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Community Structure and Growth Rate of Korean *Quercus mongolica* Forests by Vegetation Climate Zone

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Abstract: *Q. mongolica* forests are representative forest types in Korea, belonging to the intermediate succession stage with the highest species diversity. Identifying the community structure and growth rate of *Q. mongolica* forests by the vegetation climate zone can help in planning efficient forest restoration strategies for each vegetation climate zone. The proportions of major communities based on the vegetation climate zones newly adjusted by the Korea National Arboretum in 2020 were determined. Major dominant species were identified in *Quercus mongolica* forests in which *Q. mongolica* dominates by more than 50% by analyzing the importance based on the basal area of the trees using data from the 7th National Forest Inventory Survey. The basal area growth rate was analyzed for permanent sample plots from the 5th to 7th National Forest Inventory Surveys. The analysis revealed statistically significant differences in the basal area growth rate by vegetation climate zone over a 10-year period. However, it should be noted that *Q. mongolica* forests with younger age classes were more abundant in the warm southern temperate zone; thus, it is likely that age class has a greater effect on the rate of basal area increase than the vegetation climate zone.

Keywords: forest growth rate; vegetation climate zone; temperate climate; community structure; *Quercus mongolica* forest

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1. Introduction

Temperatures are expected to rise by 0.2 °C over the next 20 years and by 1.5–3.5 °C by the end of the century owing to climate change [1]. As the severity of these environmental issues increases, various programs to restore damaged forests are being advocated. For successful restoration, selecting the tree species suitable for the environmental conditions of each site is a key criterion during the planning stage. Numerous studies have been conducted in a variety of fields to investigate the relationship between plant growth and environmental conditions [2–11]. The distribution of plant communities and plant species is correlated with the climate environment [12–14]. Temperature is the primary determinant of plant distribution limits [15]. The Korean peninsula, located at the eastern end of the Asian continent, is a temperate region with distinct four seasons that follow the East Asian monsoon system. It faces the Pacific Ocean and is surrounded by sea in the east, west, and south. The winter season, spanning from December to February, is cold and dry due to the strong Siberian high-pressure system formed on the Tibetan plateau, while the summer season, spanning from June to August, is hot and humid and accounts for 70% of the annual rainfall. Although the Yellow Sea is located at the eastern end of the Eurasian continent, it supplies the Korean Peninsula with moisture from the west, affecting plant diversity and distribution in the region [16]. Moreover, the Korean Peninsula is composed of numerous mountains that are centered around the core Baekdudaegan mountain range that stretch from north to south; however, plains account for only 22.5% of the peninsula's area [16]. In addition, although the peninsula's altitude is not particularly high, its complex geographical features contribute to the diversity of its relative terrain; furthermore, unlike other areas in East Asia, the boundary between mountains and sedimentary plains is relatively unclear due to the presence of gentle slopes, which is a favorable condition for the spatiotemporal movement of plants [16]. The vegetation climate zones are classified based on the warmth and coldness indices, as well as the types of major trees distributed in each zone. The Korea National Arboretum [16] recently reclassified Korea's vegetation climate zones based on temperature data collected over a 30-year period (1980–2010) and the criteria are demonstrated in Figure 1. Before the establishment of the new vegetation climate zones, the drawings of Yim and Kira (1975) [17], which identified five vegetation climates based on Kira's standards in 1948 and 1949 [18,19], were used. The pre-revised five zones according to the warming index were subarctic vegetation climate, northern temperate vegetation climate, central temperate vegetation climate, southern temperate vegetation climate, and subtropical vegetation climate with a cold index of 10 or higher.

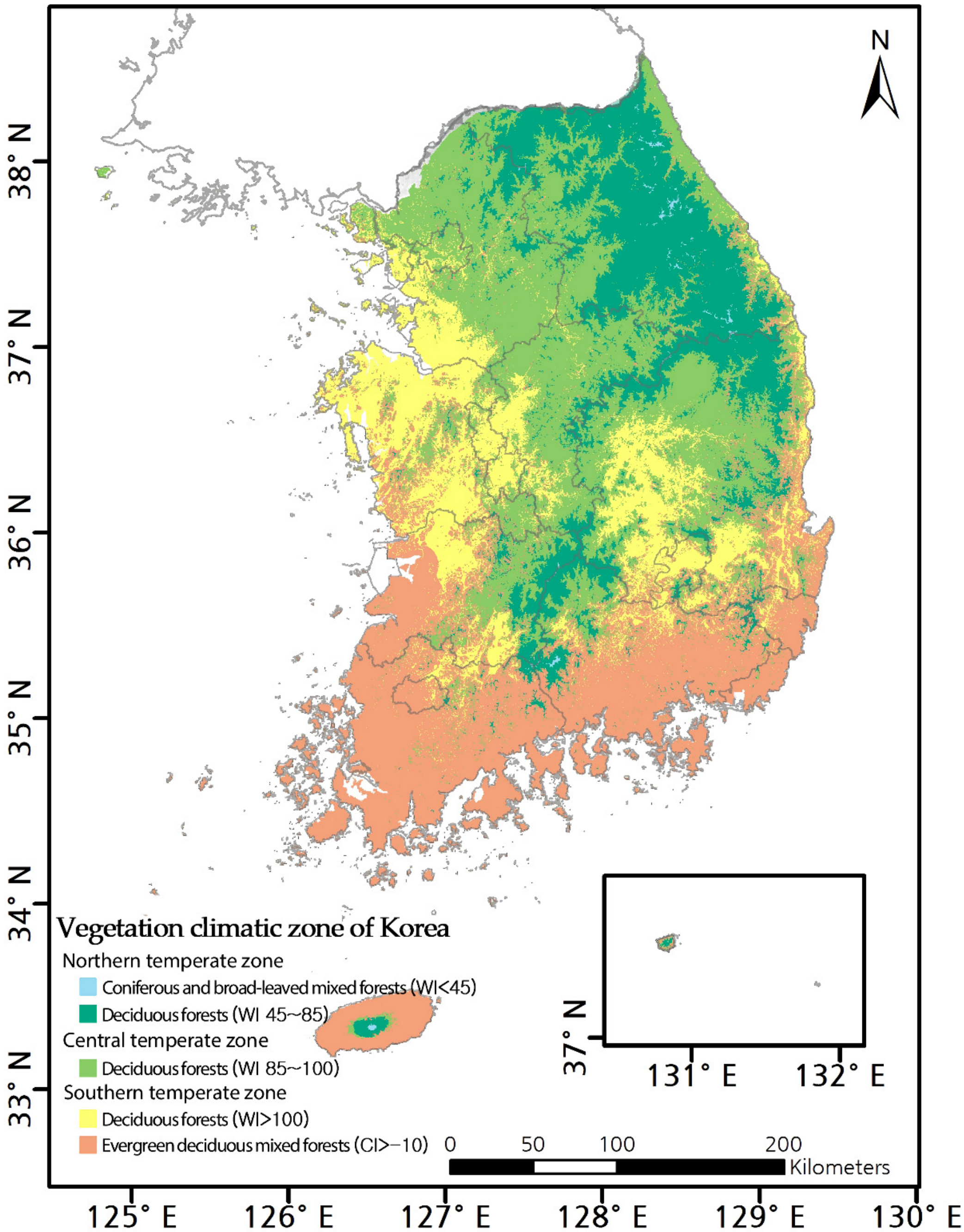

Figure 1. The newly established vegetation climate zones [16].

Further, according to Kira's research in 1991, there was a need to improve the classification of the vegetation climate zones that were established in 1975 [16]. However, the changes were not applied because the relationships between the vegetation distribution, climate, and environmental variables were not deemed significant (in the past); however, with increased awareness of the importance of these relationships, new vegetation climate zones have been re-established. The newly established vegetation climate zones (Figure 1) include five zones: northern temperate mixed coniferous and deciduous forest, northern temperate deciduous broad-leaved forest, central temperate deciduous broadleaved forest, southern temperate deciduous broad-leaved forest, and southern temperate evergreen and deciduous broad-leaved mixed forest. Significant differences have been observed between the current and conventional vegetation climate zones. For instance, the warming index for the subarctic vegetation climate zone has changed from 55 or less to 45 or less, and the distribution area of evergreen deciduous broad-leaved forests in the southern temperate zone has increased significantly due to the improvement in geographic information processing. Moreover, although the subarctic vegetation climate zone has a very narrow distribution in high-altitude growing environments, the Korea National Arboretum did not classify this plant community separately. Instead, areas with a warming index of 45 or less were classified as "mixed coniferous and deciduous forest area in the northern temperate zone".

Despite the major role played by vegetation climate zones, no study has analyzed the community structure of *Q. mongolica* forests by vegetation climate zones, although numerous studies have analyzed the stand structure and growth of *Q. mongolica* forests in Korea [20–29] or developed community planting models [30–32]. Planting with a similar species composition to that of natural forests is a typical example of restoring damaged forest ecosystems [33]. This study utilized National Forest Inventory data as a reference ecosystem, and this study aims to determine the community structure and growth rate of each vegetation climate zone in *Q. mongolica* forests in Korea using the newly adjusted vegetation climate zones. The design principle of community planting is to set the middle stage of the succession series with the highest species diversity as the restoration goal and select and place dominant species in the target succession stage based on the distribution structure of individuals [34,35]. The general succession process of Korean temperate forests is known to be *Pinus densiflora* forest, *Quercus acutissima* forest, *Q. mongolica* forest, *Quercus serrata* forest, and *Carpinus laxiflora* forest [36]. The *Q. mongolica* forest is a representative forest type of the deciduous forest zone in the Korean Peninsula and belongs to the intermediate stage of succession in which the biodiversity is the highest. Understanding the community structure and growth rate of *Q. mongolica* forests may help in effective forest restoration planning and the identification of the degree of restoration and the succession process of restoration projects. Additionally, the community structure and growth rate can be referenced for countries with similar vegetation climate zones, such as China and Japan, based on the warmth index and cold index. Moreover, many countries perform their own monitoring and forest resource surveys, so researchers can refer to the methods used in this study to understand the community structure or growth rate of the plant community of interest.

2. Materials and Methods

This study was conducted on 14,814 sample plots of the 7th National Forest Inventory (NFI) (2016–2020) and 940 sample plots from the 5th to 6th NFIs (2006–2015) (Table 1). The NFI survey started with a forest resource survey in 1964 and was expanded to nationwide surveys from the 5th NFI in 2006. Forests were investigated by applying a phylogenetic extraction method that divided the entire country at regular intervals of 4 km $\times$ 4 km. Each survey plot was circular, with a radius of 11.3 m from the center point and an area of 400 m^2 per plot. The diameter at breast height (DBH) and tree species of the woody plants with a diameter at a breast height of 6 cm or more that appeared in each survey plot were measured, and the height was measured by selecting more than ten standard trees by diameter class. This method is suitable for identifying the forests of the Korean

Peninsula with objective and scientific data at the national level by monitoring through periodic surveys of permanent sample plots. The community distribution by vegetation climate zone was analyzed using ArcMap Desktop 10.8 and Excel (Microsoft 365) using the vegetation climate distribution map [16] and the 4th Nationwide Survey on Natural Environments (National Institute of Ecology, 2014–2018). The 7th NFI (Korea Forest Service, 2016–2020), vegetation climate distribution map [16], and *eup-myeon-dong* administrative districts were used to identify community structure by the vegetation climate zone of *Q. mongolica*, a representative native tree species in Korea [37]. In the case of the 7th NFI, the vegetation climate zone was classified using ArcMap with the highest overlap ratio between the *eup-myeon-dong* administrative districts and the vegetation climate distribution map. Because the administrative district's vegetation climate zone was determined by the area ratio, the northern temperate zone coniferous and broad-leaved mixed forest had a small matching area and was therefore integrated with other vegetation climate zones. Finally, the northern temperate zone, the central temperate zone, and the southern temperate zone were classified and analyzed. For the 7th NFI data classified by the vegetation climate zone, the species composition of the *Q. mongolica* forests by vegetation climate zone was analyzed by targeting stands in which *Q. mongolica* dominated by more than 50% based on the basal area of emerging trees by referring to the criteria of Kwon et al. [27]. According to the method suggested by Curtis and McIntosh [38], the relative density, relative frequency, and relative coverage were calculated for woody plants with a DBH of 6 cm or more. Furthermore, the relative importance was calculated using the following formula: (relative density + relative frequency + relative coverage)/3. Relative coverage was calculated using the basal area, which is generally proportional to the coverage [39,40]. The Shannon–Wiener index was used to assess the biodiversity of *Q. mongolica* forests, and an analysis of variance (ANOVA) was conducted to validate differences in the mean values. The Shannon–Wiener index, also known as the Shannon entropy index, is a measure of biodiversity that considers both the number of species present in a given ecosystem and the relative abundance of each species. The formula for the Shannon index is $H = -\Sigma(p_i * log(p_i))$, where p_i is the proportion of the total individuals in the community represented by the ith species and the summation is total of all the species present in the community. The resulting value of H ranges from 0 to infinity, and the higher the value of H, the greater the biodiversity of the community.

Table 1. Distribution of study plots by vegetation climate zones.

Criteria	Northern Temperate Zone	Central Temperate Zone	Southern Temperate Zone	Total
No. of NFI plots (7th)	3159	4834	6821	14,814
No. of plots included *Q. mongolica* (7th)	2324	2783	1672	6779
No. of plots dominated more than 50% by *Q. mongolica* (7th)	618	452	262	1332
Permanent sample plots of *Q. mongolica* forests monitored for 10 years	493	295	151	940

To identify the growth rate by vegetation climate zone of Korean *Q. mongolica* forests, the basal area growth rate was analyzed for permanent sample plots in the 5th–7th NFI (2006–2020). Only permanent sample plots re-examined every 5 years were included, except for sample plots that were damaged or rapidly changed due to location changes or forest management activities. Permanent sample plots of *Q. mongolica* forests monitored for 10 years were 493 in the northern temperate zone, 295 in the central temperate zone, and 151 in the southern temperate zone (Table 1). In addition, the basal area growth rate of *Q. mongolica* forests was analyzed by the age class using information from permanent sample plots. ANOVA was conducted to examine the difference in the growth rate over

10 years depending on the climate zones and age classes, and the Scheffe test was used as a post-hoc analysis. Statistical analyses were performed using Excel and SPSS.

3. Results and Discussion

3.1. Community Distribution by Vegetation Climate Zone

Table 2 shows the area of each vegetation climate zone based on the Korean vegetation climate distribution map [16] along with the community area ratio for each vegetation climate zone based on data from the Nationwide Survey on Natural Environments. Korea's area is 97,998 km^2 when computed using the tif file of the Korean vegetation climate distribution map supplied by the Korea National Arboretum. This differs from the Korean land area (100,431.8 km^2) in the Cadastral Statistical Yearbook of the Ministry of Land, Infrastructure, and Transport [37]. Northern temperate mixed coniferous and deciduous forests [warmth index (WI) < 45] found on high-latitude or high-altitude summits, including Mounts Seorak, Deogyu, Sobek, Jiri, and Halla, account for 0.21% of the total area of the Korean Peninsula. Moreover, northern temperate deciduous broad-leaved forests (WI 45–85) account for 19.31% of the total area and are found in medium-to-high latitude and altitude areas on the peninsula. Central temperate deciduous broadleaved forests (WI 85–100) account for 31.64% of the total area and are found in low-to-medium latitude and altitude areas. Southern temperate deciduous broad-leaved forests (WI > 100) account for 17.84% of the total area and are found in low-to-medium latitude areas and low-to-medium altitude mountains and hills. Southern temperate evergreen and deciduous broad-leaved mixed forests (coldness index [CI] > −10) account for 31.01% of the total area and are found in low-latitude areas and low-altitude mountains and hills. The relative distribution ratio (%) presented in Table 2 refers to the relative proportion of a community within a given criterion. Although there are many communities in each vegetation climate zone, only the top five in each region were included in the table; the sum of the ratios for each zone equals 100%. In terms of the vegetation climate, the southern temperate zone is the largest at 48.85% (47,760 km^2), and among 765 communities nationwide, the *P. densiflora* community (20.14%) covers the most land, followed by *Q. mongolica* (10.68%) and *P. densiflora*-*Q. variabilis* communities (6.89%). The *Q. mongolica* forests are found across the Korean Peninsula; however, they showed a higher probability of appearance in the northern temperate zone (19.56%) than in the central temperate zone (9.35%) and the southern temperate zone (3.84%).

Table 2. Distribution ratios of major tree species and communities by vegetation climate zone.

	Criteria	Thermal Climate	Area (km^2) (%)	Community Distribution	Relative Distribution Ratio (%)
Northern temperate zone	Coniferous and broad-leaved mixed forests	WI < 45	203 km^2 (0.21%)	*Quercus mongolica*	85.15%
				Quercus mongolica-Pinus densiflora	10.50%
				Larix kaempferi plantation forest	1.03%
				Quercus mongolica-Quercus variabilis	0.83%
				Quercus mongolica-Betula ermanii	0.51%
	Deciduous forests	45 < WI < 85	18,876 km^2 (19.31%)	*Quercus mongolica*	19.89%
				Pinus densiflora	15.35%
				Quercus mongolica-Pinus densiflora	7.90%
				Quercus mongolica-Quercus variabilis	6.50%
				Pinus densiflora-Quercus mongolica	6.05%

Table 2. *Cont.*

	Criteria	Thermal Climate	Area (km^2) (%)	Community Distribution	Relative Distribution Ratio (%)
Central temperate zone	Deciduous forests	85 < WI < 100	30,937 km^2 (31.64%)	*Pinus densiflora*	19.92%
				Quercus mongolica	8.48%
				Pinus densiflora-Quercus variabilis	7.16%
				Quercus variabilis	5.50%
				Quercus variabilis-Pinus densiflora	4.72%
Southern temperate zone	Deciduous forests	100 > WI	17,439 km^2 (17.84%)	*Pinus densiflora*	26.95%
				Pinus densiflora-Quercus variabilis	7.25%
				Pinus densiflora-Quercus acutissima	5.20%
				Quercus variabilis	5.07%
				Pinus rigida plantation forest	4.45%
	Evergreen-deciduous mixed forests	CI > −10	30,320 km^2 (31.01%)	*Pinus densiflora*	21.62%
				Pinus densiflora-Quercus variabilis	7.56%
				Q. mongolica	6.70%
				Quercus variabilis	5.78%
				Pinus thunbergia	5.41%

WI—Warmth index; CI—Coldness index.

3.2. Community Structure of *Q. mongolica* Forests by Vegetation Climate Zone

A total of 90 species appeared in the *Q. mongolica* forests of the northern temperate zone. After *Q. mongolica*, *P. densiflora*, *Acer pseudosieboldianum*, *Fraxinus rhynchophylla*, *Tila amurensis*, *Betula schmidtii*, *Q. variabilis*, and *Acer pictum* subsp. *mono*, we found high importance values of *Q. serrata*, *Styrax obassia*, and *Maackia amurensis* in this order. In the *Q. mongolica* forests of the central temperate zone, 83 species appeared, and the descending order of the importance value was *P. densiflora*, *Q. variabilis*, *Prunus serrulata* var. *pubescens* (Makino) Nakai, *Q. serrata*, *Fraxinus rhynchophylla*, *S. obassia*, *B. schmidtii*, *A. pseudosieboldianum*, and *Castanea crenata*. In the *Q. mongolica* forests of the southern temperate zone, 84 tree species appeared, and high importance values were observed for *P. densiflora*, *Q. variabilis*, *Q. serrata*, *A. pseudosieboldianum*, *P. serrulata* var. *pubescens* (Makino) Nakai, *Fraxinus sieboldiana*, *Sorbus alnifolia*, and *Styrax japonicus.* The data regarding only the top seven species are shown in Tables 3–5.

Table 3. Dominant species in *Q. mongolica* forests in the northern temperate zone.

Tree Species	No. of Trees	Appearance Rate (%)	Basal Area (m^2/ha)	Relative Coverage RC (%)	Relative Density RD (%)	Relative Frequency RF (%)	Importance Percentage IP (%)
Quercus mongolica	20,077	100.00%	29.08	71.39%	63.35%	16.86%	50.53%
Pinus densiflora	918	39.16%	3.18	7.81%	2.90%	6.60%	5.77%
A. pseudosieboldianum	2163	48.06%	0.54	1.33%	6.83%	8.10%	5.42%
Fraxinus rhynchophylla	1071	42.88%	0.78	1.92%	3.38%	7.23%	4.18%
Tila amurensis	982	30.74%	0.92	2.25%	3.10%	5.18%	3.51%
Betula schmidtii	686	26.54%	0.96	2.36%	2.16%	4.47%	3.00%
Quercus variabilis	546	19.26%	0.99	2.44%	1.72%	3.25%	2.47%
Total	31,701	-	40.74	100%	100%	100%	100%

Table 4. Dominant species in *Q. mongolica* forests in the central temperate zone.

Tree Species	No. of Trees	Appearance Rate (%)	Basal Area (m^2/ha)	Relative Coverage RC (%)	Relative Density RD (%)	Relative Frequency RF (%)	Importance Percentage IP (%)
Quercus mongolica	15,824	100.00%	20.77	68.42%	67.27%	17.83%	51.17%
Pinus densiflora	1270	51.77%	2.81	9.27%	5.40%	9.23%	7.97%
Quercus variabilis	934	42.70%	1.77	5.83%	3.97%	7.61%	5.81%
Prunus serrulata var. *pubescens* (Makino) Nakai	676	49.56%	0.66	2.19%	2.87%	8.84%	4.63%
Quercus serrata	474	31.64%	0.70	2.31%	2.02%	5.64%	3.32%
Fraxinus rhynchophylla	404	23.67%	0.36	1.18%	1.72%	4.22%	2.37%
Styrax obassia	514	22.57%	0.17	0.55%	2.19%	4.02%	2.25%
Total	23,531	-	30.36	100%	100%	100%	100%

Table 5. Dominant species in *Q. mongolica* forests in the southern temperate zone.

Tree Species	No. of Trees	Appearance Rate (%)	Basal Area (m^2/ha)	Relative Coverage RC (%)	Relative Density RD (%)	Relative Frequency RF (%)	Importance Percentage IP (%)
Quercus mongolica	9504	100.00%	20.88	69.71%	64.43%	16.01%	50.05%
Pinus densiflora	577	48.85%	2.27	7.57%	3.91%	7.82%	6.43%
Quercus variabilis	468	37.79%	1.41	4.71%	3.17%	6.05%	4.64%
Quercus serrata	409	43.13%	1.00	3.33%	2.77%	6.91%	4.34%
A. pseudosieboldianum	541	31.30%	0.40	1.33%	3.67%	5.01%	3.34%
Prunus serrulata var. *pubescens* (Makino) Nakai	207	30.53%	0.32	1.06%	1.40%	4.89%	2.45%
Fraxinus sieboldian	273	22.52%	0.13	0.43%	1.85%	3.61%	1.96%
Total	14,751	-	29.94	100%	100%	100%	100%

Q. mongolica is a major dominating species of the medium-large diameter class in *Q. mongolica* forests, having a high relative density and coverage. In particular, *Q. mongolica* in the northern temperate zone has a smaller relative density than that in the other vegetation climate zones, but it has the largest relative coverage, suggesting that the single tree diameter and crown growth are the largest (Tables 3–5). *Q. mongolica* has a DBH of 12–18 cm in all the vegetation climate zones (Figure 2). *A. pseudosieboldianum* trees were small with a DBH of 6–12 cm. Moreover, its appearance rate was high in the northern and southern temperate zones, whereas its importance was low in the middle temperate zone. In each of the vegetation climate zones, *P. densiflora* had a high relative coverage compared to its relative density. It was distributed as a large-diameter species in *Q. mongolica* forests and had a high importance in the central temperate zone. With a medium diameter, *Q. variabilis* also showed high importance in the central and southern temperate zones.

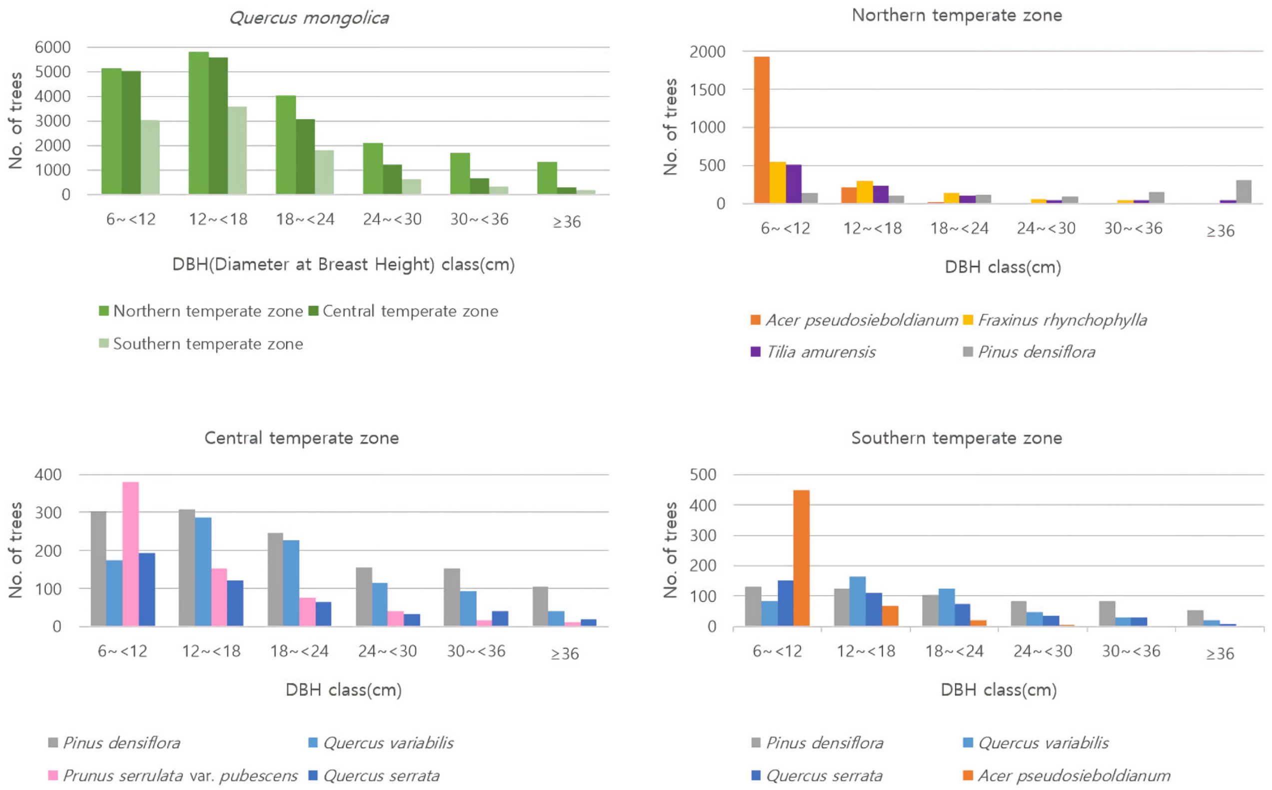

Figure 2. Diameter classes of major tree species in the *Q. mongolica* forests by vegetation climate zone.

Species diversity by vegetation climate zones was measured by the Shannon–Wiener index. In general, a higher value of the Shannon index, indicating a greater diversity of species in an ecosystem, is considered to be a positive indicator of ecosystem health and resilience. The Southern temperate zone had the highest species diversity index on average, but the difference in average was not statistically significant ($p > 0.05$, Table 6). In addition, compared to the biodiversity index of the *P. densiflora* forest (1.030), which are widely distributed in South Korea, the biodiversity index of the *Q. mongolica* forest (1.049) was higher, but it was not statistically significant.

Table 6. Species Diversity Index (Shannon–Wiener) in the *Q. mongolica* forests by vegetation climate zone.

Classification	N	Mean	SD	F(*p*)
Northern temperate zone	618	1.069	0.474	2.856 (0.057)
Central temperate zone	452	1.008	0.423	
Southern temperate zone	262	1.074	0.469	
Total	1332	1.049	0.457	

SD—Standard deviation.

3.3. Growth Rate of Q. mongolica Forests by Vegetation Climate Zone

Q. mongolica was widely distributed in regions with relatively low temperatures; however, its growth rate was higher in regions with relatively warm temperatures. *Q. mongolica* forests exhibited a basal area growth rate of 32.25% for 10 years, and the growth rate tended to increase toward the southern temperate zone, with 28.68% in the northern temperate zone, 35.86% in the central temperate zone, and 36.86% in the southern temperate zone. Table 7 shows the analysis of data for the difference in the 10-year basal area growth rate according to the climate zones. The analysis revealed that the difference in the growth rate was statistically significant across the three different temperate zones ($F = 4.239$, $p < 0.05$). The result implies that the overall basal area growth rate of *Q. mongolica* forests varies across the climate zones. We further conducted a post-hoc analysis to examine the specific differences between each temperate zone. The basal area growth rate of the central temperate zone was significantly higher than that of the northern temperate zone, but it was not different from that of the southern temperate zone. The difference in the growth rates between the northern and southern temperate zones was not statistically significant.

Table 7. Basal area growth rate of *Q. mongolica* forests for 10 years by vegetation climate zones (ANOVA results).

Classification	N	Mean	SD	F(*p*)	Scheffe
Northern temperate zone	491	28.681%	40.548	4.239 (0.015)	Central temperate zone > Northern temperate zone
Central temperate zone	294	35.862%	40.127		
Southern temperate zone	150	36.856%	34.945		
Total	935	32.250%	39.708		

The data analysis for the difference in the basal area growth rate of *Q. mongolica* forest according to the age classes is shown in Table 8. The age class 1 was excluded from the statistical analysis because the number of sample plots was too small. The overall difference in the growth rate according to age classes was statistically significant ($F = 57.343$, $p < 0.001$). This indicates that there is a significant difference in the overall growth rate depending on the age classes of the *Q. mongolica* forest. To compare the differences between individual age classes, we conducted a post-hoc analysis using the Scheffe test. The growth rate of age class 2 was significantly higher than that of age classes 3, 4, 5, and 6. The growth rate of age class 3 was higher than that of age classes 4, 5, and 6. The growth rate of age class 4 was higher than that of age class 6, but there was no significant difference from age class 5. The difference in the growth rate between age class 5 and age class 6 was not statistically significant.

Table 8. Basal area growth rate of *Q. mongolica* forests for 10 years by Age classes (ANOVA results).

Classification	N	Mean	SD	F(*p*)	Scheffe
Age class 2 (11–20 years)	6	201.464%	142.229		Age class 2 >
Age class 3 (21–30 years)	186	51.864%	52.969		Age class 3, 4, 5, 6
Age class 4 (31–40 years)	404	30.128%	31.075	57.343	Age class 3 >
Age class 5 (41–50 years)	186	23.917%	22.832	(0.000)	Age class 4, 5, 6
Age class 6 (51–60 years)	153	17.507%	22.283		Age class 4 >
Total	935	32.250%	39.708		Age class 6

Way and Oren [7] proposed that an increase in temperature generally increases tree growth, except for tropical trees, and this is because trees in temperate forests currently function below the optimum temperature and tropical trees operate at the optimum temperature. This is consistent with the higher growth rate in the relatively warm temperate southern region. However, when considering the distribution of *Q. mongolica* forest sample plots by the vegetation climate zone, forests with a high age class were found to be mainly distributed in the northern temperate zone. When considering the effects of age class and vegetation climate zone together, the effect of the vegetation climate zone was not significant. This suggests that differences due to the vegetation climate zones are not large and that the results can be attributed to age class differences. Therefore, when predicting *Q. mongolica* forest growth, age class should be prioritized over the vegetation climate zone. The basal area per ha of *Q. mongolica* forests in the northern temperate zone is 40.74 m^2/ha, and the density is 12.82%. Compared with the basal area and density in central temperate zones (30.36 m^2/ha, 13.01%, respectively) and southern temperate zones (29.94 m^2/ha, 14.08%, respectively), trees in *Q. mongolica* forests in relatively cold northern regions were thicker. In general, a forest with a basal area between 10 and 30 m^2 per ha can be considered a vigorous and healthy forest [41]. Based on these findings, *Q. mongolica* forests in the northern temperate zone have a higher basal area than the standard, and *Q. mongolica* forests in the central and southern temperate zones can be considered healthy on average.

4. Conclusions

A common approach to restoring damaged forest ecosystems is to plant trees that have a similar species composition to those found in natural forests. Community planting is a design principle that aims to create a middle stage in the process of ecological succession with the aim of attaining maximum species diversity. To achieve this goal, the dominant species that are typically found in the target stage of succession are carefully selected and placed according to their individual distribution structures. This study examined the distribution of major tree communities by the vegetation climate zone and the dominant species in the *Q. mongolica* forests, which occupy the second largest area after *Pinus densiflora* forests in Korea; the species composition in this reference system should be used during forest restoration planting. Using NFI *eup-myeon-dong* codes, the whole country was classified into three vegetation climate zones: northern temperate zone, the central temperate zone, and the southern temperate zone, and then the community structure was analyzed. Although *Q. mongolica* forests are distributed throughout the Korean Peninsula, they are more widely distributed in the colder northern part, in descending order of northern, central, and then southern temperate zones. However, over the last 10 years, the basal area growth rate tended to be higher in the regions closer to the relatively warm southern zone, as seen in the descending order of the southern temperate zone, central temperate zone, and northern temperate zone. Moreover, there is a significant difference in the overall growth rate depending on the age class of the *Q. mongolica* forests. Age class 2 (11–20 years) exhibited a high basal area growth rate, but it decreased significantly as the age class increased. Even though this trend is consistent with the general principle that growth rate is highest in warm climates and among young trees, it is significant because it provides quantitative data on the growth rate of *Q. mongolica* forests in Korea. The historical growth of trees may help predict their future development. *Q. mongolica* forests are typical forest types in Korea with a high species richness. By studying the community structure and growth rate of these forests across different vegetation climate zones, researchers can gather important data with the aim of successful restoration and growth prediction. Future studies employing simulation and visualization techniques are required to further clarify the effects of restoration. Moreover, as the NFI in Korea focuses on studying trees with a DBH of $\geq$6 cm, there is a lack of information on the initial growth rates of younger trees, particularly those in age class 1 forests. To address this knowledge gap, it is essential to conduct follow-up studies investigating the initial growth rates of *Q. mongolica* forests.

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