forest cover types

Species	Cover type						
	MM	TC	FQ	BE	PD	QM	QMp
Q. mongolica	**15.7**		25.7	23.6	8.8	**54.4**	**100**
Pinus densiflora	10.3				**83.0**	8.5	
Cornus controversa	9.9	12.0	1.7	6.8			
Acer pictum subsp. mono	7.8	16.0	9.0	2.1			
Fraxinus mandshurica	6.5						
F. rhynchophylla	5.3	6.1	**46.4**		1.3	2.0	
Taxus cuspidata		**59.6**					
A. mandshuricum		6.3					
Maackia amurensis			6.6				
Betula ermanii			4.9	**54.0**		10.4	
B. schmidtii					2.8	3.0	
B. davurica					1.6		
Sorbus alinifolia				4.4			
Carpinus laxiflora					1.2		
Tilia amurensis						4.6	
Abies nephrolepis				2.8			
Others (*)	44.4 (23)	--	5.6 (3)	6.4 (3)	1.2 (1)	17.1 (15)	--

*The number of the other species.
MM, Mixed mesophytic forest; TC, *Taxus cuspidata* forest; FQ, *Fraxinus rhynchophylla-Quercus mongolica* forest; BE, *Betula ermanii* forest; PD, *Pinus densiflora* forest; QM, *Quercus mongolica* mixed forest; QMp, *Quercus mongolica* pure forest.

Table 2. Species diversity index of 7 forest cover types

		MM*	TC	FQ	BE	PD	QM	QMP
S	T	58	16	35	29	31	52	35
	O	29	5	9	9	7	21	1
H`	T	3.530	2.443	2.636	2.692	2.429	2.948	2.122
	O	2.880	1.206	1.416	1.286	0.537	1.579	0.000
H_{max}	T	4.060	2.773	3.555	3.367	3.434	3.951	3.555
	O	3.367	1.609	2.197	2.197	1.946	3.045	0.000
J`	T	0.869	0.881	0.741	0.799	0.707	0.746	0.597
	O	0.855	0.749	0.644	0.585	0.276	0.519	0.000
1-J`	T	0.131	0.119	0.259	0.201	0.293	0.254	0.403
	O	0.145	0.251	0.356	0.415	0.724	0.481	1.000

S, species richness; H`, species diversity; $H_{max}$, maximum species diversity; J`, species evenness; 1-J`, species dominance; T, all tree species; O, tree species in canopy layer.
*The abbreviations of cover types were referred to Table 1.

est community would be increased as forest succession proceeds (Kim 2002).

Species diversity is one of the basic concepts of ecology that has been used to characterize forest communities and ecosystems and measured by species richness (the number of species present in a particular community) and species evenness (the relative abundance of the different species). In this study, Shannon-Wiener's species diversity index measures of overstory and total woody plants were calculated and presented by seven forest cover types in Table 2.

Species diversity indices (H') of total and overstory both were the highest in the mixed mesophytic forest (3.530 and 2.880), and lowest in the *Q. mongolica* pure forest (2.122 and 0.000). Comparison of species diversity among the forests can not be made by using the species diversity index only. In order to have high species diversity, both of species richness and evenness should be high (Kim 1999). So species diversity should be judged by making comparison of species diversity index with maximum species diversity index and evenness index.

So the species diversity indices of the communities in descending order were: Mixed mesophytic forest, *Q. mongolica* mixed forest, *B. ermanii* forest, *F. rhynchophylla*-*Q. mongolica* forest, *T. cuspidata* forest, *P. densiflora* forest, and *Q. mongolica* pure forest. The highest species diversity in the mixed mesophytic forest may due to the relatively high species richness and evenness in that forest cover type.

Discussion: Eco-Character of Forest Cover Types

Mixed mesophytic forest

Eighty one sample points out of 244 (33.2%) came under the mixed mesophytic forest cover type, in which no absolute dominance was found, shared importance values by a number of species. Widespread dominants included *Q. mongolica*, *P. densiflora*, *C. controversa*, *A. pictum* subsp. *mono*, *F. mandsurica*, and *F. rhychophylla* (Table 1). This type was the most diverse of the deciduous forest with 29 overstory tree species and 58 total, presenting highest species diversity index of 3.530 for all woody plant species and 2.880 in overstory among forest cover types (Table 2). In addition to this study, several recent studies (Hwang et al. 2012; Chung and Kim 2013; Lee et al. 2014) in Korean natural forests have reported the existence of the mixed mesophytic forest, typified by diversity and complexity.

Because the composition and relative abundance of the dominants varied from place to place, this forest type contains the large number of dominants. This would have resulted in the development of apparently distinct climax forest. For instance oak species dominant forest would develop on some of drier sites such as upper and/or south facing slopes, and maple and basswood dominant forest on wetter sites such as lower and/or north facing slopes.

Even though it was the canopy layer which primarily characterized the type, lower layers also had distinctive features. To the large number of canopy species must have been added the lower trees, which seldom or never attain canopy position, as *A. pseudo-sieboldianum*, *S. obassia*, *Morus bombycis*, *Magnolia sieboldii*, and *C. cordata*. Among the shrubs, *Lidera obtusiloba*, *Rhododendron schlippenbachii*, *Weigela subsessilis*, and *Staphylea bumalda* were most generally present and abundant.

In such regions of narrow valleys of Appalachian Mountains in the United States where the term of this forest type was originated, even though the species are different, trees of same genera, for example *Acer*, *Tillia*, *Betula*, *Fraxinus*, *Quercus*, *Ulmus*, and its endemic genera of *Fagus*, *Aesculus*, and *Liriodendron* show very similar physiognomy and ecological characteristics to those of this cover type. This forest type has been regarded the most complex and the oldest association of the temperate deciduous forest formation (Braun 1950; Vankat 1979; Barbour and Billings 1988). Even in Europe (European Environment Agency 2006) it has been also recognized the mixed mesophytic forest types, suggested the characteristics of diversified species composition and structure.

Taxus cuspidata forest

T. cuspidata is characterized by cold-resistance and shade tolerance, growing in high mountainous area above 1,000 m altitude in Sobaeksan and Taebaeksan (Jang et al. 2004). In this study, the authors found and recognized *T. cuspidata* dominant forest at the ridge and upper slope around 1,300-1,400 m above sea level and classified as the *T. cuspidata* forest cover type. The canopy layer of this cover type was dominated by *T. cuspidata* with 59.6% of importance value, mixed up *F. rhynchophylla*, *C. controversa*, *A. mandshuricum*, and *A. pictum* subsp. *mono.* Lower stories of the forest was composed of such species as *S. commixta*, *A. tschonoskii* var. *rubripes*, *T. cuspidata*, *P. padus*, *A. pseudo-sieboldianum*, *Euonymus sachalinensis*, *M. sieboldii*, etc. This cover type would be ecologically so fragile that if it might be once destroyed and degraded it should be difficult to restore original features as to need conservation.

Fraxinus rhynchophylla-Quercus mongolica forest

This forest cover type was mainly dominated by *F. rhyn-*

chophylla and *Q. mongolica*, occupying the forest with more than 72% of importance value (Table 1). The ash tree grows in cool and warm climate, on the moist, well-drained soil, in areas that provide enough direct sunlight. Therefore, it grows mostly in most rich soils of valleys (Choi et al. 1997; Kim et al. 2011). Lower story of the forest was composed of such species as *F. rhynchophylla*, *C. controversa*, *Q. mongolica*, *A. pictum* var. *mono*, *A. pseudo-sieboldianum*, etc.

F. rhynchophylla has four regeneration types including seedling, stump sprout, root sprout, and layering. The species is more likely shade tolerant with a long seed dispersal distance as a samara species (Han and Sim 1989). The most frequent regeneration type was by stump sprout after disturbances (Yeo and Lee 2006). Advance regenerations often exhibit more rapid growth and can better survive competition after release than trees beginning from seeds (McGee and Loftis 1986). Therefore, *F. rhynchophylla* can be easily spread into the understory of natural deciduous forest. Such regeneration strategy increases the number of advanced young ash trees which could grow up and occupy the canopy (Chung 2015).

Betula ermanii-Quercus mongolica forest

This forest cover type was characteristically distributed in ridge or around mountain summit, and above 1,200 m of relatively high altitude in limited small areas of the study area. *B. ermanii* followed by *Q. mongolica* predominated. The birch usually being more numerous and the key species in this type. Associate species were hardly varied, including *C. controversa*, *A. pictum* subsp. *mono*, *S. alinifolia*, *A. nephrolepis*, and so on (Table 1). Species diversity index of woody plant species was calculated 2.692 (Table 2).

Dominant *B. ermanii* is known as a pioneer species, often colonizing bared areas after severe fires or soil disturbance. The species tend to make small patch of stand with regenerated trees. We noticed that It often preceded its associates by invading disturbed soils that had been logged or cleared by fire.

Kim and his colleagues (Kim et al. 2015) reported that, after reaching the thrifty stage as forest succession would progress with no additional major disturbances, the abundance of *B. ermanii* would be decreased and those of other hardwood species would be increased. Eventually the species would be driven out sooner than other species found in this type and no more maintain this cover type.

Pinus densiflora forest

Even though *P. densiflora* and *Q. mongolica* together constituted the majority of density and volume stocking, we gave the name of this type as *P. densiflora* forest cover type separately from the previous type (Lee et al. 2014), due to more than 80% of importance value of the pine. In addition to the pine and oak, small number of *B. schmidtii*, *B. davurica*, *C. laxiflora*, and *F. rhynchophylla* were growing in canopy layer, presenting second lowest species diversity index of 2.429 (Table 2).

P. densiflora is shade-intolerant and commonly develops toward the even-aged stand. Once the pine stand comes to maturity and makes site condition better, the species is often replaced by the more shade-tolerant associates of deciduous trees, such as oaks, ashes, maples, and other hardwood species, which regenerate more readily in the understory of the pine stand. As years go by, pine trees are gradually decreased in abundance and finally disappear, and other trees are increased in density and stocking through natural invasion of general shade-tolerant midstory and understory associates (Kim et al. 2015).

Quercus mongolica mixed forest

Q. mongolica mixed forest cover type ranked next to the mixed mesophytic forest cover type in measure of sample area with 68 sample points out of 244 (28%). This cover type extended over broad areas chiefly on topographic positions from mid-slopes through upper-slopes up to ridges. As mentioned before, when the stand of *P. densiflora* was cut or destroyed by fire, the oak invade vigorously and became dominant through persistent sprouting in accompany with the failure of pine trees to regenerate themselves under the stand (Kim et al. 2015).

Q. mongolica was associated with 21 tree species in the canopy (Table 1), some common to dry upland sites and others more common to moist bottomland sites, including *B. ermanii*, *P. densiflora*, *T. amurensis*, *B. schmidtii*, and so on.

Chung (2015) discussed the ecological whereabouts of this cover type. On the basis of species composition of stratification, he suggested three successional progress pathways. 1) Although there was a little changes in the ratio of *Q. monoglica* of the canopy story, the species composition of this cover type would be continued for a while. As time goes by, 2) The influence of *Q. monoglica* will be gradually weaken due to growth competition of shade tolerant species in the mid-story. Consequently, 3) This cover type is likely to be changed to mixed mesophytic forest cover type by increasing the ratio of shade tolerant species such as *C. cordata*, *T. amurensis*, and *A. pictum* subsp. *mono.*

Quercus mongolica pure forest

Almost 12% (28 sample points) of the study area was solely composed of *Q. mongolica* trees in canopy (Table 1). That was the reason we named the forest the *Q. mongolica* pure forest cover type. However, we found 35 woody plant species in lower strata by the sampling procedure.

Q. mongolica have some unique characteristics to form 100% pure stands. Mainly because it sprouts readily and has strong competitive ability. Great amount of the oak trees in new production stands were sprouts, either from advance reproduction or from stumps of cut trees. New sprouts from advance reproduction arose when old stems were damaged during logging or other disturbance, like fire. Height growth of new sprouts was related to the size of the old, damaged stem. The larger the old stem, the faster the new sprout would grow (Kim 2015). In addition, the species has broad niche of topography and seldom requires good site quality Suh (1993) so as to have high competition ability against other species and to make 100% pure stand.

Q. mongolica has been well adapted to environmental conditions of Korean forests, but the dominant species might be replaced to other species by changes in the environmental factors such as global warming, climate change, and soil properties, etc. This species can also be described as a long-lived pioneer because it often requires large stand disturbances to regenerate successfully (Ishikawa and Ito 1989; Osawa 1992). Even though it is hard to conclude that *Q. mongolica* is late seral or climax species, the cover type which was dominated by *Q. mongolica* has high possibilities to maintain itself for a long period of time (Chung 2015).

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