Aboveground biomass estimation of *Quercus glauca* in evergreen forest, Kotzawal wetland, Cheju Island, Korea

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제주도 곶자왈 상록활엽수 종가시나무의 생물량 추정을 위한 상대생장식

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Abstract

This study developed allometry equation and estimated the aboveground-biomass of *Quercus glauca,* a warm-temperature, evergreen broad-leaved tree, growing in Kotzawal wetland located on Jeju Island. The allometric equations between DBH(diameter at breast height) and dry weights of stems (*Ws*), branches (*Wb*), leaves (*Wl*) and aboveground biomass (*Wab*) of Q. *glauca* were as follows: log*Ws*=2.4042logDBH-1.3045, log*Wb*=2.6436logDBH-1.6232, log*Wl* =1.5428logDBH-1.3692 and log*Wab*=2.3324logDBH-0.9181. The allometric equations between D^2H and *Ws, Wb, Wl,* and *Wab* of *Q.glauca* were as follows : log*Ws*=0.853logD^2H-1.4252, log*Wb*=0.8453logD^2H-1.5834, log*Wl*=0.5328logD^2H-1.4073 and log*Wab*=0.8265logD^2H-1.0327. The R^2 between DBH and *Ws, Wb, Wl* and *Wab* were 0.9873, 0.9711, 0.7979 and 0.993, respectively. The R^2 between D^2H and *Ws,Wb,Wl* and *Wab* were 0.9841, 0.9174, 0.7537 and 0.9876, respectively. There was no significant difference between observed and calculated values of the allomatric equations from DBH and D^2H($p>0.05$, Kolmogorov–Smirnov test). Thus, to estimate the aboveground biomass of Q. glauca, use of DBH and D^2H as an independent variables in the allometric equation is recommended.

Key Words : Allometric equation, Biomass, Evergreen broad leaved tree, *Quercus glauca*

요 약

본 연구는 제주도 곶자왈습지에서 서식하는 상록활엽수인 종가시나무의 지상부 생물량에 대한 상대생장식을 개발하기 위하여 수행되었다. 그 결과 독립변수가 DBH일 때, 줄기(*Ws*), 가지(*Wb*), 잎(*Wl*) 그리고 지상부(*Wab*)의 상대생장식은 각각 log*Ws*=2.4042logDBH-1.3045, log*Wb*=2.6436logDBH-1.6232, log*Wl*=1.5428logDBH-1.3692 그리고 log*Wab*=2.3324logDBH-0.9181 이었다. 독립변수가 D^2H일 때, 줄기(*Ws*), 가지(*Wb*), 잎(*Wl*) 그리고 지상부(*Wab*)의 상대생장식은 각각 log*Ws*=0.853logD^2H-1.4252, log*Wb*=0.8453logD^2H-1.5834, log*Wl*=0.5328logD^2H-1.4073 그리고 log*Wab*=0.8265logD^2H-1.0327이었다. 독립변수가 DBH일 때, 줄기, 가지 잎 그리고 지상부 상대생장식의 R^2값은 0.9873, 0.9711, 0.7979 그리고 0.993 이었고 독립변수가 D^2H일 때 0.9841, 0.9174, 0.7537 그리고 0.9876 이었다. 독립변수가 DBH인 상대생장식과 D^2H인 상대생장식은 모두 관측값과 예측값 사이에 통계적으로 유의한 차이가 없어 어느 상대생장식을 사용하더라도 결과에는 차이가 없었다.

핵심용어 : 상대생장식, 생물량, 상록활엽수, 종가시나무

Introduction

Due to global warming, there has been recent interest in the capacity of trees to sequester and store carbon (Cienciala et al. 2005). In addition, botanical biomass is an important indicator for assessing forest structure (Westman and Rogers 1977). Allometry is an alternative method of estimating plant productivity in situations where the volume of individual plants is very large or regrowth is so slow that extensive damage may be caused by complete harvesting of sample plots (Madgwick and Satoo 1975). This technique is based upon the estimation that some parameters, such as plant height, and diameter at breast height (DBH) can be correlated with biomass (Whittaker and Woodwell 1968). Trees selected as standard individuals must be harvested to determine the slope of a regression line, which may then be used to predict plant biomass from the easily measured parameter. Net primary productivity (NPP) is frequently measured by calculating the difference in annual biomass.

Quercus glauca is globally distributed from the Western Himalayas, throughout subtropical and tropical China to central Honshu in Japan (Yu 2005). *Q. glauca* is a major woody species that dominates in South-Western costs and low mountain area of Jeju Island on the Korea Peninsula (Kim and Kim 2012). Increased atmospheric CO_2 concentrations associated with elevated temperatures can directly affect the growth and development of plants through physiological processes. Thus, understanding the interactive effects of elevated CO_2 and temperature on plant physiological responses is essential for accurate predictions of climate change.

As a part of the National Long-Term Ecological Research Program, we studied the primary production of *Quercus glauca* on Kotzawal wetland, DongBaekDongSan (Mt.) of Seunheulgot in Jeju Island. The purpose of this study was to obtain allometric equations of *Q. glauca* for estimation of biomass.

1. Materials and Methods

1.1. Sampling and Management of Standard Individuals

This study was conducted at a sub-tropical forests dominated by *Q. glauca* in Seonheul-ri Kotzawal wetland of Jeju city (33° 30' 14.09"N, 126° 46' 51.78"E). Sixteen standard individuals plants of *Q. glauca*, which were healthy and visibly undamaged, were harvested between November 2012 and February 2013. Basal diameters of sampled standard individuals of *Q. glauca* were distributed evenly from small to large (1.4-25cm). Basal diameters (DBH) of stem and plant height (H) were measured, and the standard individuals were separated into different parts (stems, branches, and leaves) and weighed in the field. Sub-samples of stems, branches, and leaves were brought back to the laboratory and oven-dried at 80℃ to estimate green weights using over-dry weight conversion factors. Oven-dry weights of plant parts were calculated from the conversion factors and green weights of the respective plant parts.

1.2. Development of Allometric Equations

Allometric equations of *Q. glauca* were developed as previously described by Kim (1969). All measured parameters were transformed to logarithm (Kerkhoff and Enquist 2009). In this study, diameter at breast height (DBH, D) and height of tree (H) were used as parameter. Using the regression model proposed by Kittredge (1994), we analyzed log-transformed data in all regressions. That model is suitable when data have a multiplicative error structure and proportional changes are of interest, as is the case here (Kerkhoff and Enquist 2009).

$$\text{Log } Y = A + b \log X,$$

where Y is estimation of the standing crop, X is the measured parameter of standard individuals, A is the point at which the regression line crosses the Y axis, and b is the slope of the regression line. The value of the constants (A and b) were determined in a preliminary harvest of standard individuals. Allometric equations were calculated using Microsoft Execl (Microsoft Office 2008).

Allometric equations were established by variance of DBH (D) and D^2H, respectively.

1.3. Statistical Analysis

To examine how well an observed cumulative frequency distribution conforms to an expected

frequency distribution, we conducted the Kolmogorov -Smirnov Test using the SPSS program (IBM SPSS Statistics 20).

2. Results and Discussion

2.1. Allometric Equations

To develop allometric equations, DBH (D), plant height (H), D^2H, and dry weight of each organ were determined in the 16 standard individuals and are summarized in Table 1. The ranges of DBH(D) and plant height(H) of the standard individuals were 1.4-19cm and 1.81-14.5m, respectively.

Regression lines of each organ between dry weight of stems (log *Ws)*, branches (log *Wb*), leaves (log *Wl*), aboveground biomass (log *Wab*), and DBH (D) are depicted in Fig. 1. Allometric equations for estimation of biomass of each organ between dry weight and DBH are as follows:

log Ws = 2.4042logDBH-1.3045   (Fig. 1 A)
log Wb = 2.6436logDBH-1.6232   (Fig. 1 B)
log Wl = 1.5428logDBH-1.3692   (Fig. 1 C)
log Wab = 2.3324logDBH-0.9181   (Fig. 1 D)

Regression lines of each organ between dry weight of stems (log *Ws*), branches (log *Wb*), leaves (log *Wl*), and aboveground biomass (log *Wab*), and D^2H are depicted in Fig. 2. Allometric equations for estimation of biomass of each organ between dry weight and D^2H are as follows:

log Ws = 0.9007logD²H-1.4791   (Fig. 2 A)
log Wb = 0.8453logD²H-1.5834   (Fig. 2 B)
log Wl = 0.5407logD²H-1.3923   (Fig. 2 C)
log Wab = 0.8359logD²H-1.0277   (Fig. 2 D)

The values of the constants and R^2 are summarized in Table 2. The value of R^2 of the regression line for aboveground biomass was the highest in both DBH and D^2H. The value of R^2 of the regression line for each organ was the highest in D^2H. For the relationship between DBH and dry weight, the value of R^2 was the highest in aboveground biomass and lowest

in leaves. For the relationship between D^2H and dry weight, the value of R^2 was the highest in aboveground biomass and lowest in leaves. Value of R^2 for each organs was larger in the relationship between DBH and dry weight than in the relationship between D^2H and dry weight.

2.2. Statistical Analysis

As a result of the Kolmogorov-Smirnov test, allometric distributions to DBH and D^2H were similar to normal distribution. There was no statistical difference between the observed value and predictive value as calculated by the allometric equations. Traditionally, allometric equations are more accurate when more variations are considered (Yeocheon Ecological Research 2005). But when we include more variables for more exact calculation, also more time (or effort) was needed. There was no significant difference between observed and calculated values of the allometric equations from DBH (one variable) and D^2H (two variable). Thus, we recommend DBH variable for rapid allometric calculation.

Table 1. D (DBH), plant height (H), D^2H, and dry weight (kg) of stems (*Ws*), branches (*Wb*), leaves (*Wl*) and aboveground biomass (*Wab*) of standard individuals of *Q. gluaca.*

| No.	D	H	D^2H	Ws(kg)	Wb(kg)	Wl(kg)	Wab(kg)
1	1.4	1.8	3.528	0.15	0.08	0.10	0.33
2	2.3	2.3	12.167	0.35	0.28	0.40	1.03
3	2.6	2.3	15.548	0.40	0.10	0.38	0.88
4	5.3	6.9	193.821	2.83	2.36	0.26	5.45
5	5.7	6.7	217.683	3.67	1.42	0.26	5.35
6	6.1	7.1	264.191	4.77	3.20	0.26	8.23
7	7.6	7.5	433.2	3.83	7.40	0.67	11.90
8	7.8	9	547.56	5.61	6.66	0.52	12.80
9	10.9	11	1306.91	11.70	17.05	0.78	29.53
10	11.5	10.7	1415.075	16.84	20.10	1.71	38.65
11	12.1	11.3	1654.433	22.62	19.52	3.41	45.55
12	15.1	14.1	3214.941	47.49	38.36	5.43	91.27
13	19	14.5	5234.5	65.06	46.33	5.12	116.52
14	19.4	13.5	5080.86	63.54	54.83	6.47	124.84
15	20.8	13.4	5797.376	88.99	66.01	8.74	163.74
16	25.0	16.0	10000	99.28	84.58	6.47	190.32
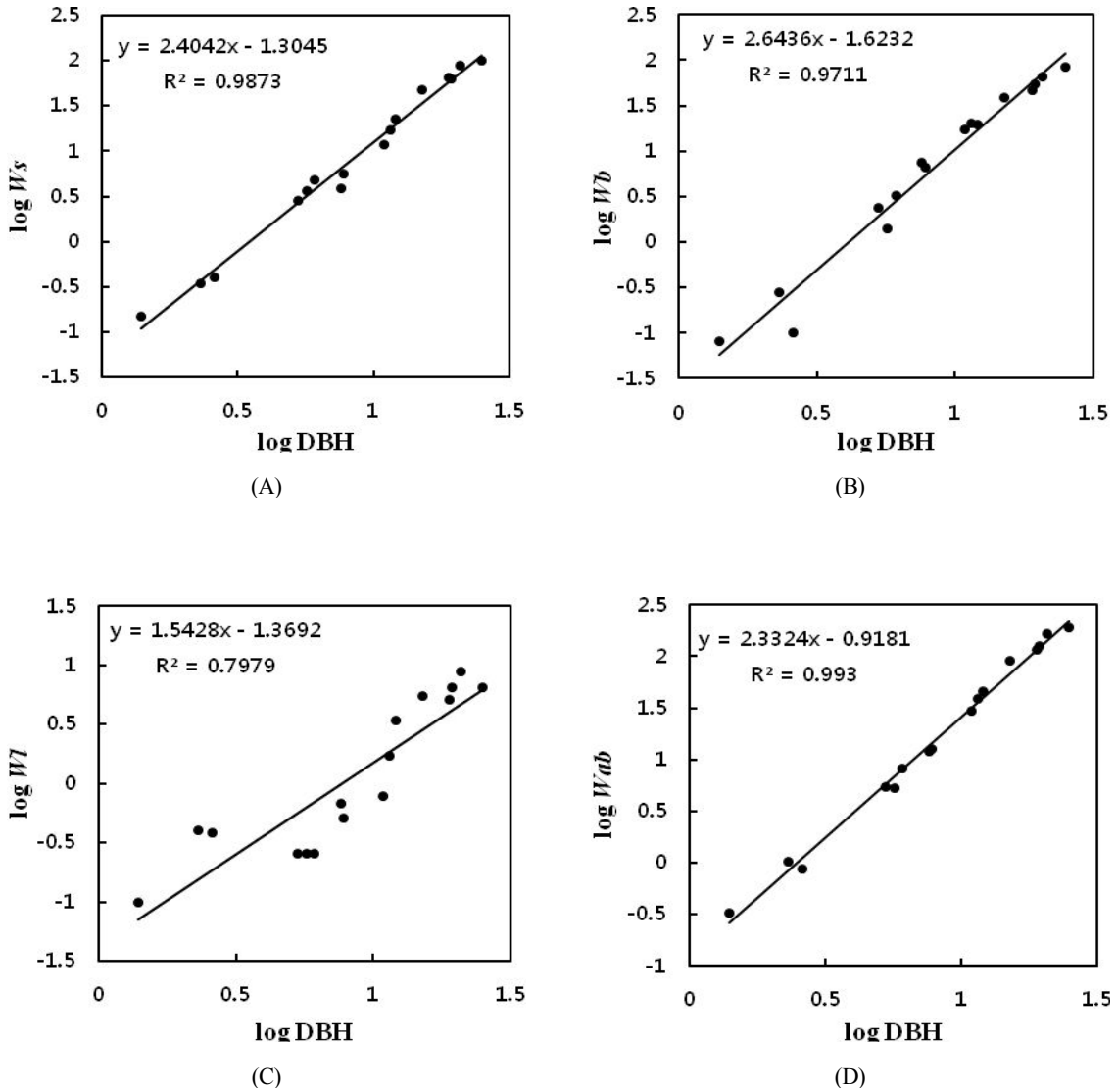
Fig. 1. Relationships between biomass components and DBH (D) of *Q. glauca*. Biomass components include stems (A), branches (B), leaves (C), aboveground biomass (D).
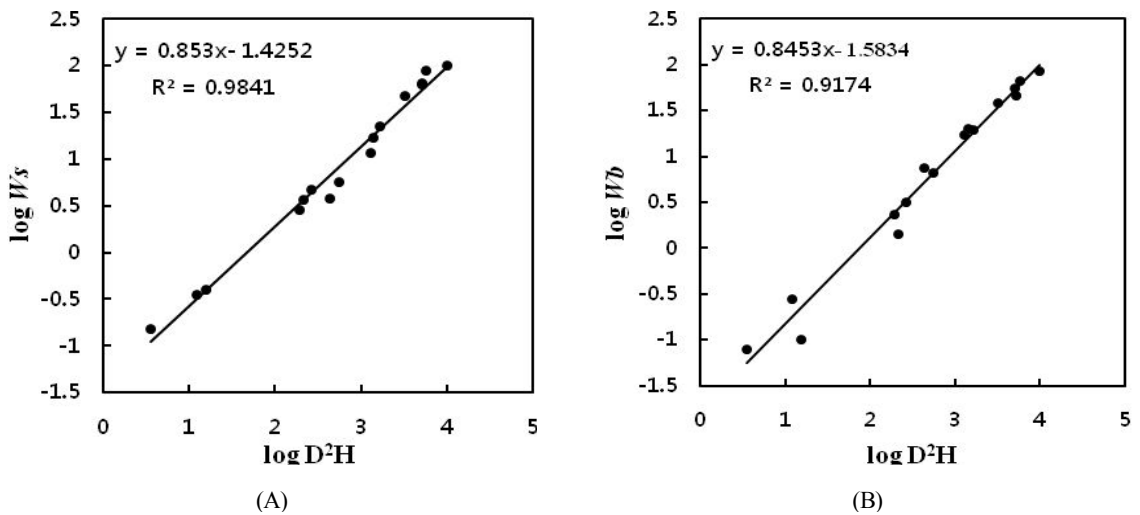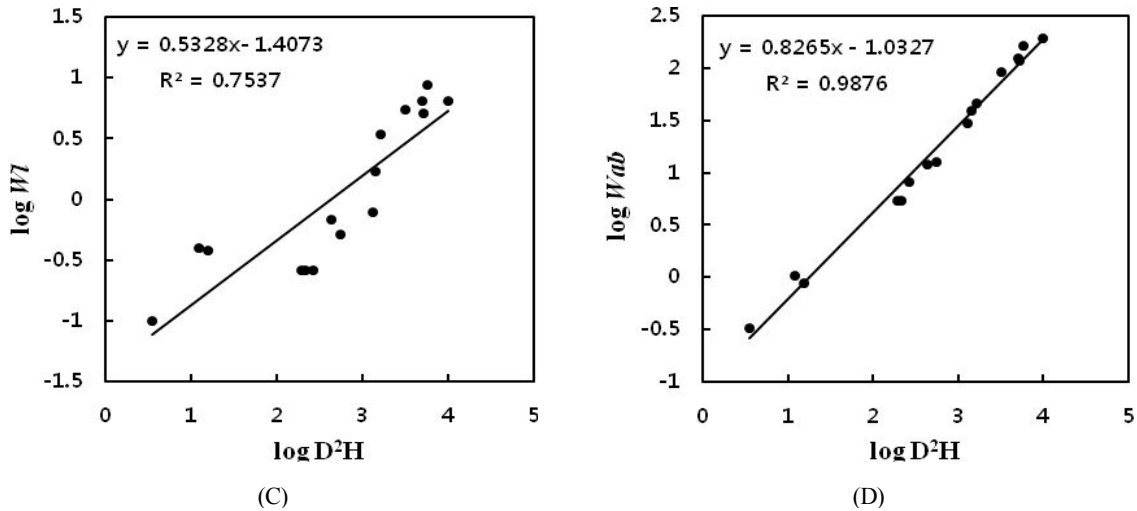
Fig. 2. Relationships between biomass components and D2H of *Q.glauca*. Biomass components include stems (A), branches (B), leaves (C), aboveground biomass (D).

Table 2. Comparisons of allometric coefficient b, constant a, and R2 of allometric equations for each organ of *Q. glauca*

Organ	DBH(D)			D^2H		
	a	b	R2	a	b	R^2
Stems	-1.3045	2.4042	0.9873	-1.4252	0.853	0.9841
Branches	-1.6232	2.6436	0.9711	-1.5834	0.8453	0.9174
Leaves	-1.3692	1.5428	0.7979	-1.4073	0.5328	0.7537
aboveground	-0.9181	2.3324	0.9930	-1.0327	0.8265	0.9876

Table 3. Comparison of observed field data and calculated values of the allomatric equations used to predict aboveground biomass of *Q. glauca* from DBH (D) and D^2H using Kolmogorov-Smirnov's test

		Variable (DBH)	Variable (D^2H)
Stems	Kolmogorov-Smirnov's Z	0.354	0.530
	p-value	1.00	0.941
Branches	Kolmogorov-Smirnov's Z	0.354	0.530
	p-value	1.00	0.941
Leaves	Kolmogorov-Smirnov's Z	0.707	0.707
	p-value	0.699	0.699
Above-ground	Kolmogorov-Smirnov's Z	0.354	0.354
	p-value	1.00	1.00

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