PERIODICUM BIOLOGORUM
VOL. 110, No 2, 151–156, 2008

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original scientific paper

Biomass of hop hornbeam (*Ostrya carpinifolia* Scop.) shrub on Velebit

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Key words: biomass, hop hornbeam shrub, weight and volume of wood, weight and volume of leaf, diameter of sprout, height of sprout and diameter of crown, the Velebit mountain.

Received April 17, 2007.

Abstract

Background and Purpose: *The paper presents results of measuring wood and leaf mass above the ground level of hop hornbeam shrubs (Ostrya carpinifolia Scop.). An important part of the study describes the development of models for quick and reliable estimation of biomass in forest ecosystems.*

Materials and Methods: *The research was done and samples collected on seaside slopes of Velebit, the area of the Obrovac forestry, on experimental subplots 1 and 2, Jesenice management unit, department 41. Biomass of wood and leaves was measured separately as weight and volume. Independable estimators were the diameter of the sprout, the height of the sprout and the diameter of the crown. The weight of wood and leaves was measured in kg, volume in m^3, diameter of the sprout in cm, height of the sprout and crown diameter in m. General linear modelling was used for the development of the model.*

Results: *The volume of wood in shrubs varied from 18.07 to 65.22 m^3/ha, the volume of leaves from 5.75 to 13.70 m^3/ha. The volume depends on the degradation stage of the shrub, that is the dimensions of the units composing it, their number in the area, entity and the manner of grouping, and the intrinsic value of site. The results show that wood and leaf mass in hop hornbeam shrubs are in particularly strong linear dependence on diameter of the sprout, height of the sprout and crown diameter. Linear regression coefficient between the volume, as well as the weight of the wood and the diameter of the sprout,was 0.920 at 30 cm height above the ground level, and 0.898 between the volume, as well as the weight of the leaves and the crown of the sprout.*

Conclusions: *The biomass above the ground level in hop hornbeam shrubs can at best be estimated by univariate regression analysis on the basis of sprout diameter, although this regression model yields nearly equal results if based on the height of the sprout and the diameter of the crown. Multivariate regression models do not give much better results than the univariate model, especially by the diameter of the sprout as the best independable estimator, where the values are nearly equal.*

INTRODUCTION

Great attention has been given to research of biomass in forest ecosystems in the world and many authors wrote about it *(1, 2, 3, 4, 6, 9, 10, 17)*. In Croatia, the research of biomass in middle aged and old entities of peduncled oak, ash, beech and fir started in 1971 at the Faculty of forestry in Zagreb, yet only of the biomass of the upper part of the tree. Since 1985, besides components of biomass above soil, the root system of medium component trees in new stands (7) has been researched.

There has been very little research of the Mediterranean karst area of Croatia *(5, 8, 14, 15, 16)*. The authors therefore wanted to continue the research, which is very important for good and rational management of forests and forest ground in karst, and for economic and other useful functions which forests have. During research the data about biomass for some important species in Eumediterranean and Submediterranean part of Croatia were collected and partly published.

The data for hop hornbeam (*Ostrya carpinifolia* Scop.), which together with pubescent oak form an important unity of Mediterranean-mountainous vegetation area of Adriatic slopes of Dinaric Mountains, including some islands, are presented here. On Adriatic slopes of Velebit it appears in the conditions of cold climate and it is the last forest unity of continental vegetation, that is toward European mountainous vegetation area *(12)*. It comes above the forest of pubescent oak and oriental hornbeam. In this area it comes in the form of open shrub, a rarely short forest. Since the browsing and uncontrolled cut had stopped in the last few years, the first signs of progression appeared. In the florist component which these unities have, except pubescent oak (*Quercus pubescens* Willd.) and hop hornbeam (*Ostrya carpinifolia* Scop.), flowering ash (*Fraxinus ornus* L.) and Montpelier maple (*Acer monspessulanum* L.) are prominent in the layer of trees and bushes and *Sesleria auctumnalis* Scop*., Asparagus tenuifolius* L*., Tamus communis* L*., Carex humilis* Leyss*., Teucrium chamaedrys* L*., Aristolochia lutea* L. and others in the layer of ground vegatation. Except for getting data about leaf and wood mass, the important part of this research also comprised the development of regression models for quick and safe estimation of biomass above soil area in the shrubs of hop hornbeam, on the basis of independent estimators (diameter of sprout, height of sprout and diameter of sprout´s crown), as parameters that can be measured on the ground with satisfying exactness.

MATERIAL AND METHODS

The research was done on Adriatic slopes of Velebit, the longest and best known Croatian mountain, in Jesenice management unit, on experimental plots with shrubs of hop hornbeam which are reprensentative for the researched area. The plots were 1 ha large, and subplots 1 and 2, which were chosen and on which measurements on vegetation were done and their main structural data obtained, were 25 m^2 (5 x 5 m) big. They were situated at 690 to 700 m above sea level and were built of cretaceous limestone, with shallow and very sceletal brown soil of characteristic A-(B)rz-R profile. Cover on the subplots ranged from 41.29% (plots 2) to 81.64% (plots 1), and medium height of sprouts on hop hornbeam was 3.61 or 1.71 m (maximal 4.15). According to Köppen´s classification and, using the data of Seletković and Katušin *(13)* obtained at meteorological stations Zadar and Knin from 1961 to 1990, this area has the climate type Cfsax with charateristic sum of yearly rainfall about 1,300 mm and average yearly temperatures 13.1 °C. It is medium warm rainy climate, with hot summers and medium monthly temperature of the warmest month, July, above 22 °C, the coldest month January, below -3 °C. The rainy season has spring and autumn – winter maximum, the driest part of the year is in warm season.

Every plot was picketed and a net of squares made where every tree and bush with crown projection was drawn on milimetar paper and numbered. This enabled planimetric determination of the area of shaded soil by crowns of every sprout. The land scheme of the projection of the crowns on the milimeter paper was scanned and transformed into digital form by using Auto Cad programme. After cutting measurements of diameter of every sprout at 30 cm height above the ground, the height of sprout and, diameter of crown determined, and leaf was separated from the tree. Specific weight of wood and leaf was measured by xylometer to get data about relation between weight and volume. All data were noted and put in a computer data bases. The entity of 142 sprouts of hop hornbeam, 4 pubescent oaks, 3 flowering ashes and 1 Montpelier maple were analyzed. Wood weight and weight of leaf were measured in kg, volume in m^3, diameter of sprout in cm, height of sprout and diameter of crown in m. The diameter of crown was obtained as an arithmetic mean of the biggest and the smallest diameter through the center of sprouts.

Basic sample statistics and correlation coefficients are shown in Tables 2 and 3. The dependence of variables of biomass (wood and leaf) on diameter of sprout, height of sprout and diameter of crown, is stated in terms of independent variables, using the general linear model

$$y = b_o + b_i . x_i$$

where y is a biomass of dependent variable (weight of wood, weight of leaf, volume of wood, volume of leaf), x_i are independable variables (stem diameter and height, diameter of crown stem) and b_o and b_i are empirical parameters.

RESULTS AND DISCUSSION

General structural data about investigated shrubs of hop hornbeam on Velebit are shown in Table 1. Besides hop hornbeam on experimental plots, other species of tree association of pubescent oak and hop hornbeam (pubescent oak, hop hornbeam, Montpelier maple) were observed. According to data on experimental plots, 25 m^2 cover included 81.64% hornbeam hop shrub of medium height 2.40 m (hop hornbeam 1.71 m, maximum 4.15 m), tree volume amounted to 0.163 m^3, leaf volume was 0.034 m^3, while shrub ground cover was 41.29%, medium height 1.99 (hop hornbeam 1.36 m), wood volume was 0.044 m^3, leaf volume was 0.0014 m^3.

Besides determining wood and leaf biomass in hop hornbeam shrubs by multivariable and univariable regression analysis in dependance to weight, wood and leaf volume with regard to diameter and height of sprout

TABLE 1

Biomass of hop hornbeam shrubs (*Ostrya carpinifolia* Scop.) on Velebit.

Plot number	Tree species	Plot (25 m²)								
		Number of stumps	Number of sprouts in stump	Medium height of sprouts	Medium diameter of sprouts	Plot coverage	Wood weight	Foliage weight	Wood volume	Foliage volume
				m	cm	%	kg	kg	m^3	m^3
1	Ostrya caroinifolia Scop.	7	97	1.71	2.25	69.36	147.16	19.50	0.138	0.0314
	Quercus pubescens Willd.	1	2	2.78	8.19	5.80	19.97	1.27	0.018	0.0017
	Fraxinus ornus L.	1	2	2.61	5.03	3.52	4.42	0.42	0.004	0.0005
	Acer monspessulanum L.	1	1	2.48	3.69	2.96	2.80	0.40	0.003	0.0006
	Σ	10	102	2.40	4.79	81.64	174.36	21.59	0.163	0.0342
2	Ostrya carpinifolia Scop.	3	45	1.36	1.87	33.72	41.86	8.01	0.039	0.0127
	Quercus pubescens Willd.	1	2	2.30	4.31	4.70	4.67	0.99	0.004	0.0013
	Fraxinus ornus L.	1	1	2.32	3.47	2.87	1.47	0.28	0.0014	0.0004
	Σ	5	48	1.99	3.22	41.29	48.00	9.28	0.044	0.0144

TABLE 2

Statistical values for the observed growth of hop hornbeam sprouts.

Variable	Descriptive Statistics (Velebit-1)							
	Valid N	Mean	Sum	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Diameter of sprout (cm)	142	2.170704	308.2400	0.250000	9.02000	3.627846	1.904691	0.159838
Height of sprout (m)	142	1.612042	228.9100	0.300000	4.15000	1.013599	1.006777	0.084487
Crown diameter (m)	142	0.703239	99.8600	0.100000	1.95000	0.162309	0.402876	0.033809
Foliage weight (kg)	142	0.193380	27.4600	0.005000	1.77000	0.087064	0.295066	0.024761
Wood weight (kg)	142	1.329366	188.7700	0.010000	14.63500	5.571653	2.360435	0.198083
Foliage volume (m3)	142	0.000312	0.0442	0.000010	0.00285	0.04420	0.000476	0.04420
Wood volume (m3)	142	0.001247	0.1771	0.000010	0.01374	0.000005	0.002216	0.000186

were analyzed, as independent variables. In Tables 2 and 3 statistical values are shown of measured sprouts of hop hornbeam and correlation coefficients between the observed variables.

Table 3 shows that the relation between all variables is very strong. Correlation coefficient ranges from 0.78 to 0.95.

The highest correlation coefficient was determined for wood weight and leaf weight, and volume of wood and leaf volume, where r=0.95 (Table 3 and Figure 1). Exceptionally strong relation was also established for the volume of wood, that is the weight of wood and sprout diameter (r=0.93), also for the height of sprout with sprout diameter where r=0.93 (Table 3 and Figure 1). Very strong relation was established for all other research variables with correlation coefficients from 0.78 to 0.90.

On the basis of sprout diameter at 30 cm above the ground, its height and crown diameter, as independent variables, and weight and volume of wood and leaf were estimated by univariant and multivariant regression analysis. Table 4 shows the regression models for estimation of biomass variables of hop hornbeam, that is the results of linear equation of wood and leaf weight and volume and independent variables and their combination. The figure includes estimation of regression parameters with coeffi-

TABLE 3

Corelations coefficients between observed variables

Variable	Correlations (Velebit-1) Marked correlations are significant at p < .05000 N=142 (Casewise deletion of missing data)						
	Diameter of sprout (cm)	Height of sprout (m)	Crown diameter (m)	Foliage weight (kg)	Wood weight (kg)	Foliage volume (m3)	Wood volume (m3)
Diameter of sprout (cm)	1.00	0.93	0.87	0.90	0.93	0.90	0.93
Height of sprout (m)	0.93	1.00	0.78	0.78	0.84	0.78	0.84
Crown diameter (m)	0.87	0.78	1.00	0.85	0.79	0.85	0.79
Foliage weight (kg)	0.90	0.78	0.85	1.00	0.95	1.00	0.95
Wood weight (kg)	0.93	0.84	0.79	0.95	1.00	0.95	1.00
Foliage volume (m3)	0.90	0.78	0.85	1.00	0.95	1.00	0.95
Wood volume (m3)	0.93	0.84	0.79	0.95	1.00	0.95	1.00

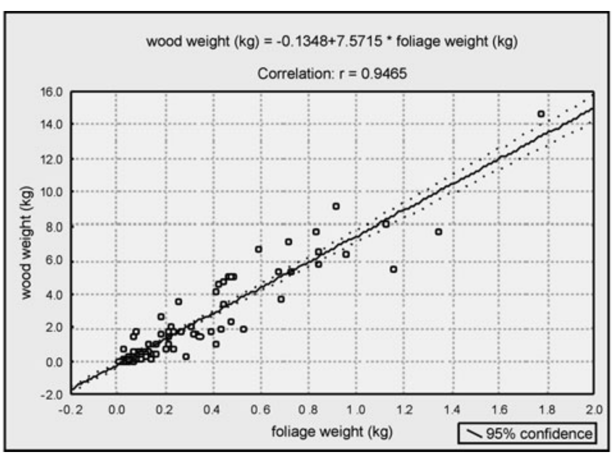
cient correlation (R) and adjusted coefficients of determination (R^2), which are indispensible for estimation of usage of the proposed models.

Univariable regression analysis revealed significant dependence of weight, that is the volume of wood and leaves on sprout diameter, height of the sprout and crown diameter. Results show that sprout diameter accounts for 85.9% variability of weight and tree volume ($R^2 = 0.859$; $p<0.000$), and 80.5% weight and volume of leaves ($R^2 = 0.805$; $p<0.000$), Figure 2. The height of sprout accounts for 70.6% variability of weight and volume of wood ($R^2 = 0.706$; $p<0.000$) and 61.3% of weight and volume of leaves ($R^2 = 0.613$; $p<0.000$), Figure 2, and crown diameter accounts for 62.7% of weight and volume of wood ($R^2 = 0.627$; $p<0.000$) and 71.7% of weight and leaf volume ($R^2 = 0.717$; $p<0.000$), Figure 2.

Multivariant regression models (R_4 in Table 4) do not give much better results from the univariant ones (R_1, R_2, R_3 in Table 4), especially for the sprout diameter as the best independent estimator, where the values are nearly equal. The results show that sprout diameter and its height with crown diameter account for 86.3% of variability in weight and wood volume ($R^2 = 0.863$) and 83.7% of weight and leaf volume ($R^2 = 0.837$).

Results of this regression model are mainly due, with regard to weight and wood volume, to sprout diameter ($r = 1.174$; $p<0.000$), then sprout height ($r = -0.198$; $p<0.026$), the least crown diameter, which is not significant because of the strong interrelation of the variable ($r = 0.07$; $p<0.257$). Regarding weight and leaf volume, what mostly accounts for the regression model are the diameter sprout ($r = 1.019$; $p<0.000$), then the crown diameter ($r = 0.234$;$p<0.001$), the least the height of the sprout ($r = 0.347$; $p<0.000$).

On the basis of the data collected on experimental plots with hop hornbeam shrubs on Velebit and analyses of the influence of sprout diameter and height and of the



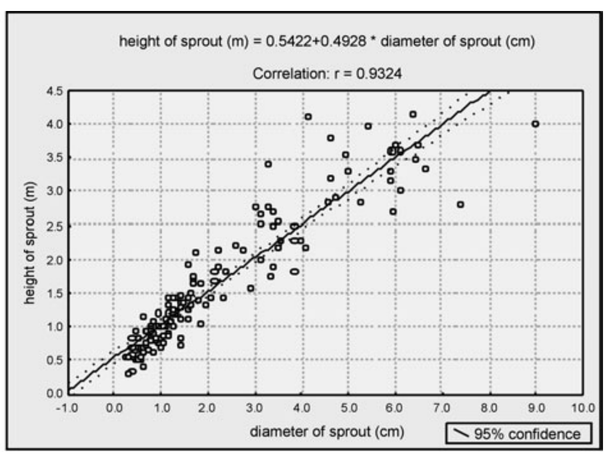


Figure 1. *Regression analysis of dependence of wood weight on foliage weight and of the height of sprout on sprout diameter*

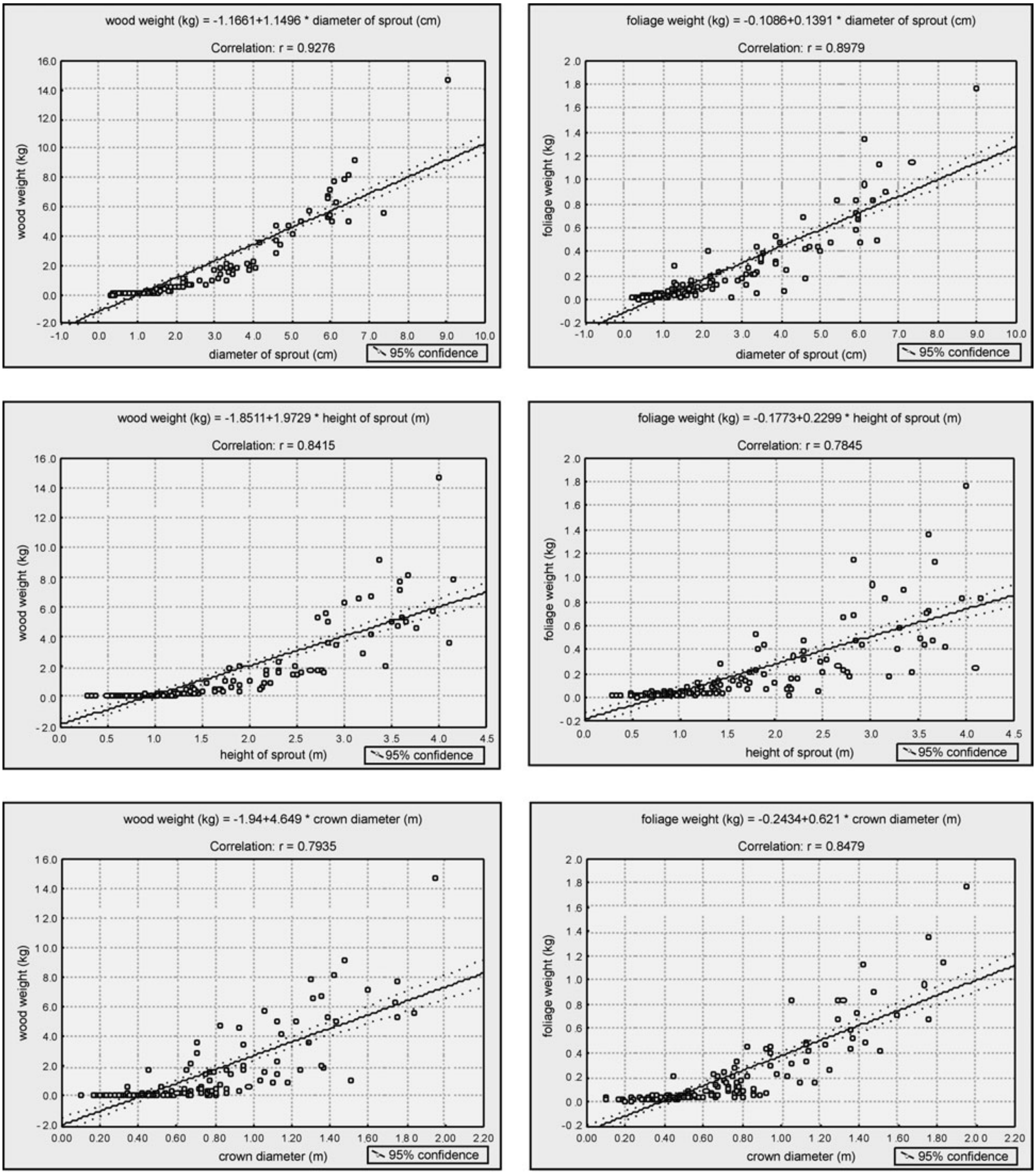


Figure 2. *Regression analysis of dependence of wood and leaf weight on the diameter of sprout, height of sprout and crown diameter*

diameter of sprout crown, as independent variables, on the volume, that is, on the weight of wood and leaves, the following conclusions can be drawn:

1. On the surface of 25 m^2, where hop hornbeam shrubs made 81.64%of ground cover, medium height was 2.40 m and average sprout diameter 4.79 cm, the volume of wood was 0.163 m^3, the volume of leaf 0.034 m^3, while in shrubs where ground cover was 41.29%, medium height of shrub was 1.99 m and average sprout diameter 3.22 cm, the volume of wood is 0.044 m^3, the leaf volume 0.014 m^3.

2. Univariate regression analysis revealed a significant dependence of the weight and volume of wood and leaf on diameter and height of sprout and crown diameter.

TABLE 4

Parameters of univariate and multivariate regression for weight and volume of wood and foliage in hop hornbeam shrubs on Velebit.

Univariate regression				
Independent variables (x)	Dependent variables (y)			
	Wood weight	Foliage weight	Wood volume	Foliage volume
	kg		m^3	
Diameter of sprout (x)				
R_1	0.928	0.898	0.927	0.898
adjusted R^2	0.859	0.805	0.859	0.805
estim. regres. parameter	0.928	0.898	0.927	0.898
t	29.388	24.136	29.341	24.134
p	0.000	0.000	0.000	0.000
b_o	-1.166	-0.109	-0.001	-0.000
b_1	1.149	0.139	0.001	0.000
Height of sprout (x)				
R_2	0.841	0.784	0.841	0.784
adjusted R^2	0.706	0.613	0.705	0.613
estim. regres. parameter	0.841	0.784	0.841	0.784
t	18.429	14.968	18.392	14.965
p	0.000	0.000	0.000	0.000
b_o	-1.851	-0.177	-0.002	-0.000
b_1	1.973	0.230	0.002	0.000
Crown diameter (x_1)				
R_3	0.793	0.848	0.794	0.848
adjusted R^2	0.627	0.717	0.628	0.717
estim. regres. parameter	0.793	0.848	0.794	0.848
t	15.427	18.927	15.453	18.930
p	0.000	0.000	0.000	0.000
b_o	–1.940	–0.243	-0.002	-0.000
b_1	4.649	0.621	0.004	0.001
Multivariate regression				
Diameter of sprout (x_1) Height of sprout (x_2) Crown diameter (x_3)				
R_4	0.930	0.917	0.930	0.917
adjusted R^2	0.863	0.837	0.863	0.837
estim.regres.parameter(x_1)	1.174	1.019	1.173	1.019
estim.regres.parameter(x_2)	–0.197	–0.348	–0.198	–0.348
estim.regres.parameter(x_3)	–0.072	0.234	–0.070	0.234
t_1	10.602	8.440	10.581	8.442
t_2	–2.246	–3.644	–2.262	–3.647
t_3	–1.138	3.368	–1.097	3.370
p_1	0.000	0.000	0.000	0.000
p_2	0.026	0.000	0.025	0.000
p_3	0.257	0.001	0.274	0.001
b_o	–0.787	–0.105	–0.001	–0.000
b_1	1.455	0.158	0.001	0.000
b_2	–0.461	–0.102	–0.000	–0.000
b_3	–0.425	0.171	–0.000	0.000

3. Multivariate regression models do not give much better results than the univariate ones, especially regarding sprout diameter as the best independent estimator where the values were nearly equal.

4. All obtained models can be applied for quick and reliable biomass estimation of a specimen (wood and leaves) in hop hornbeam shrubs.

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