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ORIGINAL ARTICLE

Effects on Vegetation Distribution of Odaesan National Park according to Climate and Topography of Baekdudaegan, Korea

Bong-Ho Han, Jin-Woo Choi[1)], Jung-Hun Yeum[2)*]

Department of Landscape Architecture, University of Seoul, Seoul 02504, Korea
[1)]Environmental Ecosystem Research Foundation, Seoul 05643, Korea
[2)]National Wetlands Center, National Institute of Environmental Research, Changnyeong 50303, Korea

Abstract

This study aimed to understand the distribution of vegetation in the eastern and western sides of the Baekdudaegan (ridge) dividing the Odaesan National Park, as influenced by its topography and climate. The actual vegetation, topography and climate for each side were used in the overlay analysis. The results of the analysis of actual vegetation showed a high distribution rate of *Quercus mongolica* forest on both the eastern and western sides. On the eastern side, the distribution rate of *Pinus densiflora* forest and *P. densiflora-Q. variabilis* forest was high, while the western side had a high distribution rate of deciduous broad-leaved tree forest and *Abies hollophylla* forest. A clear trend was identified for vegetation distribution with respect to elevation but not with respect to slope or aspect. The results of micro-landform analysis showed that the *P. densiflora* forests in the ridge and slope and the deciduous broad-leaved tree forest in the valley were respectively distributed with a high ratio. In terms of climate, the eastern side revealed an oceanic climate, with a relatively high average annual temperature, while the western side was characterized by relatively high average annual humidity and average annual precipitation. The distribution rate of *P. densiflora* forest was found to be high on the eastern side of the mountain range.

Key words : Ridge impact, Topographic characteristic, Northern temperate zone, Oceanic climate, Overlay analysis

1. Introduction

Topography and climate are key factors that affect vegetation patterns (Shin, 2006). Topographic studies demonstrated that factors affecting the vegetation pattern include vertical changes depending on the altitude above the sea level (Hou, 1983; Park et al., 1996; Byun et al., 1998; Lee, 2000a; Yoo et al., 2003), micro-landform changes depending on the slope (Yeon et al., 2006; Chang et al., 2012) and the intensity of radiation changes depending on the direction (Lee, 2000b). In particular, a study on the relationship between the micro-landform and the vegetation pattern which evaluated the slope showed that the distance between the erosion and stream affects the vegetation structure (Kikuchi and Miura, 1993). Peterson et al. (1997) indicated that the vegetation distribution depends on the vertical altitude above the sea level for the horizontal latitude difference.

The climate directly affects the vegetation distribution (Vloebeld and Leemans, 1993; Neilson, 1995) and

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[*]**Corresponding author**: Jung-Hun Yeum, National Wetlands Center, National Institute of Environmental Research, Changnyeong 50303, Korea
Phone: +82-55-530-5533
E-mail: zelkovayeum@gmail.com

most studies cover the distribution range depending on the climate of the vegetation community (Jiang, 1980; Kira, 1991). Kira (1991) separated the vegetation distribution in East and Southeast Asia into the warmth and coldness indices to identify each climate feature and reported that the tropical rain forest influences the local growing environment due to the strong rainfall. Ohsawa (1990) reported the impact of the temperature in the summer and winter on the vegetation distribution pattern of the tropical forest in East Asia according to the longitude and latitude. In addition, it was suggested that the Föhn effect from the mountains forms the local climate (Marcu and Huber, 2003) and that the forest near the ocean forms a climate without a large annual fluctuation (Yuste et al., 2003) while affecting the forest vegetation distribution.

The Baekdudaegan (ridge) is the biggest range of mountains from Baekdusan to Jirisan through Geum -gangsan, Odaesan and Deokyusan, reflecting the topographic feature of Korea with 65% of mountains. The concept of 'Baekdudaegan', mountains from Baekdusan, is based on feng shui from the Goeyro Dynasty. However, it is from the Joseon Dynasty that the concept of the range of mountains and river basins was generalized and established through a system like the Sangyeongpyo in the late period of the Joseon or the mid-18th century (Yang, 1997). The total length of Baekdudaegan is about 1,400 km and the section below the truce line is about 670 km from Hyangrobong in Goseong, Gangwon to Cheonwangbong in Jirisan. The ridge elongates along the vertical direction of the highlands on the topography, the east side near the seashore has an oceanic climate with a rapid slope and the west side has a slow slope with an inland climate (Ministry of Environment, 2002; Choung et al., 2004).

Lee et al. (2013) classifies the vegetation group of the rid into 49 types including 42 natural forests and 7 artificial forests according to the vegetation distribution. The Korea Forest Research Institute (2003) states that the Baekdudaegan vegetation includes northern warm, mid- and southern climatic regions. There are a lot of studies investigating the plant vegetation structure in each section (Kim and Choo, 2003; Lee et al., 2012; Choi et al., 2015) as well as the impact of the altitude above the sea level and micro-landform changes on the vegetation distribution (Choung, 1998; Hwang et al., 2012).

Prior studies have reported that the vegetation distribution is affected by the altitude above the sea level, the slope, direction and micro-landform, as well as the regional climate like the temperature, Föhn effect and oceanic climate. However, most studies focus on the relation to the factors affecting the vegetation distribution at the site and a limited number of studies accurately determined the vegetation difference according to the north and south or east and west based on the ridge at the local scale. In particular, it is important to understand the forest eco-system by investigating the vegetation distribution in the east and west Baekdudaegan central mountains of Korea depending on the topography and climate. Odaesan National Park, the site of the study, is a representative park with a clear distinction between the oceanic climate at the east slope and the inland climate at the west slope.

Therefore, the aim of this study is to investigate how the climate features including the annual average temperature, precipitation and humidity and the topographic features depending on the elevation, slope, direction and micro-landform affect the vegetation distribution as the basic data for vegetation manage -ment of protected areas.

2. Materials and Methods

2.1. Study area

The Odaesan National Park is located between N. 37°42' - 37°-49' and E. 128°42' - 128°44' with a total

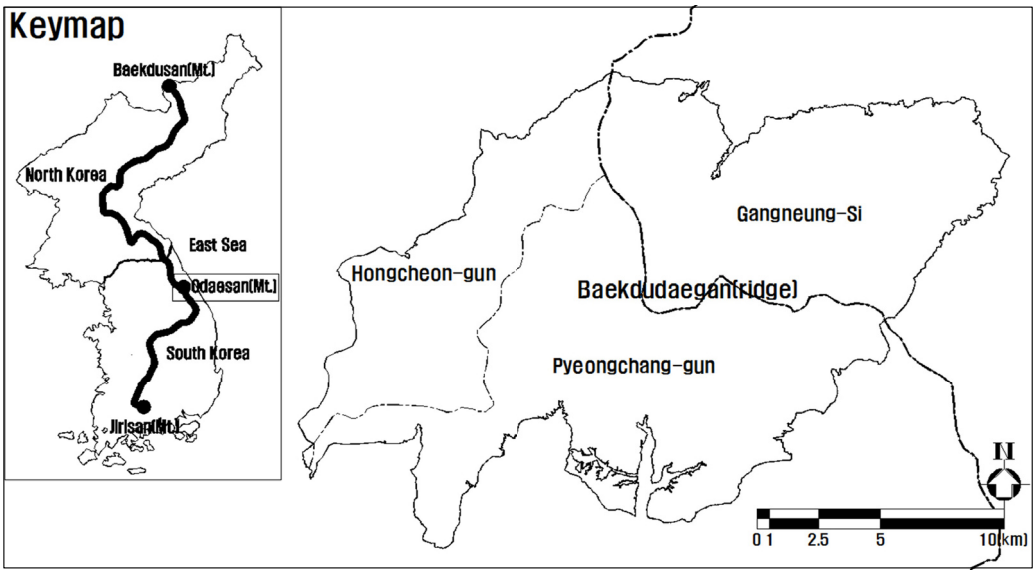


Fig. 1. Location of study area.

area of 326 ㎢. The park is located in the northeast of Gangwondo facing Seoraksan on the north and Taebaeksan on the south along with the axis of Baekdudaegan and contains peaks like the main Birobong (1,563 m), Durobong (1,422 m), Sangwangbong (1,491 m), Horyeongbong (1,561 m), Dongdaesan (1,338 m) and Noinbong (1,338 m). Gangneung-si is in the east while Pyeongchang-gun and Hongcheon -gun are located west of the ridge (Fig. 1).

The national park is in the northern limit area of the northern temperate zone and the western and eastern parts of Baekdudaegan are affected by the inland climate and oceanic climate, respectively (Yim and Lee, 1975). In particular, the climate data of the Korean Meteorological Administration (1981 - 2010) show that the Woljeongsa region marked the lowest average temperature in Korea of 6.6 - 9℃ and the largest annual average precipitation among inland areas of more than 1,700 mm.

2.2. Survey and analysis method

2.2.1. Current vegetation

The current vegetation type was classified based on the vegetation physiognomy of the tree layer and areas like Buddhist temples and garden trees were classified based on the land use status. The study distinguished coniferous trees and broad-leaf trees from aerial photographs obtained by the National Geographic Information Institute (taking year of 2012). The photographs were used to draw the current vegetation map and form blocks of vegetation and land use types with a topographic map of 1/5,000 scale recording the characteristics of the site. The site survey result was mapped using the AutoCAD Map 2004 and ArcGIS 10.1 then the area and ratio for each type of actual vegetation were calculated. The vegetation types in the northern temperate and mid-temperate areas were reconstructed based on the afforestation tree species for each temperate region designated by the Korea Forest Service (2017).

2.2.2. Topography and climate

The topography was analyzed with the 3D Analyst Tool and the Spatial Analyst tool in ArcGIS 10.1 to determine the elevation, slope, aspect and micro -landform. The Digital Elevation Model (DEM) was

analyzed by extracting the contour from the numerical topographic map (1/25,000). The cell size was 90 m, adequate for the numerical model by Sharma et al. (2011). A total of 16 sections was collected at 100 m above the sea level (Lee et al., 2013) and the slope introducing the criteria was proposed based on the designation, modification and cancellation guidelines for forest preservation provided by the Korea Forest Service. The area consisted of a slow slope (0-15°), slope (15-20°), rapid slope (20-25°), steep slope (25-30°) and extremely steep slope (over 30°) and the slow slope area was classified as a flat area (0-5°). The area was divided into 8 directions excepting the flat area (Yeon et al., 2006). The micro-landform was analyzed by the Neighborhood (Focal statistics) using the map algebra of the ArcGIS 10.1 Spatial Analyst Tool with the generated DEM for the ridge, slope and valley.

The annual average temperature and humidity and the annual precipitation comprised the average data for 20 years as of 2013 (1994 - 2013) obtained from the climate data of the KMA (Korea Meteorological Administration). The study analyzed the existing vegetation distribution status for the average temperature, humidity and precipitation over the last 30 years in Gangneung-si on the east side and Hongcheon-gun and Pyeongchang-gun on the west side.

2.2.3. Overlay analysis

The mapping and analysis of land use adequacy is one of the most useful applications of the Geographic Information System (GIS) to the planning and management of land use (Collins et al., 2001). The GIS analysis is widely used in the ecological field and analyzes the land adequacy and habitation definition of animals and plants (Pereira and Duckstein, 1993; Store and Kangas, 2001) as well as the geographic preference (Bonham-Carter, 1994). Carver (1991) states that overlay analysis is effective for analyzing and checking the overlay feature as a pre-process for Multi-Criteria Evaluation.

The study performs an overlay analysis of the altitude above the sea level, slope, direction, micro-landform and existing vegetation to investigate the vegetation distribution feature depending on the topography on the east and west sides of Baekdudaegan. The study uses the intersection tool of ArcGIS 10.1 overlay functions and analyzes the area (m^2) and ratio (%) of the vegetation types at each elevation above the sea level, slope, direction and micro-landform.

3. Results

3.1. Actual vegetation

The analysis of the actual vegetation survey in Odaesan National Park (Table 1) shows that the *Q. mongolica* forest in the northern temperate comprises the largest ratio at 56.6%, followed by the *P. densiflora* forest at 13.0% and the deciduous broad-leaved forest at 8.5%. The *A. holophylla* forest accounts for 0.2% while the *A. holophylla* - *Q. mongolica* forest and *A. holophylla* - deciduous broad-leaved forest are 0.8% and 0.2%, respectively. The national park is a representative *A. holophylla* forest (Lee et al., 2008) in Korea, distributed around the valley slope while the artificial *A. holophylla* forest is distributed around the Temple. The *T. cuspidata* forest is distributed around the peak on the ridge and the *A. nephrolepis* forest appears on the ridge slope. The *L. leptolepis* forest around the south forest in the park accounts for 2.9% of the total area and artificial forests including *P. koraiensis* takes 0.4%. A ranch is on the eastern border of the National Park and the grassland accounts for 6.4%.

The national park is located in the northern temperate zone and has a distribution of deciduous broad-leaved forests in the northern temperate zone like the *T. cuspidata, A. nephrolepis, A. holophylla, P. koraiensis, Betula ermani, Ulmus laciniata* and

Table 1. Area and ratio of vegetation types of east and west side of Baekdudaegan in Odaesan national park

Types	Divide*	East side of Baekdudaegan		West side of Baekdudaegan				Total	
		Gangneung-si		Pyeongchang-gun		Hongcheon-gun			
		Area(㎡)	Ratio (%)	Area(㎡)	Ratio (%)	Area(㎡)	Ratio (%)	Area(㎡)	Ratio (%)
1. *Taxus cuspidata* forest	N	-	-	29,271	0.0	17,159	0.0	46,430	0.0
2. *Abies nephrolepis* forest	N	-	-	27,756	0.0	2,169	0.0	29,925	0.0
3. *Abies holophylla* forest	N	-	-	548,118	0.4	112,701	0.2	660,820	0.2
4. *Abies holophylla-Pinus densiflora* forest	N	-	-	-	-	72,809	0.1	72,809	0.0
5. *Abies holophylla-Quercus mongolica* forest	N	-	-	1,336,119	0.9	1,208,401	1.7	2,544,521	0.8
6. *Abies holophylla*-Decidious broad-leaved tree forest	N	-	-	630,731	0.4	184,258	0.3	814,989	0.2
7. *Pinus koraiensis* forest	N	103,546	0.1	174,077	0.1	1,778	0.0	279,400	0.1
8. *Pinus densiflora* forest	C	28,732,669	24.8	11,384,643	8.1	2,424,820	3.4	42,542,132	13.0
9. *Pinus densiflora-Abies holophylla* forest	N	-	-	245	0.0	96,656	0.1	96,901	0.0
10. *Pinus densiflora-Quercus mongolica* forest	N	5,765,340	5.0	6,802,262	4.8	1,195,868	1.7	13,763,471	4.2
11. *Pinus densiflora-Quercus variabilis* forest	C	19,105,231	16.5	-	-	-	-	19,105,231	5.8
12. *Quercus mongolica* forest	N	49,293,583	42.6	79,108,774	56.2	56,687,160	80.2	185,089,518	56.6
13. *Quercus mongolica-Pinus densiflora* forest	N	56,298	0.0	-	-	-	-	56,298	0.0
14. *Quercus mongolica*-Decidious broad-leaved tree forest	N	267,260	0.2	1,367,014	1.0	1,097,201	1.6	2,731,475	0.8
15. *Quercus serrata* forest	C	-	-	15,034	0.0	-	-	15,034	0.0
16. *Quercus variabilis* forest	C	1,762,322	1.5	-	-	-	-	1,762,322	0.5
17. *Quercus variabilis-Pinus densiflora* forest	C	212,457	0.2	-	-	-	-	212,457	0.1
18. Decidious broad-leaved tree forest	N	8,366,477	7.2	13,200,466	9.4	6,203,388	8.8	27,770,331	8.5
19. Decidious broad-leaved tree-*Abies holophylla* forest	N	-	-	6,239,480	4.4	1,160,757	1.6	7,400,238	2.3
20. *Larix leptolepis* forest	A	626,629	0.5	8,828,692	6.3	133,712	0.2	9,589,032	2.9
21. *Robinia pseudo-acacia* forest	A	-	-	1,641	0.0	-	-	1,641	0.0
22. Other artifical forest	A	601,086	0.5	666,156	0.5	-	-	1,267,242	0.4
23. Rock	E	5,869	0.0	-	-	-	-	5,869	0.0
24. Shrub	E	-	-	15,496	0.0	17,052	0.0	32,549	0.0
25. Grassland	E	11,888	0.0	9,057,488	6.4	672	0.0	9,070,048	2.8
26. farmland	E	4,349	0.0	371,011	0.3	19,863	0.0	395,223	0.1
27. Nursery field	E	-	-	771	0.0	-	-	771	0.0
28. Planted area	E	-	-	918	0.0	-	-	918	0.0
29. Area of Forest Damage	E	11,887	0.0	70,430	0.1	-	-	82,317	0.0
30. River and Lake	E	410,659	0.4	431,282	0.3	33,933	0.0	875,874	0.3
31. Road	E	146,246	0.1	124,868	0.1	-	-	271,114	0.1
32. Urbanized Area	E	171,134	0.1	138,159	0.1	-	-	309,293	0.1
33. Etc.	E	-	-	151,396	0.1	-	-	151,396	0.0
Total	-	115,654,929	100.0	140,722,300	100.0	70,670,356	100.0	327,047,585	100.0

*N: Northen temperate zone tree, C: Central cool temperate zone tree

Tilia amurensis. Also, there are 14 vegetation types in the northern temperate zone and 5 vegetation types such as oak trees in the mid-temperate zone including the *Quercus serrata, Q. variabilis* and *P. densiflora* forests. In the event of joint dominance of the mid- and northern temperate zones, the vegetation is included in the northern temperate zone based on the border where the northern temperate zone begins.

Gangneung-si on the east side of Baekdudaegan has an oceanic climate close to the East Sea and the vegetation distribution includes the *Q. mongolica* forest (42.6%), *P. densiflora* forest (24.8%) and *P. densiflora* - *Q. variabilis* forest (16.5%). The vegetation is mainly mid-temperate area and trees in the northern temperate zone like the *B. ermani, A. holophylla, A. nephrolepis* and *T. cuspidata* are not included. Pyeongchang-gun, on the west side of the ridge, has a vegetation distribution of *Q. mongolica* forest (56.2%) followed by deciduous broad-leaved forest (9.4%), *P. densiflora* forest (8.1%), grassland (6.4%) and *L. leptolepis* forest (6.3%). The *Q. mongolica* forest and deciduous broad-leaved forest have a high distribution ratio whereas the *P. densiflora* forest has a relatively low ratio. The area contains the ranch, the grassland accounts for 6.4% of the total area and the *L. leptolepis* forest is widely distributed on the border. Hongcheon-gun has a distribution of *Q. mongolica* forest (80.2%), deciduous broad-leaved forest (8.8%), *P. densiflora* forest (3.4%), *A. holophylla* - *Q. mongolica* forest (1.7%) and *P. densiflora* - *Q. mongolica* (1.7%). Pyeongchang-gun and Hongcheon-gun, on the west side of Baekdudaegan, have a high distribution ratio of *Q. mongolica* and deciduous broad-leaved forests but a low ratio of *P. densiflora* forest compared to Gangneung-si on the east side of the ridge. The ratio of the vegetation in the northern temperate zone is high with the *A. holophylla* forest, *A. nephrolepis* forest and *T. cuspidata* forest.

3.2. Topography

Analysis of the elevation above the sea level of Odaesan National Park (Fig. 2) shows that 11.2% of Gangneung-si is at 700-800 m and 53.3% is from 400 m to 900 m. Pyeongchang-gun, on the west side of the ridge, has the highest ratio in the area at 1,000-1,100 m (21.9%) and 58.6% in the area from 800 m to 1,100 m. Hongcheon-gun has the highest ratio of 20.3% in the area of 1,000-1,100 m and the areas from 900 m to 1,100 m comprise 55.8% of the total area.

The rapid slope area (20-25°) comprises the highest ratio of 24.4% and the extremely steep slope area over 30° accounts for 12.1% of Gangneung-si. The slow slope area (5-15°) takes up the largest ratio of 33.2% in Pyeongchang-gun and the ratio of steep areas is low compared to Gangneung-si and Hongcheon -gun. Hongcheon-gun has the highest ratio of rapid slope area (20-25°) with 28.8%. This area appears to be the steepest with a higher ratio of steep areas than Pyeongchang-gun.

The direction analysis shows that 19.9% of the Gangneung-si is toward the east while the north and the east directions account for 53.2%. Pyeongchang -gun located in the south has the highest south-bound portion at 15.2% and the east, west and southerly portions are evenly distributed. Hongcheon-gun, located in the northwest, is 19.9% northwest bound and the west- and north-bound sections take up 53.2%. Pyeongchang-gun, on the west side of Baekdudaegan, has a high ratio of south-bound areas with a lot of sunlight but Hongcheon-gun has a distribution around the northwest with almost no sunlight.

The micro-landform analysis shows that the east and west sides of the ridge have no large difference but Hongcheon-gun has a relatively high ratio of valley. The western part of Baekdudaegan has a high elevation compared to the eastern part and in

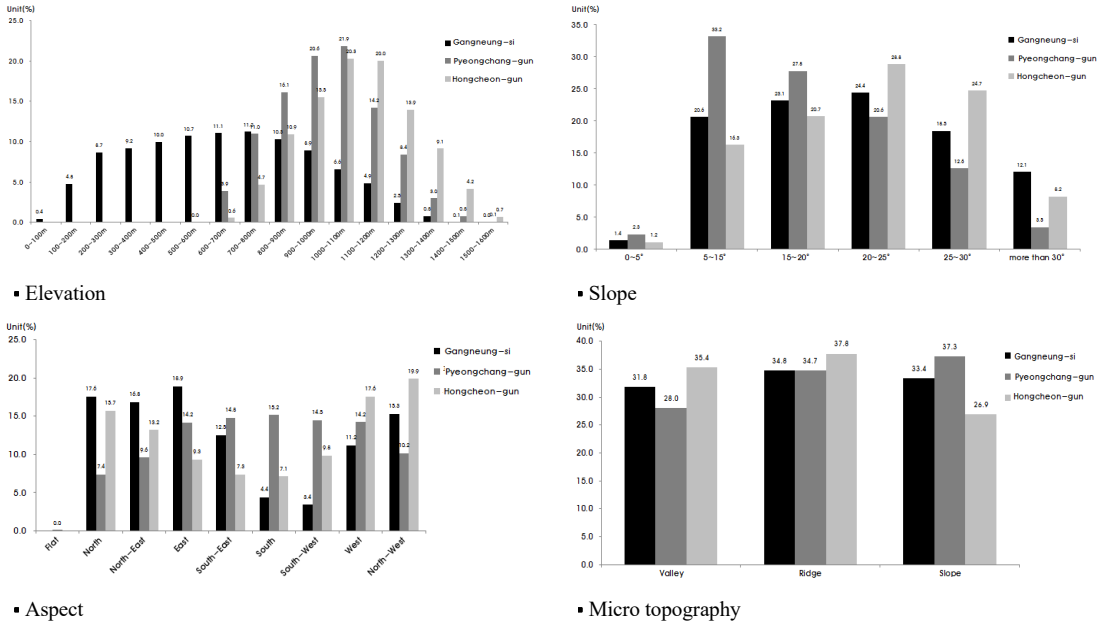


Fig. 2. Topology analysis of Odaesan national park.

particular, Hongcheon-gun has a high ratio of valleys in the environment with almost no sunlight.

3.3. Climate

Analysis of the annual average temperature, humidity and precipitation at Odaesan National Park for the last 20 years (1994 - 2013) shows that the annual average temperature, humidity and precipitation at Gangneung-si on the east side of Baekdudaegan are 13.4℃, 59.8% and 1,448.0 mm, respectively. Pyeongchang-gun, on the west side of the ridge, has an annual average temperature, humidity and precipitation of 7.0℃, 73.2% and 1,733.0 mm, respectively. Hongcheon-gun has an annual average temperature, humidity and precipitation of 10.7℃, 66.1% and 1,445.8 mm, respectively.

The annual average temperature for all the regions fluctuates with no significant change. The temperature of Gangneung-si on the east side of the ridge is higher than that of Pyeongchang-gun and Hongcheon -gun and is double that of Hongcheon-gun. This is in agreement with the report from Choung et al. (2004) that the cities on the east side of Baekdudaegan have a higher temperature than those on the west side. Gangneung-si has a slightly lower humidity compared to 20 years ago but the other 2 areas show a slight increase. The annual average humidity of Pyeongchang -gun and Hongcheon-gun on the west side of Baekdudaegan is higher than that of Gangneung-si on the east side. The precipitation fluctuates annually but has decreased in the 3 regions in recent years compared to 20 years ago.

4. Discussion

4.1. Topography and current vegetation

The vertical distribution map of the current vegetation depending on the topography of Odaesan National Park (Fig. 3) shows that the east side with a cross-section from Jingogae through Noinbong (1,338 m) to Sogeumgang contains 34.0% of *P. densiflora* forest, *P. densiflora* - *Q. variabilis* forest,

Q. mongolica and *P. densiflora* - *Q. mongolica* forest below 500 m above the sea level. The forest distribution between 500 m and 800 m elevation is *Q. mongolica* forest, *P. densiflora* - *Q. variabilis* forest, *P. densiflora* forest and mixed deciduous broad-leaved forest, with a ratio of 34.1%. 19.8% of the forest in the area of 800 and 1,000 m elevation is *Q. mongolica* forest, *P. densiflora* forests, *P. densiflora* - *Q. variabilis* forest and mixed deciduous broad-leaved forest. *Q. mongolica* forests, *P. densiflora* forests and deciduous broad-leaved forests account for 12.1% of the area from 1,000 to 1,400 m elevation. The west side of Baekdudaegan with a cross-section from Jingogae through Dongdaesan (1,433 m) and Birobong (1,563 m) contains *Q. mongolica* forest, *P. densiflora* forest and *L. leptolepis* forest in 11.1% of the area from 500 m to 800 m elevation. *Q. mongolica* forests, deciduous broad-leaved forests and *P. densiflora* forests account for 32.6% of the area at 800-1,000 m elevation. *Q. mongolica*, deciduous broad-leaved forests and grass vegetation comprise 54.1% of the area at 1,000-1,400 m elevation while *Q. mongolica* forests, *Q. mongolica* - deciduous broad-leaved forests, *A. holophylla* - *Q. mongolica* forests, *A. nephrolepis* forests and *T. cuspidata* forests take up 2.2% each for the area over 1,400 m elevation. Elevation at the east side starts from 10 m and *P. densiflora* forest and *P. densiflora* - *Q. variabilis* forest comprise a high ratio of the area below 500 m elevation. The ratio of *Q. mongolica* forest is higher and *P. densiflora* forests, *P. densiflora* - *Q. variabilis* forests and deciduous broad-leaved forests are distributed in the area between 500 m and 800 m of elevation. Elevation at the west side of Baekdudaegan begins at 620 m and the *Q. mongolica* forest has a high distribution in all the areas. The *P. densiflora* forest and *L. leptolepis* forest have a high ratio in the area of 500-800 m elevation while the deciduous broad-leaved forest has a high ratio in the area over 800 m of elevation, resulting in a difference in the vegetation distribution between the east and the west.

Choi et al. (1996) analyzed the deciduous broad-leaved forest between 700 m and 900 m of elevation on the east side of the ridge toward the direction from Jingogae to Noinbong. Kim et al. (1996) classified the group between 1,100 m and 1,400 m elevation as *Q. mongolica* forest. Han et al. (2015) classified the *Q. mongolica* forest, *Q. mongolica* - deciduous broad-leaf tree forest, *Q. mongolica* - *P. koraiensis* forest, *A. holophylla* - *Q. mongolica* forest and *A. holophylla* - deciduous broad-leaved forest between 1,115 m and 1,495 m elevation on the west side of Baekdudaegan, which had similar vegetation distribution at each elevation level under analysis. Im and Kim (1992) stated that the *Q. mongolica* forest is distributed between 1,200 m and 1,500 m elevation at Hallasan and at 800-1,000 m around 36 degrees of the north latitude in the study on the *Q. mongolica* forest with the highest ratio in Odaesan National Park. A study on the plant community distribution and topographic feature (Yeon et al., 2006) showed that *Q. mongolica* forest is intensively distributed at 965 m. The national park is located at around 37.5° of the north latitude and the *Q. mongolica* forest is mainly distributed above 600 m. Cogbill and White (1991) stated that the vegetation distribution area decreases by 100 m if the latitude increases by 1 degree from the relation regression between the latitude and elevation. In line with that, it is assumed that the elevation where the main distribution of the *Q. mongolica* forest begins decreases at high latitudes. Hou (1983) stated that, based on the latitude, longitude and elevation, vertical factors affect the vegetation distribution, causing the temperature to drop and become colder as the elevation increases. In addition, *P. koraiensis, A. nephrolepis* and *A. holophylla* are intensively distributed in the cold northeast forest of China and the vegetation is similar to the west side of

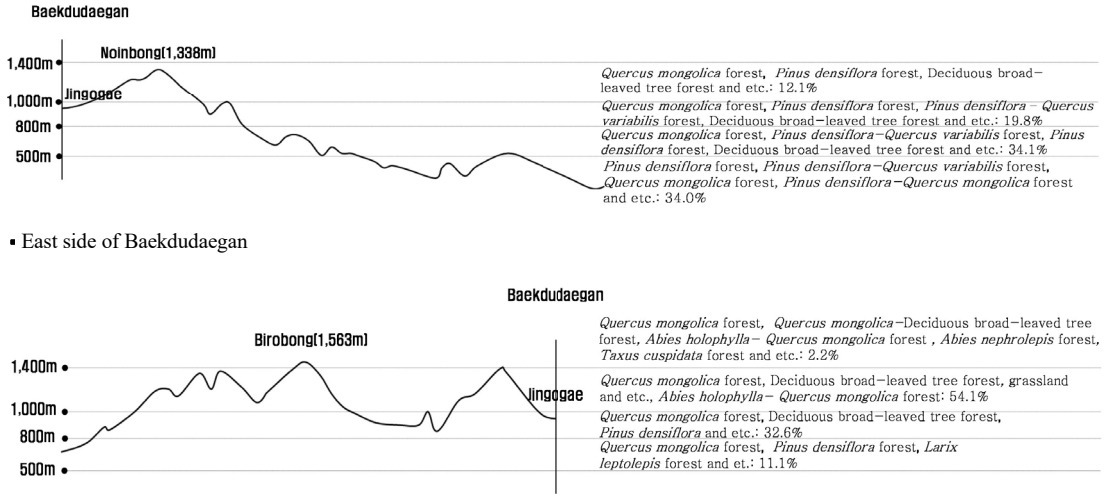
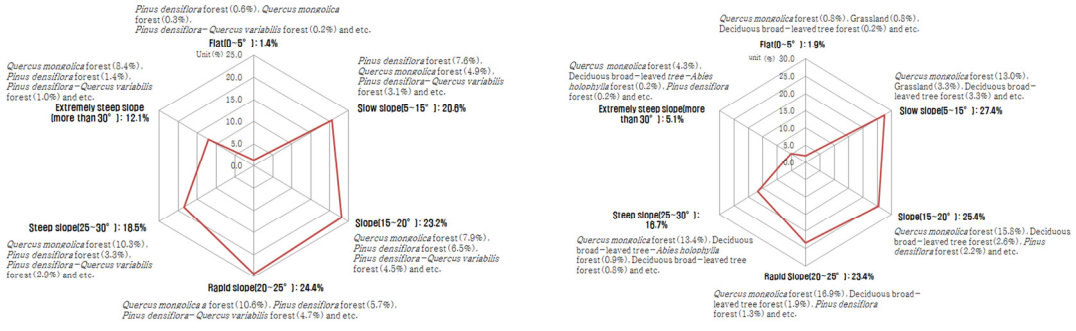


Fig. 3. Vegetation analysis according to elevation of Odaesan national park.

Baekdudaegan.

The comparison of the major vegetation distribution on the east and west sides of Baekdudaegan (Fig. 4) shows that the ratio of *Q. mongolica* forest is relatively high in the steep and extremely steep areas in the east and that the slow slope, slope and rapid slope areas have a relatively high ratio in the west. The largest ratio of *P. densiflora* forest is in the eastern slow slope area, with an even distribution in the slope and rapid slope while the *P. densiflora* forest in the west has the highest portion in the slope area and a large portion in the rapid slope area. The *P. densiflora* - *Q. variabilis* forest makes up a high ratio of the slope and rapid slope areas in the east. The slow slope area has the highest ratio of the western deciduous broad-leaved forest, with even distributions of the slope and rapid slope areas. This shows a similar trend to the results of the study by Jang (2007) on the locational environment in terms of the plant



▪ East side of Baekdudaegan ▪ West side of Baekdudaegan

Fig. 4. Vegetation analysis according to slope of Odaesan national park.

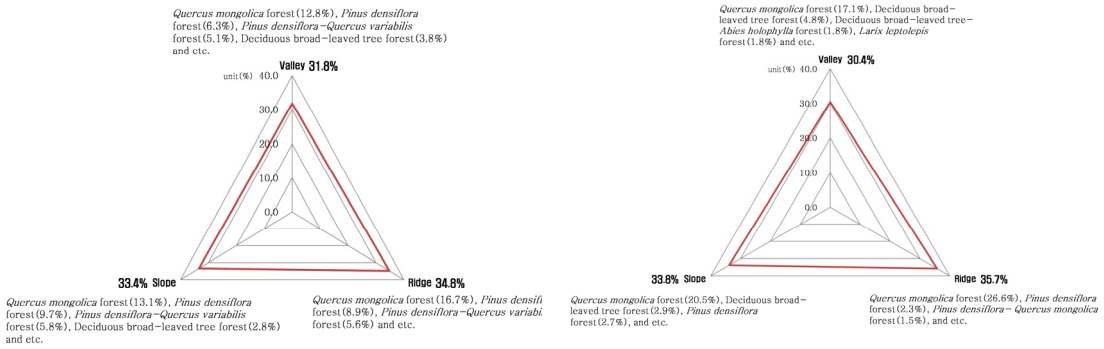
▪ East side of Baekdudaegan ▪ West side of Baekdudaegan

Fig. 5. Vegetation analysis according to aspect of Odaesan national park.

sociology, indicating that the distribution tendency of *Q. mongolica* forest according to the slope is not clear. Yoon (2003) stated that 80% of the *P. densiflora* forest is found in areas with less than 20° following a study on the spatial distribution and prediction of *P. densiflora* forest in Korea. The east side of Baekdudaegan shows no specific trend but the west side shows a high distribution in the slope (15 - 20°).

The result of analysis on the aspect of major vegetation areas on the east and west sides of Baekdudaegan (Fig. 5) showed that the *Q. mongolica* forest is intensively distributed in the east, northwest, north and northeast directions in the east, with even distributions in the west and a relatively high ratio in the west, northwest, southwest and south directions. Like the *Q. mongolica* forest, *P. densiflora* forest in the east part has a high distribution from the east to the northwest through the north and a relatively high distribution from the northwest to the south through the southwest in the west. *P. densiflora* - *Q. variabilis* forest is evenly distributed in all directions except in the south and southwest in the east area while the deciduous broad-leaved forest is evenly distributed in all directions except the southwest in the west area. The major vegetation distribution on both sides of Baekdudaegan depends on the ratio of the aspect and there is no clear difference between the east and west. Lee (1995) stated that the *Q. mongolica* forest is mainly distributed to the south and north slopes and is intense in the east (12.5%) and northwest directions (15.3%) on the east side of Baekdudaegan. The west direction (15.3%) has a high ratio on the west of the ridge while the north and west directions have a high portion with less sunlight. In a study on the spatial feature and prediction of *P. densiflora* forest in Korea, Yoon (2003) reported that there is no significant difference according to the direction with 20.5% in the north and 27.2% in the south direction, unlike a previous study which found that the distribution of *P. densiflora* forest is low in the north and high in the south. The study also did not find any features specific to either area.

The actual vegetation distribution analysis of the micro-landform (Fig. 6) showed that the *Q. mongolica* forest comprises a high ratio of the ridge in the east and west Baekdudaegan and the *P. densiflora* forest shows a similar trend due to taking up a high ratio of the ridge and slope. The *P. densiflora* - *Q. variabilis* forest in the east is evenly distributed on the ridge, valley and slope while the deciduous broad-leaved forest in the west has a high rate in the valley. In a study on Amami Oshima in the western part of Japan, Hara et al. (1996) stated that



▪ East side of Baekdudaegan ▪ West side of Baekdudaegan

Fig. 6. Vegetation analysis according to micro-landform of Odaesan national park.

the micro-landform distribution from the ridge to the valley affects the vegetation pattern. Both sides have a distribution of *P. densiflora* forest by the land climax of the ridge (Bae and Hong, 1996), and *P. densiflora* - *Q. variabilis* forest has a higher ratio than the deciduous broad-leaved forest in the east. Ohsawa (1993) stated that this distribution is affected by the fact that the evergreen coniferous forest is largely distributed in the oceanic climate.

4.2. Climate and current vegetation

The result (Table 2) of actual vegetation analysis according to the climate shows that the annual average temperature, humidity and precipitation in the east of Baekdudaegan are 13.2℃, 61.2% and 1,470.6 mm, respectively. *Q. mongolica* forest (42.6 %) has the highest distribution, followed by the *P. densiflora* forest (24.8%), *P. densiflora* - *Q. variabilis* forest (16.5%), deciduous broad-leaved forest (7.2%) and *P. densiflora* - *Q. mongolica* forest (5.0%). Pyeongchang-gun, on the west side of the ridge, has an annual average temperature, humidity and precipitation of 6.8℃, 73.4% and 1,828.0 mm, respectively and its major vegetation types include the *Q. mongolica* forest (56.2%), deciduous broad-leaved forest (8.1%), *P. densiflora* forests (8.1%), grassland (6.4%), *A. holophylla* - *Q. mongolica* forest, *A. nephrolepis* forest and *T. cuspidata* forest. Hongcheon-gun has an annual average temperature, humidity and precipitation of 10.4℃, 68.7% and 1,426.7 mm, respectively and its major vegetation type includes *Q. mongolica* forest (80.2%), *P. densiflora* forest (3.4%), *A. holophylla* - *Q. mongolica* (1.7%), deciduous broad-leaved forest - *A. holophylla* (1.6%), *A. nephrolepis* forest and *T. cuspidata* forest.

The east side of Baekdudaegan, with high annual average temperature and low precipitation, has a relatively high distribution of *P. densiflora* forests and *P. densiflora* - *Q. variabilis* forests and is included in the southern temperate zone with a warmth index of 115.4 (℃. month). Pyeongchang -gun, on the west side of Baekdudaegan with low temperature and high humidity and precipitation is included in the northern temperate zone with a warmth index of 67.3 (℃. month). Hongcheon-gun is included in the southern temperate zone with a warmth index of 103.3 (℃. month). The major vegetation includes *Q. mongolica* forests, deciduous broad-leaved forests and deciduous broad-leaved - *A. holophylla* forests.

The results of overlay analysis of the topography (elevation, slope, direction, micro-landform) and climate (temperature, humidity, precipitation) in the

Table 2. Vegetation analysis according to atmosphere of Odaesan national park

Division	East side of Baekdudaegan	West side of Baekdudaegan	
	Gangneung-si	Pyeongchang-gun	Hongcheon-gun
Average temperature(℃)	13.2	6.8	10.4
Average humidity(%)	61.2	73.4	68.7
Average precipitation(mm)	1470.6	1828.0	1426.7
Major vegetation type	*Quercus mongolica* forest (42.6%), *Pinus densiflora* (24.8%), *Pinus densiflora -Quercus variabilis* forest (16.5%), Deciduous broad -leaved tree forest(7.2%), *Pinus densiflora-Quercus mongolica* forest(5.0%)	*Quercus mongolica* forest(56.2%), Deciduous broad-leaved tree forest (8.1%), *Pinus densiflora* forest (8.1%), Grassland(6.4%), *Abies holophylla-Quercus mongolica* forest (0.9%), *Abies holophylla*-Deciduous broad-leaved tree forest(0.4%), *Abies nephrolepis* forest(0.0%), *Taxus cuspidata* forest(0.0%) and etc.	*Quercus mongolica* forest (80.2%), Deciduous broad -leaved tree forest(8.8%), *Pinus densiflora* forest(3.4%), *Abies holophylla-Quercus mongolica* forest(1.7%), Deciduous broad-leaved tree-*Abies holophylla* forest (1.6%), *Abies nephrolepis* forest(0.0%), *Taxus cuspidata* forest(0.0%)

east and west areas of Baekdudaegan in Odaesan National Park indicate that the environment like the topographic elements including the elevation and micro-landform as well as climate elements like the annual average temperature, humidity and precipitation affect the vegetation distribution on both sides of the ridge. The difference in vegetation distribution according to the aspect and slope is not clear.

This study is a case study of investigating the vegetation distribution depending on the climate and topography on both sides of Baekdudaegan and although this study has limitation to only show the tendency of relationship between environment and vegetation due to the GIS overlay analysis based on the vegetation polygon, it would be utilized as fundamental data for future vegetation management studies.

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