Aboveground biomass and carbon storage in *Betula platyphylla* stands in Gangwon Province, South Korea

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Abstract: This study was conducted to determine the stem density and biomass expansion factor and to develop allometric equations and assess carbon storage of *Betula platyphylla* stands in Gangwon province, South Korea. The study sites were located in Hoengseong and Hongcheon, South Korea. Twenty sample trees were harvested for data collection and analysis (10/site). The results showed that stem density (g/cm^3) was 0.497 at Hoengseong and 0.537 at Hongcheon. The aboveground biomass expansion factors were 1.262 and 1.209 for Hoengseong and Hongcheon, respectively. The aboveground biomass (ton/ha) at Hoengseong was 85.35, whereas it was 124.39 at Hongcheon. Furthermore, the aboveground carbon stocks (ton C/ha) for Hoengseong and Hongcheon were 32.34 and 62.19, respectively. Stem wood had the highest biomass percentage followed by branches, stem bark, and leaves, respectively. Our results could be very useful to improve biomass and carbon storage estimates for *Betula platyphylla*.

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1. Introduction

The concentration of carbon dioxide in the atmosphere is increasing due to global warming, natural disasters such as abnormal high temperature phenomenon, severe drought, and typhoon damage. Therefore, the importance of various activities to reduce carbon dioxide emissions are being realized in connection with global warming (IPCC 2003). Accordingly, concerns about forests with the ability to absorb and store carbon dioxide are increasing, and forest biomass and carbon storage are attracting attention (Laitat et al. 2000; Son et al. 2007; Watson et al. 2000). Forests have a larger carbon storage function per unit area than any other ecosystem on Earth (Houghton 2007; Li et al. 2011), and an effective means to reduce the high concentration of carbon dioxide in the atmosphere is by increasing forest area (Peichl and Arain 2006; Taylor et al. 2007). In addition, as 64% of Korea's national land area is forest, Korea has a large carbon depository with a large potential in proportion to national land area (Gang et al. 2010). Thus, forest tree biomass data are very useful to grasp the structure and state of a forest.

Betula platyphylla grow on high mountains north of Gangwon province in fertile, sunny, wet lands at locations of forest fires or stripped land. *B. platyphylla* grow quickly and have a peculiar bark and tree type that can be used for various purposes (Lee et al. 1998). The afforestation area of *B. platyphylla* has increased 10 times (to 6.4%, 12,026 ha) compared to that in 2009, which is similar to oaks species (Korea Forest Service 2011). *B. platyphylla* increases in afforestation area due to its rapid growth, so the importance of a property analysis of it biomass and carbon storage is increasing accordingly.

Studies on *B. platyphylla* forests include a study on the matter production of *B. platyphylla* and wild-walnut tree plantations in Chungju area (Park 2000), a study on carbon fixation over the aboveground part of *B. platyphylla* and wild-walnut tree plantations in Chungju area (Lee and Park 2007), a study on the stand control plan of *B. platyphylla* (Lee et al. 2012), a study on growth changes in *Pinus densiflora*, *Larix kaempferi*, *B. platyphylla*, *Quercus acutissima* (Byun et al. 2007) and seedlings, and a study on the plantation density control effect of birches depending on topdressing level (Lee et al. 1988), but biomass and carbon storage studies in *B. platyphylla* are insufficient.

Therefore, this study was conducted to calculate the biomass and carbon storage by analyzing stem density and biomass expansion factor and to develop allometric equations to estimate *B. platyphylla* tree biomass in Gangwon province.

2. Material and Methods

Study site

The study areas were located in *B. platyphylla* forests with a mean age of 23 and 30 years, and were distributed in the national forest at Yuldong-ri, Gapcheon-myeon, Hoengseong-gun and Changchon-ri, Nae-myeon, Hongcheon-gun, Gangwon-do, Korea. As a result of a fossil-wood investigations, the average stand density/ha was 1,200 and 763, indicating that thinning work was being conducted at Hongcheon rather than at Hoengseong.

The diameters at breast height (DBH) ranged from 6–22 cm at Hoengseong, with most distributed between 10 and 12 cm, and 6–28 cm at Hongcheon, mainly distributed over 12, 14, and 18 cm (Fig. 1). The average DBH values were 13.7 cm and 18.6 cm, and the average tree heights were 15.1 m and 16.6 m at Hoengseong and Hongcheon, respectively. The average DBH and the average tree heights showed that growth was superior at Hongcheon where thinning was vigorously conducted. The elevations were 373 m and 893 m above sea level and the slopes were 25° and 14° at Hoengseong and Hongcheon, respectively (Table 1).

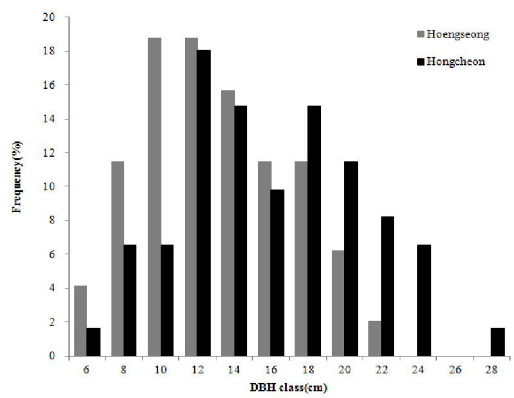

Figure 1. Diameter at breast heigh class distribution of *Betula platyphylla* in Hoengseong and Hongcheon, South Korea.

Table 1. Stand characteristics of the study sites in Hoengseong and Hongcheon, South Korea.

Site	Hoengseong	Hongcheon
Location	37°34'59.9" N, 128°06'07.5" E	37°42'15.0" N, 128°26'01.9" E
Aspect	NE	SW
Slope (°)	20-30	7-20
Altitude (m)	372-374	872-914
Density (tree/ha)	1200	763
Mean AGE (years)	22.8	30.2
Mean DBH (cm)	13.7	18.6
Mean Height (m)	15.1	16.6

Sample trees and measurements

Four plots (20 m × 20 m) were established and five trees were harvested from each plot. The sample trees were chosen based on the diameter distributions of the stands. A disc of 5 cm thickness was collected from every 2 m section of trunk, and the first and last discs were collected from the first and last meter of the log. After collecting the discs, the remaining trunks were weighed using a weighing scale to determine fresh weight. The crown layer was partitioned into branches and leaves, and fresh weights of the different biomass components were measured. After measuring fresh weight, samples (<350 g) were collected and dried to a constant weight at 100°C (Korea Forest Research Institute 2007).

Analytical methods

Stem density was calculated by dividing dry weight of the stem (biomass) by its total volume (g cm^3) (IPCC 2006). The biomass expansion factor (BEF) was determined by dividing the biomass of the upper part of a tree (such as branches and leaves) by the stem biomass (stem wood and bark) (Hosoda and Iehara 2010; KFRI 2010). The relationship between DBH and aboveground biomass was analyzed. The model formulas used to develop the biomass equations were:

Model 1 : $\log Y = A + B \log X + \varepsilon$
where: Y = biomass(kg)
X = DBH (cm)
A, B = estimated parameters
log = natural logarithm

Biomass was estimated depending on the region by deriving a biomass estimate regression equation by parts and then applying a diameter measurement at breast height in a stand unit. Its suitability was tested using R^2 statistics, and the Sprugel correction factor was used to correct the algebraic regression equation (Sprugel 1983). Carbon storage was calculated by multiplying by 0.5, a carbon factor provided by the IPCC (2004), and all data analysis used SAS (2004).

3. Results and Discussion

Stem density and BEFs

Mean stem density (g/cm^3) was 0.497 at Hoengseong, which appeared similar after sampling trees. The mean stem density was 0.537 at Hongcheon, which was slighlty high as the DBH's were 19.0 and 28.1 cm (Table 2).

As shown in previous studies, the stem density of Betulaceae is 0.51 (Korea Forest Research Institute 2010), which was similar to our result.

The BEFs were 1.262 at Hoengseong and 1.209 at Hongcheon. The two stands showed no big average difference, but these values were lower compared to the suggested IPCC value of 1.4 (IPCC, 2004). However, it was included in 1.15–3.2, which is the range for temperate zone broadleaf forests (IPCC 2004).

Previous studies suggested that stem density and BEFs can differ depending on region, environmental factors, and geographical conditions (Park et al. 2005; Seo et al. 2010). Therefore, as there are almost no previous *B. platyphylla* studies, it was thought that various study data shall be established depending on region, environmental factors, and geographic conditions.

Table 2. Stem density and biomass expansion factors of *Betula platyphylla.* in Hoengseong and Hongcheon, South Korea.

DBH(cm)	Stand density (g/cm^3)	Biomass expansion factor
Hoengseong		
7.0	0.487	1.167
10.0	0.549	1.150
10.6	0.481	1.151
12.0	0.448	1.213
13.0	0.476	1.255
14.0	0.457	1.207
15.0	0.480	1.186
17.0	0.541	1.452
18.0	0.533	1.382
20.0	0.519	1.461
Mean	0.497	1.262
Hongcheon		
DBH(cm)	Stand density (g/cm^3)	Biomass expansion factor
7.9	0.572	1.087
10.8	0.488	1.205
13.6	0.521	1.175
16.0	0.472	1.181
19.0	0.630	1.200
21.4	0.553	1.173
22.0	0.484	1.337
23.1	0.495	1.283
24.1	0.536	1.225
28.1	0.615	1.221
Mean	0.537	1.209

Allometric equations

The results of estimating biomass by parts using DBH as an independent variable and using the data from 20 sample trees (10 from each site) are as follows (Table 3). The coefficients of determination (R^2) in the biomass estimation equation for Hoengseong were 0.909–0.984, and the coefficients of determination in the biomass estimation equation for Hongcheon were 0.910–0.991. The coefficients of determination by parts depending on region was > 90%, showing very high suitability. The parameters a and b, in the biomass estimation equation ranged from -7.118 to -2.094 and 1.976–3.500 respectively at Hoengseong and -6.512 to -2.219 and 1.803–3.130, respectively, at Hongcheon. All B parameters were positive, indicating that as DBH increased biomass also increased. In addition, as a result of schematizing the biomass using an estimated value versus an observed value, a very high suitability was seen at Hoengseong (Fig. 2) and Hongcheon (Fig. 3).

Table 3. Regressions of tree component biomass on the diameter at breast height of *Betula platyphylla* in Hoengseong and Hongcheon, South Korea.

Biomass component	N	Estimated coefficients		RMSE	R^2	CF
		a	b			
Hoengseong	Equation : logY=a+blog(X)					
Stem	10	-2.094	2.287	0.116	0.978	1.0008
Stem wood		-2.366	2.336	0.107	0.982	1.0007
Stem bark		-3.320	1.976	0.209	0.909	1.0027
Branch	10	-6.840	3.500	0.272	0.949	1.0046
Leave	10	-7.118	3.005	0.224	0.952	1.0031
Above ground	10	-2.483	2.527	0.107	0.984	1.0007
Hongcheon	Equation : logY=a+blog(X)					
Stem	10	-2.219	2.381	0.124	0.985	1.0001
Stem wood		-2.620	2.475	0.129	0.985	1.0001
Stem bark		-2.684	1.803	0.112	0.979	1.0001
Branch	10	-6.175	3.130	0.206	0.977	1.0009
Leave	10	-6.512	2.694	0.359	0.910	1.0084
Above ground	10	-2.303	2.476	0.102	0.991	1.0001

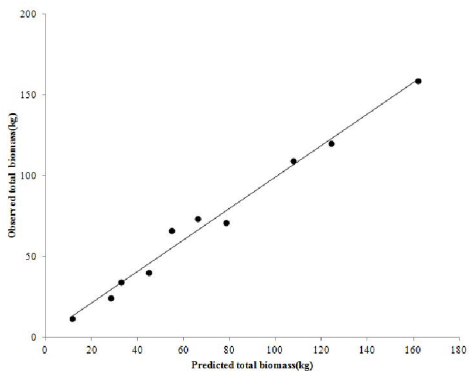

Figure 2. The observed and predicted aboveground biomass production of *Betula platyphylla in* Hoengseong, South Korea.

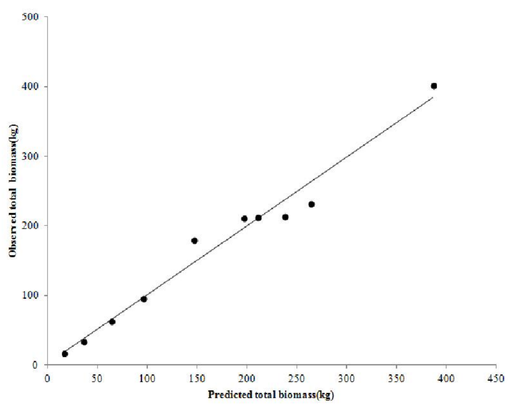

Figure 3. The observed and predicted aboveground biomass production of *Betula platyphylla* in Hongcheon, South Korea.

Biomass

The biomasses of the two regions were estimated using the developed allometric equation (Fig. 4). The average biomass (ton/ha) at Hoengseong was 85.35 (range, 14.26–194.17). In contrast, the average biomass (ton/ha) at Hongcheon was 124.39 (range, 13.74–290.74). Thus, the average biomass was higher at Hongcheon where growth of forest trees was vigorous, but the pattern by diameters showed a higher value at Hoengseong (1,200 tree/ha), where forest tree density was high. Therefore, biomass had a very close relationship with forest tree density.

As a result of a previous study, biomass was 79.33 ton/ha in a 22 year old birch forest (Park et al. 2000), which was comparable to the biomass estimates at Hoengseong. The biomass of *Alnus sibirica*, which included 12–18 year old Betulaceae in Gyeonggi province is 45.46 ton/ha (Chae and Kim 1977).

In comparison to the other *Betula* species, the total biomass of 22 year old *Betula alba* forest in the U.K. was 62.8 ton/ha (Ovington 1956), whereas the total biomass of a 22 year old *Betula ermanii* forest in Japan was 62.5 ton/ha (Satoo 1970). In contrast, the total biomass of a 20 year old *Betula verrucosa* forest in Russia was 80.3 ton/ha (Ovington 1962) and the total biomass of a 24 year old *Betula verrucosa* forest in the U.K. was 79.9 ton/ha (Ovington and Madgwick 1959), which were comparable to the results of our study. Thus, biomass differed depending on the DBH and height and showed various differences depending on stand density even though the ages of the forests were similar.

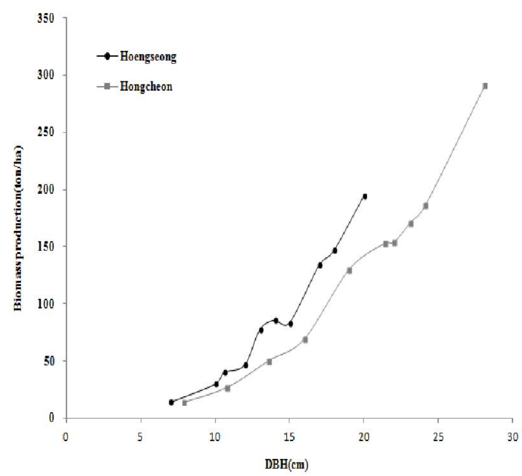

Figure 4. Comparison of the aboveground biomass production between Hoengseong and Hongcheon region in South Korea.

Biomass distribution type

As a result of analyzing the biomass component distribution of the birch forests, the Hoengseong results showed that stem wood had the highest biomass distribution with 69.1%, followed by branches at 16.7%, stem bark at 10.7%, and leaves at 3.4%. For Hongcheon, the stem wood had 72.6% of the total biomass followed by branches (14.2%), stem bark (10.4%), and leaves (2.9%). Both Hoengseong and Hongcheon showed the sequence of stem wood > branches > stem bark > leaves. Besides, as a result of comparing the composition ratio by region, Hongcheon with a high DBH showed a decreasing trend for the composition ratio of branches and leaves but an increase in stem wood(Fig. 5). This shows the same trend as a previous study that the ratio of leaves and branches decrease as DBH increases (Kim et al. 2011).

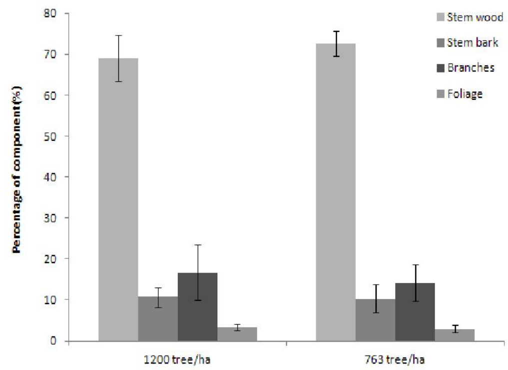

Figure 5. Biomass distribution patterns of *Betula platyphylla* in Hoengseong and Hongcheon, South Korea.

Carbon storage

Hoengseong had a total of 42.68 ton C/ha (stems, 32.35 ton C/ha; branches, 8.75 ton C/ha; and leaves, 1.58 ton C/ha), and Hongcheon had a total of 62.19 ton C/ha (stems, 50.62 ton C/ha; branches 9.79 ton C/ha, and leaves, 1.78 ton C/ha) (Table 4).

Table 4. Carbon storage in the different tree components of *Betula platyphylla* in Hoengseong and Hongcheon, South Korea.

Component	Stem	Stem wood	Stem bark	Branches	Leaves	Aboveground total
Hoengseong	32.35	28.25	4.10	8.75	1.58	42.68
Hongcheon	50.62	45.19	5.43	9.79	1.78	62.19

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