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〈Report〉

Biomass Estimation of Shrub *Lindera obtusiloba* by Allometry

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ABSTRACT: Allometric equations for biomass measurement of the shrub species, *Lindera obtusiloba*, were developed. The allometric equations between $(BD)^2H$ and dry weight of leaves (W_l), stems and branches (W_{sb}), roots (W_r) and total weight (W_t) of the *Lindera obtusiloba* were as follows: W_l=0.7318 $(BD^2H)^{0.6108}$, W_{sb}=0.6067 $(BD^2H)^{0.8355}$, W_r=0.4524 $(BD^2H)^{0.7608}$, W_t=1.672 $(BD^2H)^{0.7664}$. The R^2s between $(BD)^2H$ and W_l, W_{sb}, W_r and W_t of the *Lindera obtusiloba* were 0.9251, 0.9571, 0.9353 and 0.9546, respectively. Root weight of this *Lindera obtusiloba* was about 38% of the aboveground biomass.

Key words: Allometric equation, Biomass, *Lindera obtusiloba*, Shrub

INTRODUCTION

The two major functions, energy flow and material cyclings, of ecosystems are based on the primary production of the ecosystem. The most accurate means of measuring net primary productivity (NPP) would measure the net photosynthetic rates of photosynthetic tissues, then subtract the respiration rates of nonphotosynthetic tissues, and finally extrapolate to the community level. This assessment of NPP, however, is not possible on a large scale (Barbour et al. 1987). Allometric method is an alternative way of estimating productivity in those situations where the volume of individual plants is very large or regrowth is so slow that extensive damage may be caused by complete harvest of sample plots (Madgwick and Satoo 1975). This technique is based upon the assumption that some easily measured parameters, such as plant height, diameter at breast height (DBH), can be correlated with biomass (Whittaker and Woodwell 1968). A few trees 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 change in biomass through time.

In case of forest ecosystems, allometric methods mainly restricted to trees which occupy most of the production and can be used as timber (Kittredge 1944, Kang and Kwak 1998, Park et al. 2003). Kim (1970) has developed allometric equations for estimation of the primary production of the different varieties of shrubby mulberry. However, there are few attempts to develop allometric equation for shrub species which consist of understory vegetation of forests (Whittaker and Woodwell 1968).

In addition to timber production, forests have an important position for sequestration of carbon dioxide from the atmosphere. Tans et al. (1990) reported that the temperate forests play an important role in decreasing the carbon dioxide of the atmosphere. Heath et al. (2003) and Pregitzer (2003) suggested that measurement of biomass of understory vegetation of forests is necessary for understanding of carbon distribution in forest ecosystems. As mentioned before, however, allometric equations for estimation of forest biomass are restricted to trees (Kim and Sung 1972, Park and Lee 1990, Kang and Kwak 1998, Park 2003, Park et al. 2003).

As a part of National Long-Term Ecological Research Program, we began to study the primary production and nutrient cycling in major plant communities, *Quercus mongolica*, *Q. variabilis* and *Pinus densiflora*, at Mt. Worak National Park in Chungbuk Province. The shrub layer of the *Q. mongolica* forest was dominated by *L. obtusiloba*. The purpose of this study was to obtain allometric equations of *L. obtusiloba* for estimation of biomass.

MATERIALS AND METHODS

Sampling and Management of Standard Individuals

Twenty standard individuals of *L. obtusiloba* were harvested in August 2006 from *Quercus acutissima* forest in Kongju Chungnam Province and *Q. mongolica* forest in Mt. Worak National Park in Chungbuk Province. Basal diameters of sampled standard individuals of *L. obtusiloba* were distributed evenly from small to large. Roots were excavated carefully. In a laboratory, basal diameters (*BD*) of stem and plant height (*H*) were measured. Soil particles in roots were washed out with tap water. Leaves, stem and branches, and roots were weighed separately after drying till constant weight in 80℃ oven.

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Development of Allometric Equations

Allometric equations of *L. obtusiloba* were developed after modified Kim (1970). Kim (1970) used stem diameter of 30 cm height of shrubby mulberry. In this study, basal diameter (*BD*) was used. Using the regression model proposed by Kittredge (1944),

$$Y = AX^b \quad (\log Y = A + b \log X) \qquad (1)$$

where Y is the estimate of standing crop, X is the measured parameter of the 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) is determined in a preliminary harvest of standard individuals. Allometric equations were calculated by Microsoft Excel 2002.

RESULTS AND DISCUSSION

Allometric Equations

The $(BD)^2$, $(BD)^2H$, and dry weight of each organ of the 20 standard individuals for development of allometric equations were summarized in Table 1. The ranges of *BD* and plant height of standard individuals were 3.3～35.7 mm and 0.40～3.17 m, respectively.

Regression lines of each organ between dry weight of leaves (W_l), stems and branches (W_{sb}), roots (W_r) and total (W_t), and $(BD)^2H$ were depicted in Fig. 1. Allometric equations for estimation of biomass of each organ between dry weight and $(BD)^2H$ were as follows:

$$W_l = 0.7318\ (BD^2H)^{0.6108} \qquad \text{(Fig. 1 A)}$$
$$W_{sb} = 0.6067\ (BD^2H)^{0.8355} \qquad \text{(Fig. 1 B)}$$
$$W_r = 0.4524\ (BD^2H)^{0.7608} \qquad \text{(Fig. 1 C)}$$
$$W_t = 1.672\ (BD^2H)^{0.7664} \qquad \text{(Fig. 1 D)}$$

The values of constants and R^2 are summarized in Table 2. R^2 of the regression line for stems and branches (W_{sb}) was the highest. And R^2 of the regression line for total weight (W_t) was similar to that of W_{sb} (Table 2). From these results, total biomass of *L. obtusiloba.* can be estimated with allometric equation of W_t (Fig. 1 D). Net primary productivity of *L. obtusiloba* could be measured by calculating the change in biomass through time.

Roots Ratio

The ratio of roots biomass to aboveground biomass of *L. obtusiloba* was 38%, which was calculated with the data of standard individuals. This value was higher than the general value, 25%, in trees (Johnson and Risser 1974). The most of the roots were harvested because the roots of *L. obtusiloba* were extended horizontally in upper soil layer. However, roots biomass estimation in this study must be underestimated because some of the fine roots must be missing during digging out of roots. Therefore, root biomass ratio of this shrub species would be higher than 38%. If diverse shrub species examined, more accurate data of root ratio to aboveground biomass in shrub could be obtained.

Allometric equations for estimation of biomass of *L. obtusiloba* developed in this study can be applied to the study of net primary production, absorption of nutrients and carbon in this shrub species. There are many shrub species such as *Rhododendron mucronulatum*, *R. schlipppenbachii*, *Ligustrum obtusifolium*etc. which are consisting of understory vegetation of forests. Therefore, it is quite necessary to develop the allometric equations for estimation of biomass of these shrub species. This will be a great

Table 1. Basal diameter (*BD*), square of *BD*, plant height (*H*), $(BD)^2H$, and dry weight (g) of leaves (W_l), stem and branch (W_{sb}), root (W_r), and total weight (W_t) of standard individuals of *Lindera obtusiloba*

No	*BD* (mm)	*H* (m)	BD^2H	W_l (g)	W_{sb} (g)	W_r (g)	W_t (g)
1	3.3	0.44	4.79	2.59	3.18	1.80	7.57
2	3.5	0.40	4.90	1.62	2.59	2.04	6.25
3	4.5	0.77	15.59	5.12	8.90	4.99	19.01
4	4.6	0.59	12.48	4.59	7.21	3.78	15.58
5	4.7	0.54	11.93	2.20	2.92	2.18	7.31
6	4.7	0.56	12.37	5.43	6.69	6.84	18.96
7	5.0	0.40	10.00	1.97	2.44	1.17	5.58
8	5.0	0.54	13.50	2.63	2.64	1.73	7.00
9	6.0	0.83	29.88	3.34	9.06	4.08	16.48
10	6.5	1.00	42.33	8.55	15.64	9.73	33.92
11	10.3	0.97	102.91	19.19	33.50	15.71	68.40
12	10.4	1.27	137.36	11.23	30.20	16.31	57.74
13	10.4	1.80	194.69	21.34	54.27	19.52	95.13
14	10.4	1.67	180.63	22.26	57.90	32.87	113.03
15	10.6	0.96	107.87	12.65	30.89	19.41	62.95
16	14.2	1.52	306.49	40.43	93.55	48.83	182.81
17	17.2	2.41	712.97	29.77	220.11	69.40	319.28
18	20.9	1.53	668.32	30.75	73.70	35.82	140.27
19	23.0	2.84	1502.36	43.35	270.20	113.76	427.31
20	35.7	3.17	4040.13	147.06	595.23	315.50	1057.79

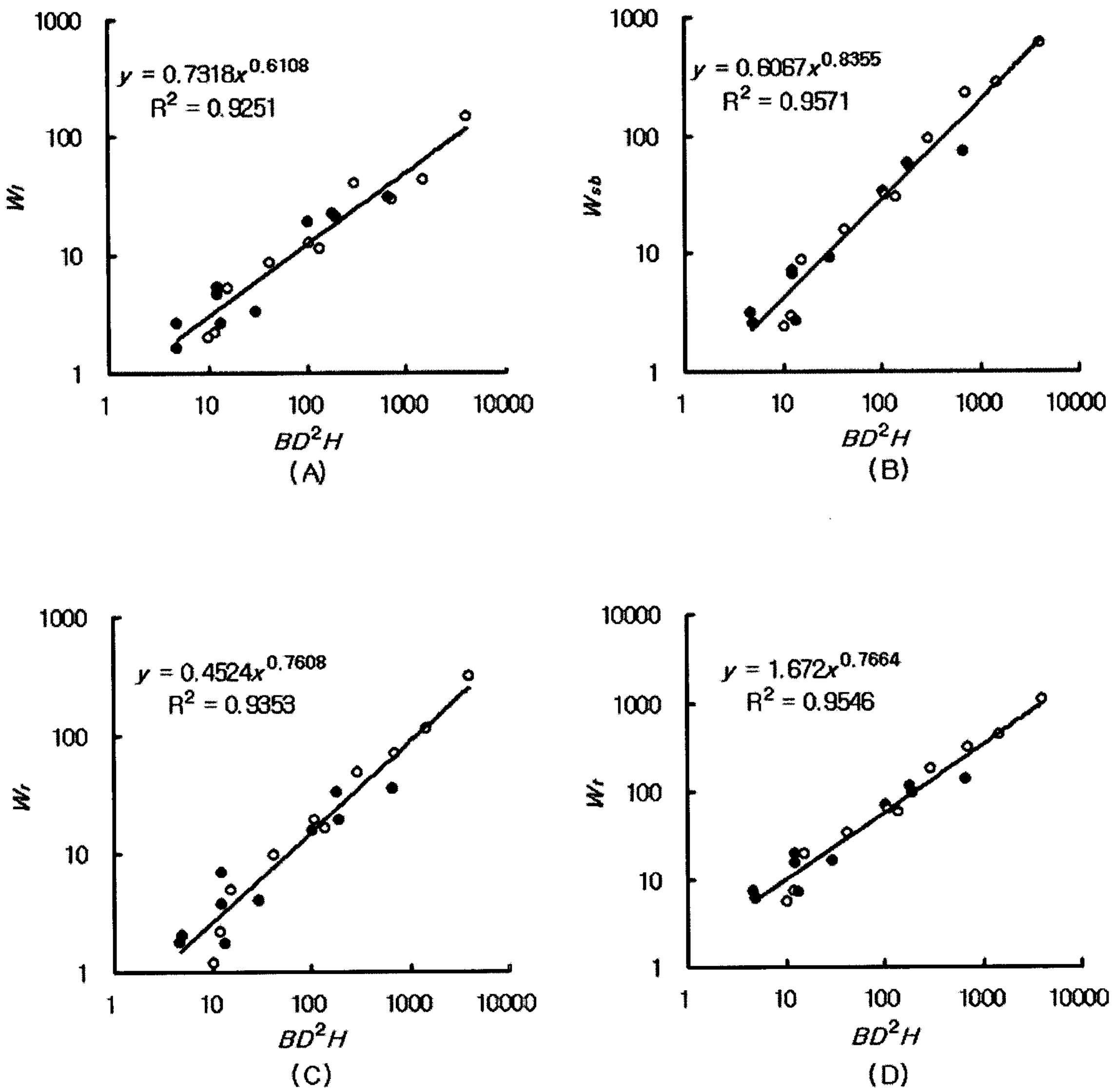

Fig. 1. Allometric relations of $(BD)^2H$ and the leaf weight (W_l, A), stem and branch weight (W_{sb}, B), root weight (W_r, C), and total weight (W_t, D) of *Lindera obtusiloba.* Open circles and closed circles indicate standard individuals sampled from Kongju and Mt. Worak National Park, respectively.

Table 2. Comparisons of allometric coefficient b, constant A and R^2 of allometric equations for each organ of *Lindera obtusiloba*

Organ	b	A	R^2
Leaves	0.6108	0.7318	0.9251
Stems + Branches	0.8355	0.6067	0.9571
Roots	0.7608	0.4524	0.9353
Total weight	0.7664	1.672	0.9546

contribution for understanding of energy flow, nutrient cyclings and carbon sequestration in forest ecosystems (Heath et al. 2003, Pregitzer 2003).

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