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Allometric Relations in Hinoki (*Chamaecyparis obtusa* (Sieb. et Zucc.) Endl.) Trees

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Abstract

The allometric relationships between different dimensions of a hinoki (*Chamaecyparis obtusa* (Sieb. et Zucc.) Endl.) tree were examined on the basis of 55 destructive samples, which were collected from four different stands and whose age ranged from 12 to 59 years. The use of $D_{0.1}{}^2H$ ($D_{0.1}$, stem diameter at a height of $H/10$; H, tree height) as an independent variable of the allometric equation made the equation applicable to any hinoki stands for estimating the weight of organs, such as stem, branches, leaves, roots, and aboveground per tree. In the case of the estimation of the branch weight, the use of stem diameter D_B at a height of clear bole length increased accuracy of the estimates to a considerably higher extent. For the leaf weight, it was advisable either to use D_B or branch weight as an independent variable. With respect to leaf area, it was proved that accuracy of the estimates based on leaf weight was quite high. As far as the root weight was concerned, the use of DBH resulted in more accurate estimates than the use of $D_{0.1}{}^2H$ or stem weight as an independent variable. A reasonable procedure for estimating the biomass of hinoki trees or stands with fairly high accuracy was diagrammatically proposed.

Key words : allometric equation, hinoki, independent variable, stem diameter at a height of clear bole length, stem diameter at a height of one-tenth of tree height.

I. Introduction

Biomass survey is one of the most vital keys for studying the production structure and functions of forest ecosystems. Estimation of the forest biomass is mostly based on the use of the allometric correlation between different dimensions of a tree. The basic methods had been established (*e.g.*, OGAWA and KIRA, 1977; KARIZUMI, 1977), where tree height was introduced as a second independent variable into the allometric equation, so that accuracy of the estimates, such as stem, branch, and root weight per tree, was increased to a considerable extent by the combined use of DBH (stem diameter at breast height) and tree height. OGAWA and KIRA (1977), furthermore, suggested that substituting stem diameter at a height of 10% of tree height for DBH as an independent variable of the allometric equation not only made the equation applicable regardless of tree size to any stands of the same species, but also improved accuracy of the estimates.

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SHINOZAKI *et al.* (1964b) provided a more elaborate technique, where stem diameter at a height of clear bole length could serve as an overall bias for estimates of leaf and branch amounts in any stands regardless of their age or habitat. For the estimation of root weight, it was proved that the use of DBH was more valid theoretically (KIRA and OGAWA, 1968) in addition to more convenient practically (KARIZUMI, 1977).

Although hinoki (*Chamaecyparis obtusa* (Sieb. et Zucc.) Endl.), as well as sugi (*Cryptomeria japonica* (L. f.) D. Don), is one of the most important species for plantations in Japan, the primary productivity of the hinoki forests had been studied less frequently than the sugi forests (*e.g.*, SAITO, 1977). Our Laboratory has been carrying out intensive studies on the structure and functions of hinoki plantations for the last 20 years (*e.g.*, NINOMIYA and HOZUMI, 1983; MIYAURA and HOZUMI, 1985; HAGIHARA and HOZUMI, 1986; OGAWA *et al.*, 1986; MORI and HAGIHARA, 1991; PAEMBONAN *et al.*, 1992; HAGIHARA and YAMAJI, 1993). As a result, data sampled destructively from the hinoki stands have been accumulated (HAGIHARA, 1978; TANAO, 1982; NAKAGAKI, 1983; IIJIMA, 1991; YAMAJI, 1991; MORI, 1992; YOKOTA and HAGIHARA, unpublished).

In this paper, we examine the allometric relationships between different dimensions of hinoki trees on the basis of the data mentioned above. In the light of the results, we try to propose a reasonable procedure for estimating the biomass of hinoki trees or stands with considerably higher accuracy.

II. Materials and Methods

1. *Site description*

As shown in Fig. 1, data used for this paper were collected from the following four hinoki (*Chamaecyparis obtusa* (Sieb. et Zucc.) Endl.) stands (see Appendix 1) located in Aichi Prefecture, central Japan:

Fig. 1. Map of Aichi Prefecture, central Japan, showing the location of stands. The stand at Dando is located ca. 50 km east of the stand at Nagoya.

1) Inabu; This stand (HAGIHARA, 1978; TANAO, 1982; NAKAGAKI, 1983; MORI, 1992) is located on a 35° slope with a north exposure at an elevation of 500 m in Nagoya University Forest. Artificial management was made only at an initial stage just after the plantation was established. Tree density ranged from 6000 to 7500 trees ha^{-1}. Undergrowth vegetation was almost absent.

2) Nagoya; This stand (YOKOTA and HAGIHARA, unpublished) is established on a flat area at 50 m above the sea in experimental forests on Nagoya University. Tree density was 15000 trees ha^{-1}. No artificial managements had been made since the plantation was set up. Since the canopy was fully closed, undergrowth vegetation rarely existed.

3) Dando; The stand (IIJIMA, 1991) is located on a 25° west facing slope at 900 m above the sea in a national forest on Shinsiro District Forest Office, Nagoya Regional Forest Office. Tree density was ca. 2700 trees ha^{-1}. It was four years since thinning had been applied to the stand. Ground vegetation consisted of a dense population of suzudake (*Sasamorpha borealis* (Hack.) Nakai) around 2 m tall.

4) Hourai; This stand (YAMAJI, 1991) on Aichi Prefectural Forest Research Institute is situated on an 18.5° north-west facing slope at 435 m above the sea. Tree density was 2281 trees ha^{-1}. The stand had been free from any artificial management over 20 years preceding the survey. Undergrowth vegetation was rarely present.

2. *Methods*

After the trees were felled, the following measurements were obtained : tree height H, clear bole length (height to the first living branch) H_B, stem diameter at 1.3 m height above the ground (DBH) D, stem diameter at a height of $H/10$ $D_{0.1}$, stem diameter at a height of clear bole length D_B.

After the linear dimensions were measured, the felled trees were provided for the stratified clip technique, in which stratum was 0.0-0.3 m, 0.3-1.3 m, 1.3-2.3 m, and at intervals of 1 m upward. Phytomass contained in each stratum was separated into stem, branches, and leaves, and then was weighed. Roots were washed and weighed after excavation. Concerning stem volume with bark per tree v_S, its calculation was based on stem diameters at both ends of the strata.

Samples were taken from each stratum for estimating the ratio of dry/fresh phytomass for each organ and specific leaf area for leaves. Roots also were sampled. These samples were dried in ventilated ovens at 85℃ for a few days, were desiccated to a room temperature, and were weighed. The fresh phytomass was converted into dry phytomass of stem w_S, branches w_B, leaves w_L, and roots w_R per tree using the respective ratios.

Leaf area of the leaf samples was determined with area meters (Murayama NCE-3, Hayashi AAM-5, Hayashi AAC-100) and then specific leaf area was calculated as leaf area on a leaf dry weight basis for each stratum. Leaf area per tree u was calculated multiplying the leaf dry phytomass by the specific leaf area.

III. Results and Discussion

1. Stem weight

Figure 2 shows the allometric relationship of stem weight w_s [kg] to DBH D [cm]. It is apparent from the figure that the w_s-D allometry differs between one mature stand and the other younger stands (see Appendix 1). As shown in Fig. 3, the discrepancy appearing in Fig. 2 is improved in the allometric relationship between w_s and D^2H (H [m], tree height). However, the plotted data tend to be grouped into larger sized trees and smaller sized trees, for which the regression lines are slightly different than each other in gradient on logarithmic coordinates.

Figure 4 shows that the tendency recognized in Fig. 3 is completely vanished introducing stem diameter $D_{0.1}$ [cm] at a height of $H/10$ in place of D into the allometric equation. It follows that the $w_s-D_{0.1}{}^2H$ allometry can be represented by a single regression line on logarithmic coordinates ($r^2=0.997$). It is, therefore, concluded that the use of $D_{0.1}{}^2H$ as an independent variable makes the allometric equation applicable to any hinoki stands. This relationship is given in the form,

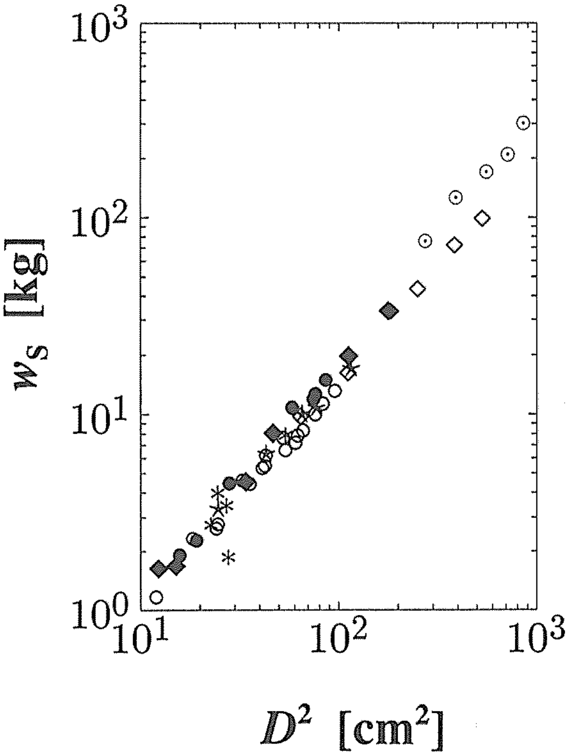

Fig. 2. Relationship between stem weight w_s and DBH D in hinoki stands. The data are plotted on logarithmic coordinates. Data sources (see Appendix 1) : ✳; YOKOTA and HAGIHARA (unpublished), ○; HAGIHARA (1978), ★; TANAO (1982), ◆; NAKAGAKI (1983), ●; MORI (1992), ◇; YAMAJI (1992), ⊙; IIJIMA (1991).

$$w_S = 0.01652(D_{0.1}{}^2H)^{0.9983}. \tag{1}$$

The value of the allometric constant in Eq. (1) is fairly close to unity. It follows that the stem weight is probably proportional to $D_{0.1}{}^2H$. Assuming the proportionality, the proportional constant is estimated to be 0.01735±0.00015 (SE) kg cm^{-2}m^{-1} (r^2=0.995).

Table 1. Values of the constants g and h in the allometric regression ($y = g\,(D_{0.1}{}^2H)^{h}$) of the dry weight of an organ per tree y on $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height).

Organs	g [kg (cm^{-2} m^{-1})^{h}]	h	r^2	No. of data
Stem	0.01652	0.9983 (0.0081)	0.997	53
Branches	0.001669	1.0145 (0.0432)	0.916	53
Leaves	0.006440	0.8930 (0.0538)	0.844	53
Roots	0.006001	0.9843 (0.0468)	0.946	27
Aboveground	0.02497	0.9723 (0.0133)	0.991	53

The value of h is represented with the standard error SE in parentheses.

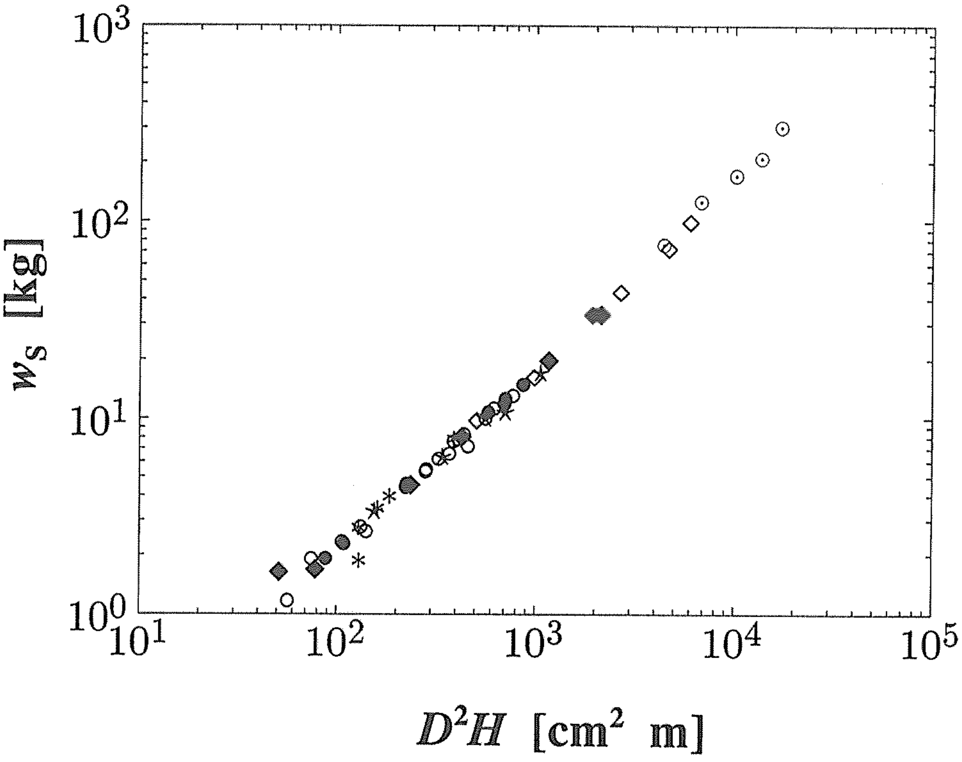

Fig. 3. Relationship between stem weight w_S and D^2H (D; DBH, H; tree height). The symbols are the same as in Fig. 2.

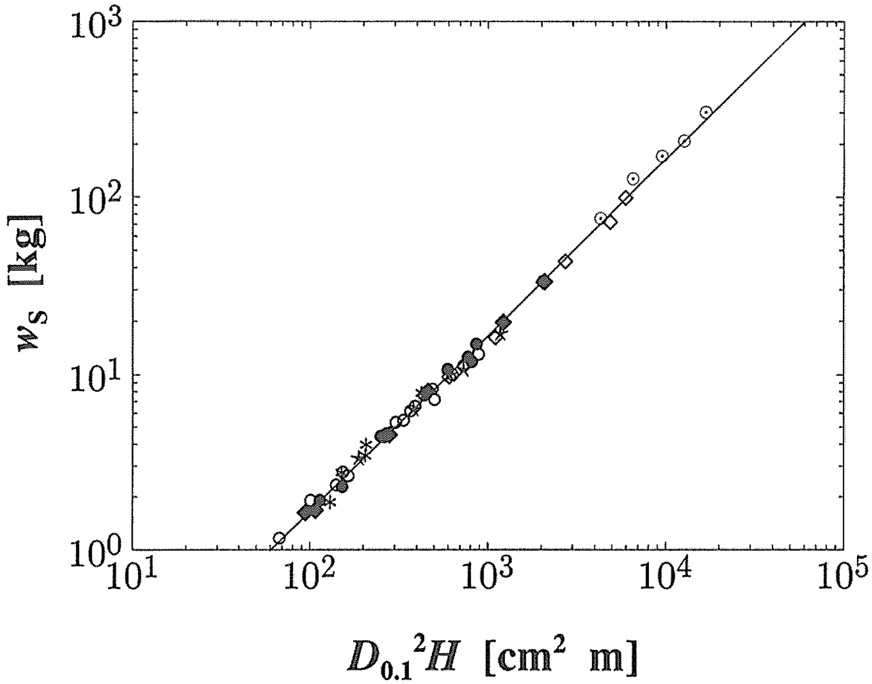

Fig. 4. Allometric relationship between stem weight w_S and $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height). The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (1).

2. Branch weight

Figure 5 shows the allometric relationship between branch weight w_B [kg] and $D_{0.1}{}^2H$. This relationship represents a considerable dispersion of the observed data around the regression line as compared with the allometric relationship of w_s to $D_{0.1}{}^2H$ (Fig. 4). The allometric relationship of w_B to $D_{0.1}{}^2H$ is given in the form,

$$w_B = 0.001669(D_{0.1}{}^2H)^{1.015}. \qquad (2)$$

Figure 6 shows the allometric relationship of w_B to w_S. The dispersion of the data occurs along the regression line with just the same degree as in the the case of the $w_S - D_{0.1}{}^2H$ allometry (Fig. 5). The allometric relationship of w_B to w_S is given in the form,

$$w_B = 0.1080 w_S{}^{1.016}. \qquad (3)$$

We examined the regression of w_B on stem diameter D_B [cm] at a height of clear bole length. As shown in Fig. 7, the inter- and intra-stand differences appearing in the $w_B - D_{0.1}{}^2H$ (Fig. 5) and $w_B - w_S$ (Fig. 6) allometries tend to be improved in the $w_B - D_B$ allometry ($r^2 = 0.952$). The allometric relationship of w_B to w_S is given in the form,

$$w_B = 0.007988 D_B{}^{2.707}. \qquad (4)$$

3. *Leaf weight*

Figure 8 shows the allometric relationship between leaf weight w_L [kg] and $D_{0.1}{}^2H$, the figure in which there exists segregation among stands. As shown in Fig. 9, on the other hand, the $w_L - w_B$ allometry is represented by a single regression line on logarithmic coordinates ($r^2=0.919$). These allometric equations are respectively given by

$$w_L = 0.006440(D_{0.1}{}^2H)^{0.8930}, \tag{5}$$

$$w_L = 1.794 w_B{}^{0.8788}. \tag{6}$$

Figure 10 shows the allometric relationship between w_L and D_B. The segregation among stands tends to disappear in the $w_L - D_B$ allometry ($r^2=0.927$), as well as in the $w_L - w_B$ allometry (Fig. 9). The allometric equation of the $w_L - D_B$ relationship is given in the form,

$$w_L = 0.02263 D_B{}^{2.452}. \tag{7}$$

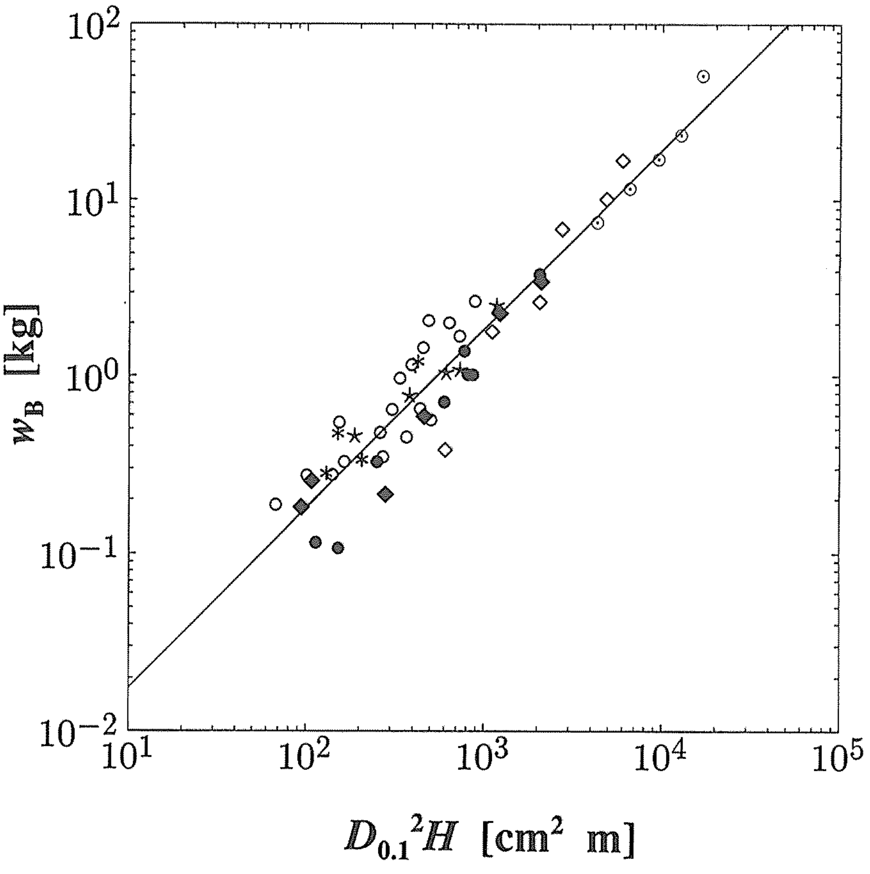

Fig. 5. Allometric relationship between branch weight w_B and $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height). The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (2).

The value of the allometric constant in Eq. (7) is much larger than a constant, whose value can be expected to be 2.0 according to the pipe model theory (SHINOZAKI *et al.*, 1964a). This might be because the regression was made over the whole range of the observed data. SHINOZAKI *et al.* (1964b) pointed out that the proportionality of w_L to $D_B{}^2$ tended to segregate between canopy trees and suppressed trees and the proportional constant was larger in the canopy trees than in the suppressed trees.

4. *Leaf area*

As shown in Fig. 11, leaf area u [m^2] represents a good correlation on w_L on logarithmic coordinates ($r^2=0.988$). This relationship is written by

$$u=5.017w_L{}^{0.9597}. \tag{8}$$

The value of the allometric constant is smaller than 1.0. This result suggests that mean specific leaf area ($=u/w_L$) in a tree tends to become smaller with increasing tree size.

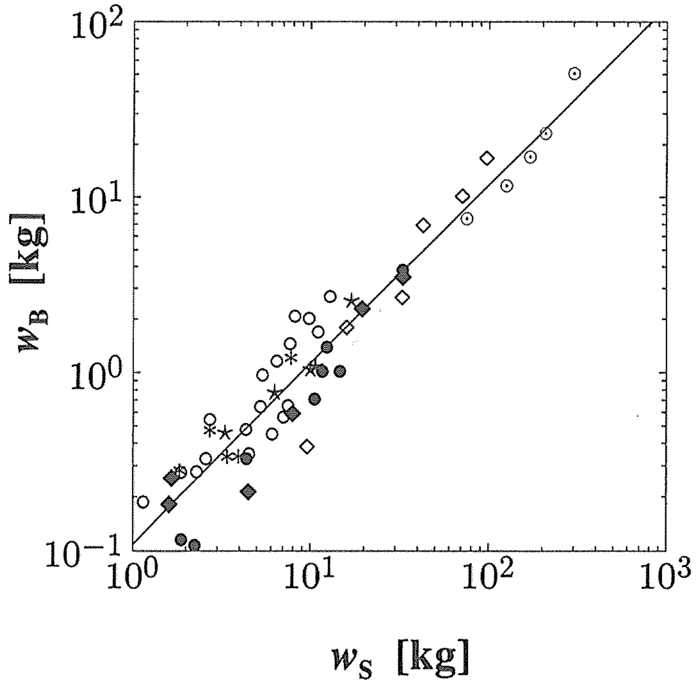

Fig. 6. Branch weight w_B-stem weight w_S allometry. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (3), where the standard error SE for the allometric constant is 0.0424, the coefficient of determination r^2 0.919, and the number of data n 53.

5. *Root weight*

Figures 12 and 13 respectively show the allometric relationships of root weight w_R [kg] to $D_{0.1}{}^2H$ and to w_S, the data available for which figures are confined to the Inabu stand (see Appendix 1). In both relationships, the plotted data have a weak tendency to segregate in response to changes in stand age. These allometric equations are respectively

$$w_R = 0.006001(D_{0.1}{}^2H)^{0.9843}, \tag{9}$$

$$w_R = 0.3541 w_S{}^{0.9831}. \tag{10}$$

Figure 14 shows the allometric relationship between w_R and D^2. The intra-stand difference appearing in the $w_R - D_{0.1}{}^2H$ (Fig. 12) and $w_R - w_S$ (Fig. 13) allometries tends to disappear almost completely in the allometric relationship of w_R to D^2 ($r^2 = 0.951$). This

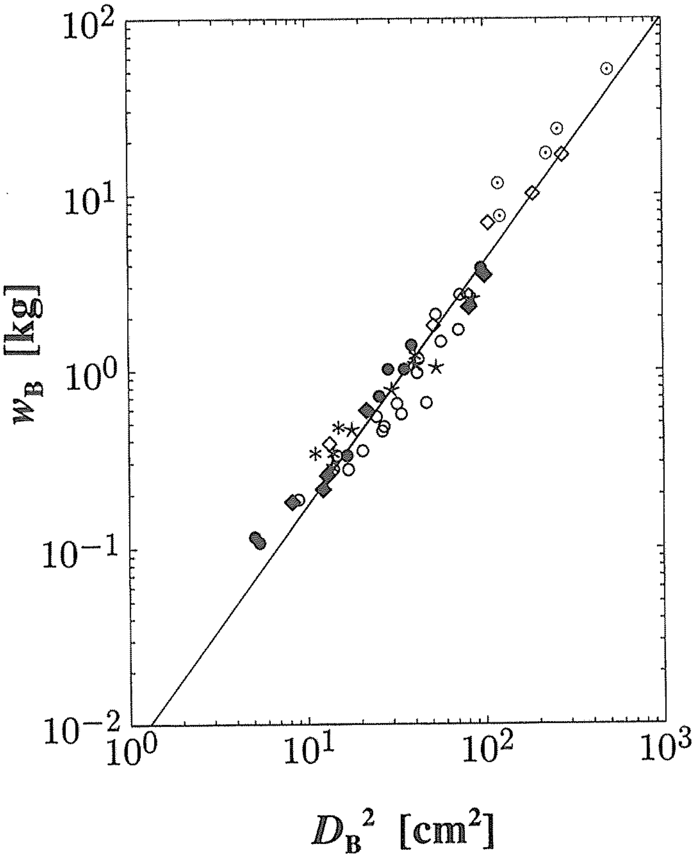

Fig. 7. Allometric relationship of branch weight w_B to stem diameter at a height of clear bole length D_B. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (4), where SE for the allometric constant is 0.0860, r^2 0.952, and n 52.

relationship is given in the form,

$$w_R = 0.02750(D^2)^{1.148}. \tag{11}$$

The value of the allometric constant in Eq. (11) is close to unity. KIRA and OGAWA (1968) theoretically pointed out owing to the pipe model theory (SHINOZAKI *et al.*, 1964a) that w_R was proportional to D^2 or stem sectional area just above the ground.

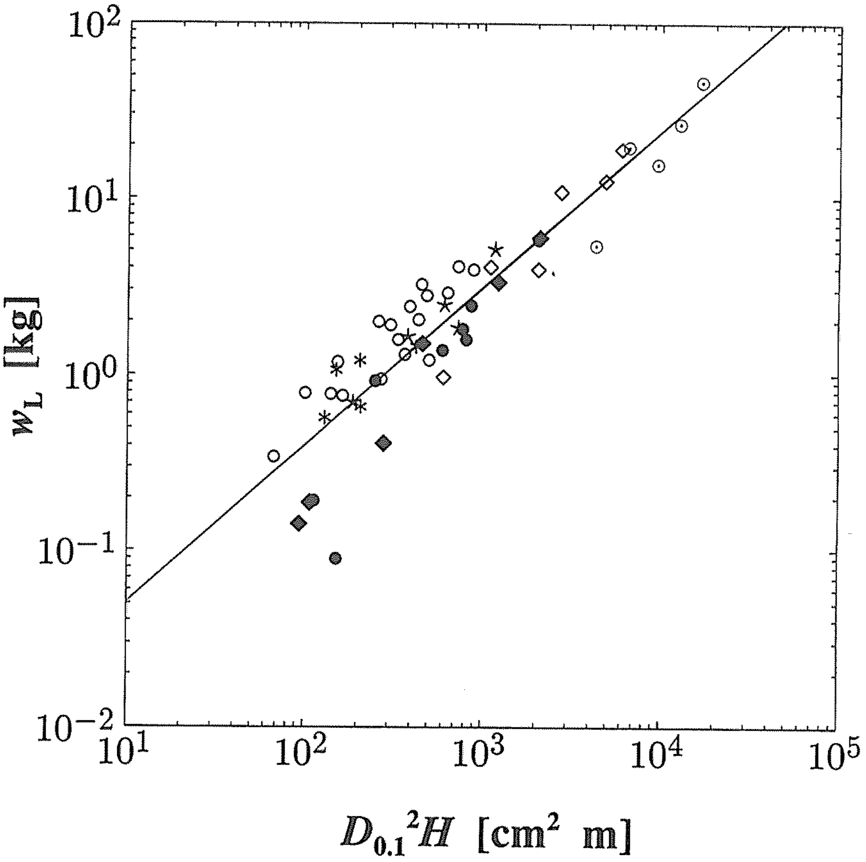

Fig. 8. Allometric relationship between leaf weight w_L and $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height). The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (5).

6. *Aboveground weight*

Figures 15 and 16 respectively show the allometric relationships of aboveground weight w_T [kg] to $D_{0.1}{}^2H$ and to stem volume v_S [dm^3]. Both relationships represent a satisfactory fit of the data to the respective single regression lines on logarithmic coordinates ($r^2=0.991$ for both cases),

$$w_T=0.02497(D_{0.1}{}^2H)^{0.9723}, \tag{12}$$

$$w_T=0.6258v_S{}^{0.9542}. \tag{13}$$

These equations make us find non-destructively the aboveground weight of standing trees with fairly high accuracy, if we have only to know either the linear dimensions $D_{0.1}$ and H or v_S of the standing trees (PAEMBONAN *et al.*, 1992).

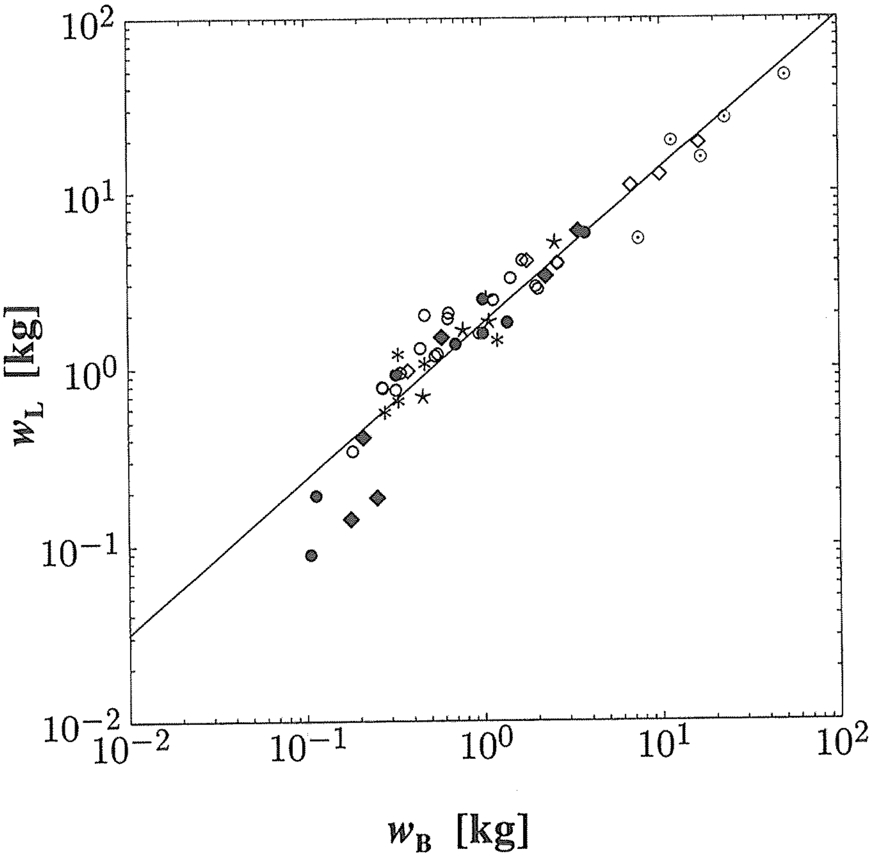

Fig. 9. Leaf weight w_L-branch weight w_B allometry. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (6), where SE for the allometric constant is 0.0366, r^2 0.919, and n 53.

IV. Conclusions

We recognized that the use of $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height) as an independent variable of the allometric equation permits us to estimate the weight of organs, such as stem (Fig. 4, Eq. (1)), branches (Fig. 5, Eq. (2)), leaves (Fig. 9, Eq. (8)), and roots (Fig. 12, Eq. (9)), with moderate accuracy. Aboveground weight also can be estimated with quite high accuracy using $D_{0.1}{}^2H$ (Fig. 15, Eq. (12)) as an independent variable of the allometric equation. Values of the constants in the allometric equations are recompiled in Table 1 together with the coefficient of determination r^2 produced from and the number of data provided for the regression analysis.

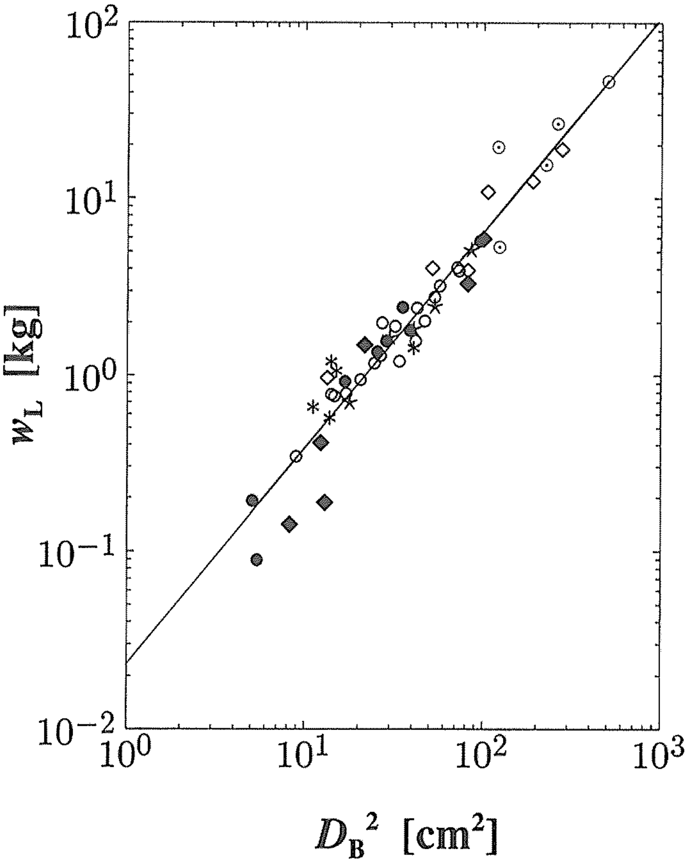

Fig. 10. Allometric relationship of leaf weight w_L to stem diameter at a height of clear bole length D_B. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (7), where SE for the allometric constant is 0.0974, r^2 0.927, and n 52.

With respect to the estimation of the branch weight, the use of stem diameter at a height of clear bole length D_B increases accuracy of the estimate to considerably higher extent (Fig. 7, Eq. (4)). In the case of the leaf weight, it is advisable to use either D_B (Fig. 10, Eq. (7)) or leaf weight (Fig. 9, Eq. (6)) as an independent variable. Concerning the leaf area, it is probable to estimate using the estimate of the branch weight (Fig. 11, Eq. (8)). As far as the root weight is concerned, the use of DBH, which is theoretically valid as well (KIRA and OGAWA, 1968), results in a more accurate estimate than the use of $D_{0.1}{}^2H$ or stem weight as an independent variable (Fig. 14, Eq. (11)). Figure 17 diagrammatically gives a standard procedure for estimating the weight of an organ and leaf area per tree in hinoki stands.

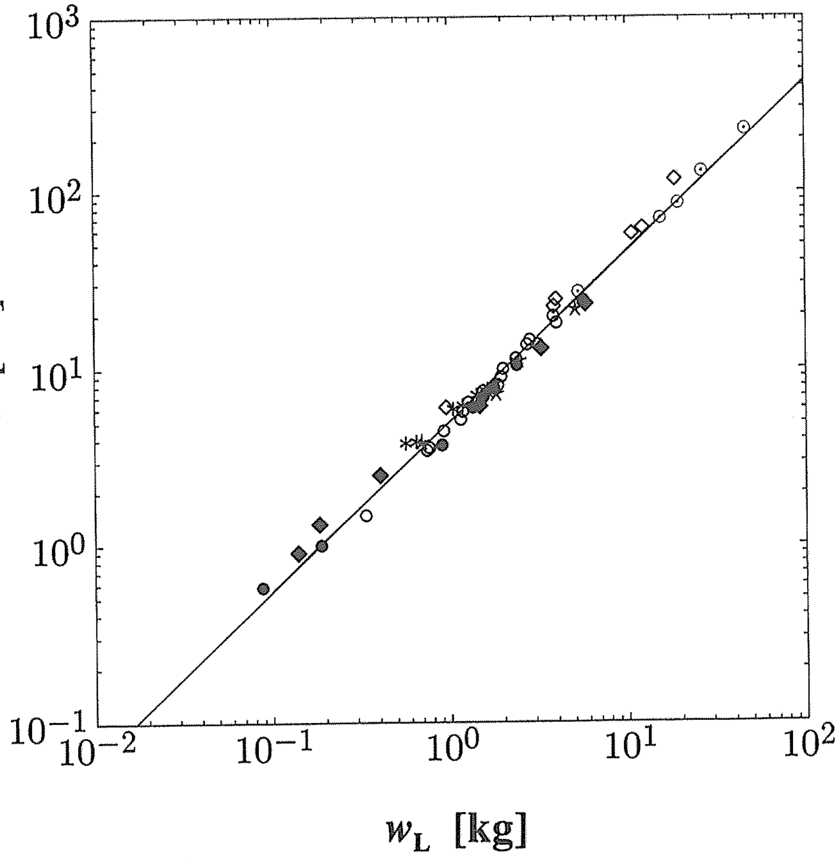

Fig. 11. Allometric regression of leaf area u on leaf weight w_L. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (8), where SE for the allometric constant is 0.0149, r^2 0.988, and n 53.

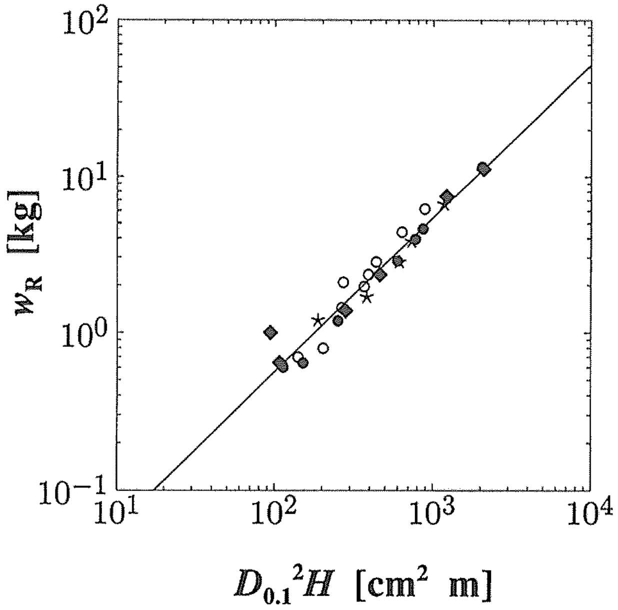

Fig. 12. Allometric relationship between root weight w_R and $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height). The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (9).

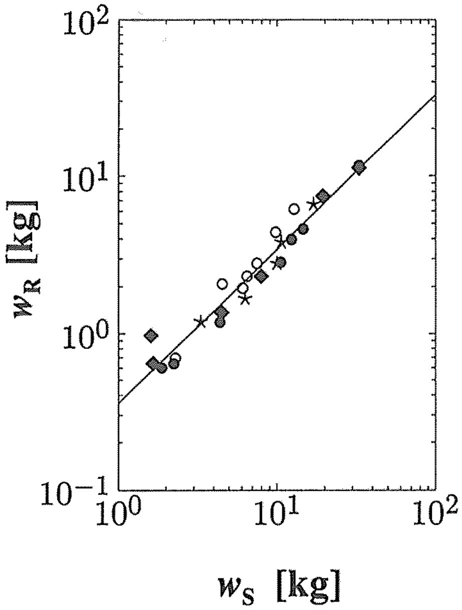

Fig. 13. Root weight w_R-stem weight w_S allometry. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (10), where SE for the allometric constant is 0.0487, r^2 0.947, and n 25.

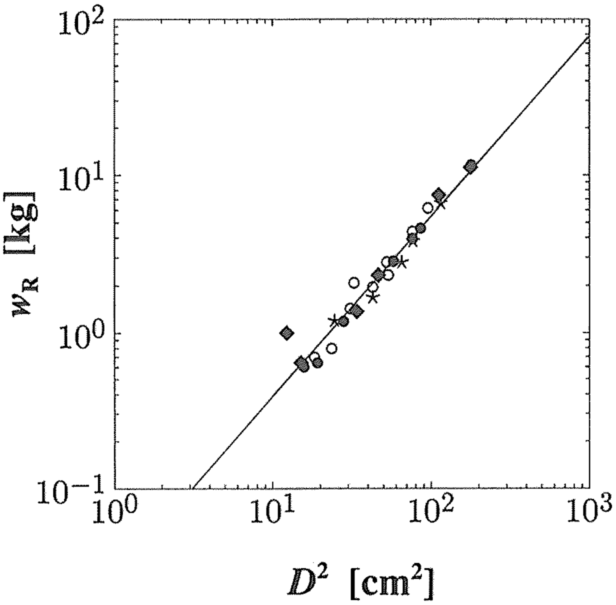

Fig. 14. Allometric regression of root weight w_R on DBH squared D^2. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (11), where SE for the allometric constant is 0.0521, r^2 0.951, and n 27.

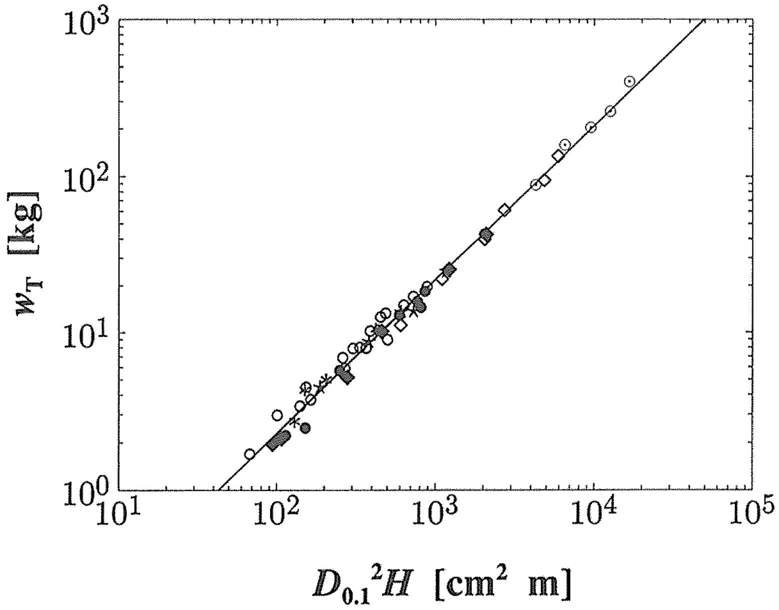

Fig. 15. Allometric relationship between aboveground weight w_T and $D_{0.1}{}^2H$ ($D_{0.1}$; stem diameter at a height of $H/10$, H; tree height). The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (12).

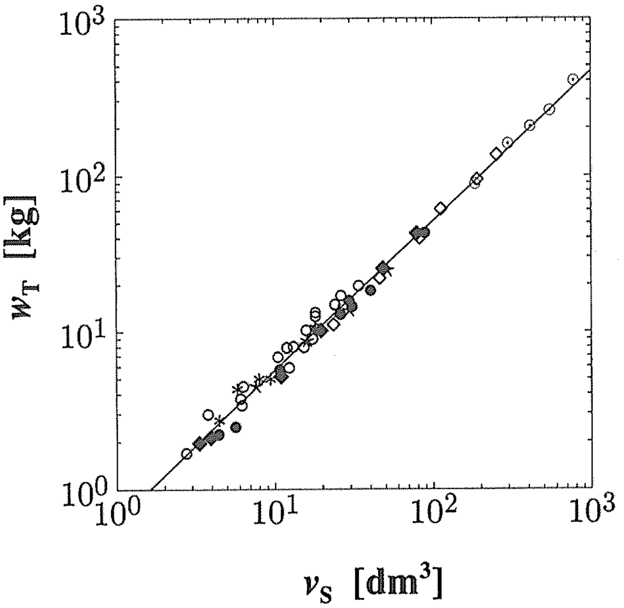

Fig. 16. Allometric regression of aboveground weight w_T on stem volume v_S. The symbols are the same as in Fig. 2. The straight line corresponds to Eq. (13), where SE for the allometric constant is 0.0127, r^2 0.991, and n 53.

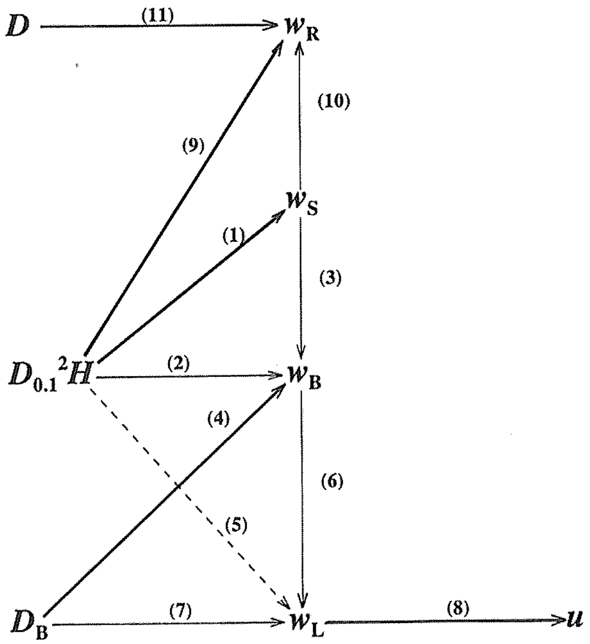

Fig. 17. Diagrammatic representation of procedures for estimating the weight of each organ and leaf area per tree in hinoki stands. Numerals in parentheses refer to Equation No. in the text. For the symbols, see the text. Lines : ···, $r^2<0.90$; —, $0.90\leqq r^2<0.95$, —; $r^2\geqq0.95$.

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ヒノキ林木の相対成長

萩原秋男・横田岳人・小川一治

愛知県内に存在する4箇所のヒノキ林から得られた，林齢が12年から59年に渡る55個体について相対成長関係を調べた。樹高の1/10の高さでの幹直径$D_{0.1}$の自乗に樹高Hを乗じた$D_{0.1}{}^2H$を相対成長式の独立変数とした相対成長式は，個体サイズに関わりなく4林分から得られた個体の器官（幹，枝，葉，根，地上部）重のデータに良く当てはまった。枝重の場合，独立変数として生枝下高での幹直径D_Bの使用が推定精度を高めた。また葉重の場合，独立変数としてD_Bを使用して推定するか，または枝重から推定するかが推定精度を高めるものであった。葉面積の場合には，葉重との相対成長関係から推定するのが適当であった。根重の場合，胸高直径との相対成長式から推定するのが，$D_{0.1}{}^2H$とか幹重との相対成長式から推定するよりも推定の精度を高めた。

Appendix 1. Size dimensions of sample trees. D; stem diameter at breast height of 1.3 m above the ground, $D_{0.1}$; stem diameter at a height of one-tenth of tree height, D_B; stem diameter at a height of clear bole length, H; tree height, H_B; clear bole length, w_S; dry weight of stem, w_B; dry weight of branches, w_L; dry weight of leaves, w_R; dry weight of roots, v_S; stem volume with bark, u; leaf area.

Site	Age	D	$D_{0.1}$	D_B	H	H_B	w_S	w_B	w_L	w_R	v_S	u	Authors
	[yr]	[cm]			[m]		[kg]				$[\mathrm{dm}^3]$	$[\mathrm{m}^2]$	
Nagoya	12	4.77	5.16	3.88	5.70	2.85	2.73	0.469	1.05	–	5.82	5.89	YOKOTA and HAGIHARA (unpublished)
	12	5.28	5.28	3.72	4.67	2.10	1.85	0.280	0.567	–	4.47	3.79	
	15	4.97	5.25	3.34	7.55	4.55	3.95	0.334	0.653	–	9.44	3.85	
	16	7.35	7.67	6.40	7.25	2.65	7.79	1.20	1.42	–	18.1	7.04	
	16	5.22	5.89	3.76	5.94	3.24	3.42	0.333	1.19	–	8.00	6.17	
Inabu	16	3.47	3.79	3.00	4.73	1.66	1.15	0.184	0.338	–	2.76	1.47	HAGIHARA (1978)
	16	3.98	4.62	4.14	4.75	1.25	1.88	0.271	0.776	–	3.79	3.55	
	16	4.93	5.32	3.84	5.84	2.41	2.60	0.323	0.751	–	6.09	3.43	
	16	4.97	5.35	4.97	5.39	1.30	2.73	0.537	1.16	–	6.35	5.12	
	16	5.98	6.46	5.22	6.30	2.25	4.36	0.472	1.96	–	10.5	8.88	
	16	6.43	6.68	5.68	6.85	2.25	5.26	0.636	1.88	–	12.0	7.97	
	16	7.89	8.28	7.56	6.64	1.95	7.73	1.43	3.18	–	18.2	13.5	
	16	8.15	8.59	7.32	6.63	2.30	8.20	2.05	2.74	–	18.2	13.5	
	16	9.14	9.90	8.47	7.46	2.00	11.1	1.67	4.02	–	26.4	17.8	
	17	5.73	6.27	4.54	6.93	3.20	4.54	0.344	0.930	2.06	12.4	4.42	
	17	7.35	7.54	6.53	6.90	2.10	6.51	1.14	2.38	2.30	15.9	11.3	
	17	8.75	9.30	–	7.38	–	9.86	1.99	2.85	4.33	24.2	14.3	
	18	4.30	4.94	3.76	5.80	2.40	2.30	0.273	0.765	0.688	6.21	3.57	
	18	9.80	10.5	8.56	8.10	2.60	12.9	2.66	3.85	6.09	34.1	19.4	
	19	7.26	7.71	6.86	7.40	1.85	7.53	0.642	2.01	2.78	18.7	9.82	
	20	6.53	7.10	6.47	6.70	1.40	5.40	0.953	1.55	–	13.2	7.39	
	20	6.56	6.95	5.16	7.65	3.35	6.12	0.444	1.28	1.93	15.4	6.38	
	20	7.80	8.15	5.83	7.60	3.00	7.10	0.556	1.19	–	17.5	5.70	
	21	4.87	5.95	–	5.77	2.70	–	–	–	0.782	–	–	
	21	5.57	6.45	–	6.40	–	–	–	–	1.41	–	–	
Inabu	22	4.97	5.47	4.23	6.30	2.83	3.32	0.458	0.698	1.20	7.63	3.86	TANAO (1982)
	22	6.56	6.94	5.47	7.95	3.25	6.31	0.772	1.64	1.68	16.1	7.54	
	23	10.8	11.3	9.26	9.17	3.33	17.0	2.54	5.10	6.63	51.9	21.4	
	24	8.79	8.94	6.40	9.18	4.69	10.7	1.08	1.83	3.82	29.8	7.21	
	25	8.09	8.44	7.32	8.60	2.56	9.99	1.04	2.46	2.81	25.5	11.0	
Inabu	24	13.3	13.1	9.99	12.1	4.73	32.8	3.42	5.82	11.0	79.2	22.6	NAKAGAKI (1983)
	24	10.6	10.8	9.04	10.4	3.80	19.4	2.25	3.26	7.32	48.3	12.8	
	24	6.81	7.07	4.65	9.21	5.32	7.92	0.580	1.47	2.29	19.6	6.10	
	24	5.83	6.33	3.50	6.96	4.09	4.46	0.210	0.404	1.35	10.9	2.47	
	24	3.88	4.55	3.60	5.18	1.76	1.65	0.251	0.184	0.630	3.92	1.30	
	24	3.50	4.74	2.86	4.17	2.26	1.60	0.178	0.139	0.957	3.32	0.890	
Inabu	25	13.4	13.7	9.80	11.0	5.75	33.1	3.77	5.68	11.4	89.8	23.8	MORI (1992)
	25	9.29	9.26	5.95	10.1	6.00	14.7	1.00	2.41	4.54	40.7	10.3	
	25	7.64	7.73	5.06	10.0	5.90	10.6	0.703	1.35	2.82	26.2	6.00	
	25	5.32	5.60	4.11	8.04	4.38	4.40	0.323	0.910	1.17	10.8	3.67	
	25	4.39	5.19	2.33	5.67	3.71	2.25	0.106	0.0881	0.632	5.67	0.571	
	25	3.98	4.52	2.26	5.59	3.58	1.89	0.114	0.190	0.594	4.44	0.987	
	25	8.66	9.32	5.36	9.40	5.30	11.7	1.00	1.55	–	31.0	6.85	
	25	8.75	9.14	6.24	9.30	4.48	12.4	1.37	1.78	3.91	29.7	7.76	
Hourai	26	15.9	16.0	10.3	10.7	5.30	42.8	6.82	10.7	–	113	56.5	YAMAJI (1991)
	27	23.1	23.0	16.6	11.3	5.38	97.7	16.5	18.7	–	256	115	
	27	19.6	20.0	13.8	12.2	5.90	71.2	9.98	12.3	–	192	61.0	
	27	13.5	13.9	9.07	10.6	5.60	32.8	2.63	3.87	–	82.9	22.0	
	27	10.6	11.2	7.19	8.87	5.06	16.0	1.77	3.98	–	46.4	24.1	
	27	8.02	8.75	3.66	7.92	5.85	9.60	0.377	0.956	–	23.7	5.99	
Dando	58	29.3	28.9	22.3	20.1	10.6	302	50.5	46.3	–	783	225	IIJIMA (1991)
	58	26.8	25.8	16.1	19.1	12.1	209	23.2	26.5	–	554	129	
	58	23.7	22.9	15.0	18.3	11.2	171	17.0	15.5	–	416	70.1	
	58	19.8	19.4	11.0	17.5	13.1	126	11.6	19.5	–	302	85.5	
	59	16.6	16.4	11.1	16.1	9.60	75.6	7.53	5.32	–	186	26.8	