Regression models for estimating biomass of resprouted pubescent oak (Quercus pubescens Willd.), italian oak (Quercus frainetto Ten.) and Holm oak (Quercus ilex L.)

Topić, Vlado; Antonić, Oleg; Španjol, Željko; Vrdoljak, Žarko

Source / Izvornik: **Glasnik za šumske pokuse: Annales Experimentis Silvarum Culturae Provehendis, 2000, 37, 123 - 131**

Journal article, Published version
Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

Permanent link / Trajna poveznica: https://urn.nsk.hr/urn:nbn:hr:108:819882

UDK 630*222+537+(4-015) (Quercus pubescens Willd., Q. frainetto Ten., Q. ilex L.)

REGRESSION MODELS FOR ESTIMATING BIOMASS OF RESPROUTED PUBESCENT OAK (*QUERCUS PUBESCENS* WILLD.), ITALIAN OAK (*QUERCUS FRAINETTO* TEN.) AND HOLM OAK (*QUERCUS ILEX* L.)

VLADO TOPIĆ[1], OLEG ANTONIĆ[2], ŽELJKO ŠPANJOL[3], ŽARKO VRDOLJAK[4]

[1]Institute for the Adriatic Cultures and Karst Melioration, Put Duilova 11, 21000 Split, Croatia
[2]Rudjer Bošković Institute, Bijenička 54, 10000 Zagreb, Croatia
[3]Faculty of Forestry, University of Zagreb, Svetošimunska 25, 10000 Zagreb, Croatia
[4]Viška 24, 21000 Split, Croatia

The development of models for the quick biomass estimation of dominant Mediterranean tree and shrub species is an important part of long-term research on competition between forestry and livestock grazing in Croatia. This paper introduces regression models for estimating biomass above the ground in the second growth forest that were developed for pubescent oak (*Quercus pubescens* Willd.), Italian oak (*Quercus frainetto* Ten.) and the holm oak (*Quercus ilex* L.). Samples were collected in Dalmatia, Croatia. Foliage and wood biomass was independently measured as weight and volume. Independent estimators were crown diameter, height and number of stems. General linear modelling was used for model development. The yielded models are appropriate for the quick and confident estimation of the population biomass (foliage and/or wood) of the examined oak species in second growth forests.

Key words: foliage volume and weight, Mediterranean oaks, second growth forest, wood volume and weight

INTRODUCTION

The biomass of trees and its components is a parameter which is hard to measure but is of utmost importance for forest management (Attiwill and Ovington, 1968). Consequently, the building of models for tree biomass estimation as a function of easily measurable dendrometric variables (see e.g. Baskerwille, 1965, Whittaker and Woodwell, 1968, Cunia, 1986 or Lukić and Kružić, 1996) is an important subject of forest research.

Pubescent oak (*Quercus pubescens* Willd.), Italian oak (*Quercus frainetto* Ten.) and holm oak (*Quercus ilex* L.) belong to the major tree species of the Croatian Adriatic coast and islands. The first two are sub-Mediterranean species and the third is an eu-Mediterranean species. The natural areas of spread of these species are significantly reduced, basically due to constant human impact during history. Their stands in Croatia, as well as elsewhere in the Mediterranean region, are mainly second growth forests, resprouted after repetitive cutting for firewood. Forests from seeds are rare, basically due to the negative impact of goat and sheep grazing which can also often endanger the resprouting of the existing second growth forest.

Competition between forestry and livestock grazing in Mediterranean forests and related cost-benefit analyses are the objects of long-term research in Croatia (e.g. Topić and \upe, 1996). An important part of this research comprises the development of models for the quick biomass estimation of dominant trees and shrubs that are being grazed by livestock. The basic aim of this paper was the building and optimisation of multivariate regression models for the estimating of the biomass of the three mentioned oak species as a function of easily measurable dendrometric variables.

MATERIAL AND METHODS

Samples were collected on the typical second-growth stands for each oak species, located in Dalmatia, Croatia. Pubescent and Italian oak were analysed on an individual tree basis and holm oak was analyzed on a stem basis (due to the usually large number of stems in one individual tree). In total, 129 individuals of pubescent oak, 176 individuals of Italian oak and 162 stems (44 individuals) of holm oak were sampled for foliage volume and weight, wood volume and weight, height and crown diameter. Weights were measured in kg, volumes were measured in m^3, heights were measured in decimeters and crown diameters were measured in centimeters.

Foliage volume and weight, wood volume and weight, and also total volume and weight (derived as the sum of foliage and wood) were examined as separate dependent variables in terms of height, crown diameter and number of stems as independent variables. The reason for the inclusion of a number of stems as an independent variable is different for the holm oak in relation to the other two oak species. For the holm oak, this variable could describe competition between stems of the same individual (an increasing number of stems decreases the biomass of a particular stem). For the other two oak species, this variable could be a multiplier (an increasing number of stems increases individual biomass). The basic statistics of the sampled independent variables are shown in Table 1.

Table 1.Basic statistics of the sampled independent variables. N – number of observations, AVR – average, MED – median, MIN – minimum, MAX – maximum, LQU – lower quartile, UQU – upper quartile, STD – standard deviation.

	N	AVR	MED	MIN	MAX	LQU	UQU	STD
pubescent oak (*Quercus pubescens*)								
number of stems	129	1.83	1	1	8	1	2	1.19
plant height (m)	129	2.85	2.9	0.5	4.7	2.3	3.5	0.93
crown diameter (m)	129	1.69	1.75	0.50	3.25	1.35	2.00	0.53
Italian oak (*Quercus frainetto*)								
number of stems	176	2.74	2	1	11	1	4	1.88
plant height (m)	176	2.70	2.5	1	5.7	2.1	3.3	0.88
crown diameter (m)	176	1.70	1.75	0.30	4.00	1.20	2.10	0.75
holm oak (*Quercus ilex*)								
number of stems	44	3.68	2	1	12	1	5	3.14
stem height (m)	162	3.55	3.6	1.8	5.6	3.1	4.2	0.80
crown diameter (m)	162	0.65	0.50	0.10	1.90	0.30	1.00	0.46

Multivariate regression models for estimating biomass variables as a function of the mentioned three independent variables were derived using a general linear modelling procedure (Ott, 1993). The model was generally defined as:

$$y = b_0 + S\, b_{ij} x_i^j \quad 1)$$

where y is a biomass variable (foliage volume, foliage weight, wood volume, wood weight, total volume or total weight), x_i is an independent variable (number of stems, height or crown diameter, i = 1 to 3), j is 1 or 2 (linear or quadratic term) and b_0 and b_{ij} are empirical parameters. Each included term was examined as a separate regressor in the general linear model. An optimal model for each oak species and for each biomass variable was found by using a backward stepwise procedure (Ott, 1993). The significance of the predictive power of the regressors was tested using t-test (Ott, 1993).

RESULTS AND DISCUSSION

The statistics and empirical parameters of the optimised regression models are presented in Table 2 for pubescent oak, in Table 3 for Italian oak and in Table 4 for holm oak. The relations between estimated and observed values are shown in Fig. 1.

Summarising the results presented in Tables 2, 3 and 4, the following can be concluded:

1. All regressors selected by the backward stepwise procedure are significant according to the t-test at a probability level of p=0.05
2. The set of selected regressors is different for the particular oak species and for the particular biomass variable.

Fig. 1. Scatterplots of observed values (y-axis= of biomass variables versus respective values predicted by regression models in terms of independent variables (x-axis). 1st row - foliage weight, 2nd row - wood weight, 3rd row - total weight. 1st column - pubescent oak (Quercus pubescense), 2nd column - italian oak (Quercus frainetto), 3rd column - holm total volume are the same, but differently scaled.

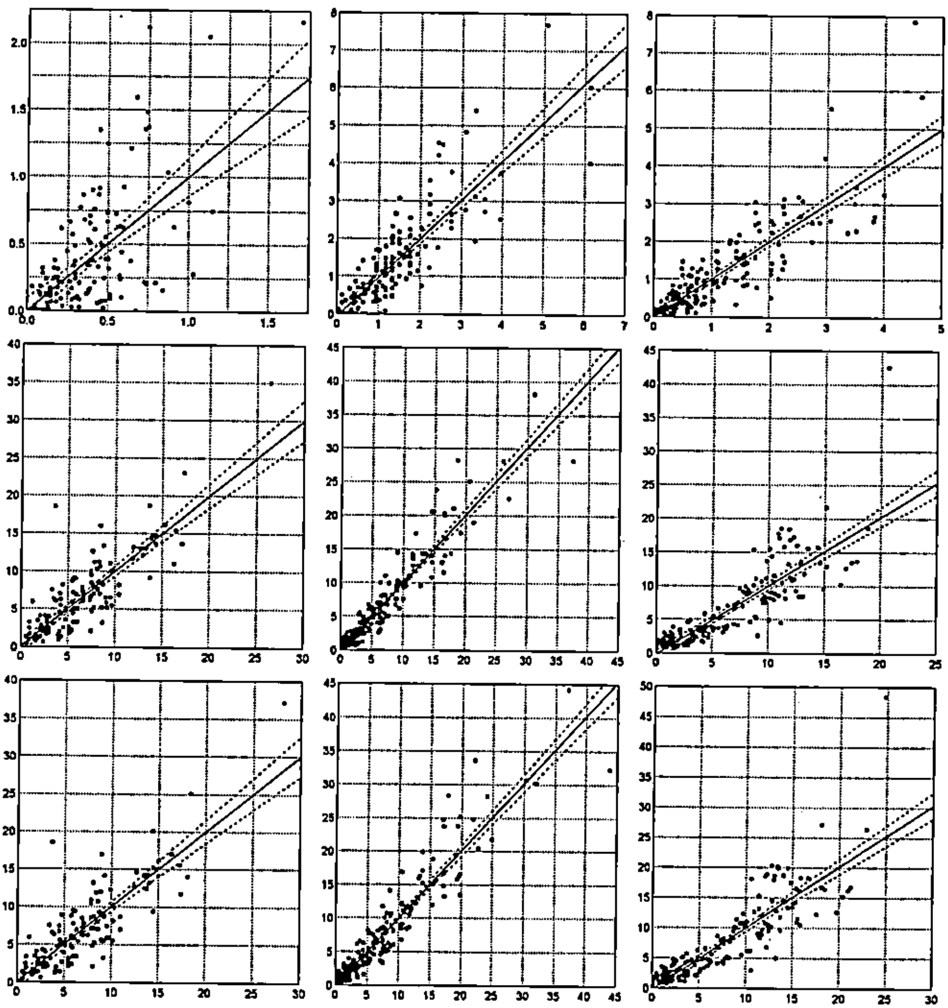

Table 2. Regression models for estimating biomass variables of pubescent oak (*Quercus pubescens*). General linear model follows equation $y = b_0 + \Sigma\, b_{ij} x_i^j$, $i = 1$ to 3, $j = 1$ to 2, where y is a biomass variable (foliage, wood or total weight or volume) b_0 and b_{ij} are empirical parameters, x_i is an independent variable, ns is number of stems, h is height (m), cd is crown diameter (m) and 2 indicates quadratic term. Weights are in kg and volumes are in m^3. R is regression coefficient. F is the ratio between regression mean square and residual mean square and p(F) is respective probability. SE(b) is standard error of respective empirical parameter (b). The t-value and respective p-value are used to test the hypothesis that respective empirical parameter (b) is equal to zero. Underlining indicates insignificance of the respective regressor after the model optimisation using the backward stepwise method.

	model statistics			intercept	ns	ns2	h	h2	cd	cd2
foliage weight	R	0.6544	b	0.3381390	–	–	–	0.0240438	-0.6402174	0.2863598
	F	31.199	SE(b)	0.2114261	–	–	–	0.0064921	0.2618475	0.0743543
	p(F)	0.0000	t	1.5993245	–	–	–	3.7035617	-2.4450007	3.8512877
			p(t)	0.1122731				0.0003177	0.0158787	0.0001866
wood weight	R	0.8404	b	6.3705735	1.0559999	–	-3.4959148	1.1960273	-7.4580808	3.1943473
	F	59.149	SE(b)	2.4714032	0.2559427	–	1.4921459	0.2570105	2.4419461	0.6894039
	p(F)	0.0000	t	2.5777151	4.1259236	–	-2.3428774	4.6536135	-3.0541545	4.6334920
			p(t)	0.0111252	0.0000675		0.0207411	0.0000083	0.0027674	0.0000090
foliage volume	R	0.6442	b	0.0004913	–	–	–	0.0000331	-0.0009164	0.0003981
	F	29.562	SE(b)	0.0002916	–	–	–	0.0000090	0.0003611	0.0001025
	p(F)	0.0000	t	1.6851724	–	–	–	3.6973855	-2.5378671	3.8826676
			p(t)	0.0944503				0.0003247	0.0123818	0.0001664
wood volume	R	0.8316	b	0.0064957	0.0009087	–	-0.0041145	0.0012610	-0.0062173	0.0027665
	F	55.152	SE(b)	0.0023720	0.0002457	–	0.0014321	0.0002467	0.0023437	0.0006617
	p(F)	0.0000	t	2.7384572	3.6991338	–	-2.8729616	5.1119101	-2.6527215	4.1810809
			p(t)	0.0070899	0.0003247		0.0047914	0.0000012	0.0090377	0.0000546
total weight	R	0.8430	b	6.5410384	1.0988442	–	-3.4300505	1.2134589	-8.0974650	3.4678587
	F	60.408	SE(b)	2.5962058	0.2688674	–	1.5674972	0.2699891	2.5652612	0.7242178
	p(F)	0.0000	t	2.5194607	4.0869366	–	-2.1882338	4.4944729	-3.1565850	4.7884192
			p(t)	0.0130353	0.0000783		0.0305421	0.0000159	0.0020078	0.0000047
total volume	R	0.8348	b	0.0068134	0.0009587	–	-0.0040640	0.0012909	-0.0071195	0.0031464
	F	56.563	SE(b)	0.0025496	0.0002640	–	0.0015394	0.0002651	0.0025193	0.0007112
	p(F)	0.0000	t	2.6722716	3.6309335	–	-2.6399893	4.8686992	-2.8260377	4.4238682
			p(t)	0.0085552	0.0004128		0.0093650	0.0000034	0.0055017	0.0000211

3. The estimation of the foliage biomass variables is less reliable than the estimation of the wood and total biomass variables for all three oak species.
4. The best models were yielded for Italian oak and the worst models were yielded for pubescent oak.
5. All models are applicable for the quick and confident estimation of the population biomass (foliage, wood and total) of examined oak species in second growth forests, but not for the estimation of individual tree biomass.

Table 3.Regression models for estimating biomass variables of Italian oak (*Quercus frainetto*). General linear model follows equation $y = b_0 + \Sigma\, b_{ij} x_i^j$, $i = 1$ to 3, $j = 1$ to 2, where y is biomass variable (foliage, wood or total weight or volume) b_0 and b_{ij} are empirical parameters, x_i is independent variable. ns is number of stems, h is height (m), cd is crown diameter (m) and 2 indicates quadratic term. Weights are in kg and volumes are in m^3. R is regression coefficient. F is the ratio between regression mean square and residual mean square and p(F) is respective probability. SE(b) is standard error of respective empirical parameter (b). The t-value and respective p-value are used to test the hypothesis that respective empirical parameter (b) is equal to zero. Underlining indicates insignificance of the respective regressor after the model optimisation using the backward stepwise method.

	model statistics			intercept	ns	ns2	h	h2	cd	cd2
foliage weight	R	0.8732	b	-0.2655202	–	–	–	–	–	0.4004902
	F	558.32	SE(b)	0.0758318	–	–	–	–	–	0.0169493
	p(F)	0.0000	t	-3.5014341	–	–	–	–	–	23.6287363
			p(t)	0.0005880	–	–	–	–	–	0.0000000
wood weight	R	0.9420	b	-0.9009434	0.7215554	-0.0644158	–	0.4078357	-3.7703674	2.6047109
	F	268.06	SE(b)	0.8756470	0.2785582	0.0317769	–	0.0454533	0.8181532	0.2176649
	p(F)	0.0000	t	-1.0288888	2.5903215	-2.0271283	–	8.9726230	-4.6083881	11.9666117
			p(t)	0.3049936	0.0104210	0.0442114	–	0.0000000	0.0000079	0.0000000
foliage volume	R	0.8421	b	-0.0003422	–	–	–	–	–	0.0005689
	F	424.13	SE(b)	0.0001236	–	–	–	–	–	0.0000276
	p(F)	0.0000	t	-2.7688509	–	–	–	–	–	20.5943873
			p(t)	0.0062354	–	–	–	–	–	0.0000000
wood volume	R	0.9308	b	0.0004642	–	–	–	0.0003308	-0.0033874	0.0024183
	F	371.52	SE(b)	0.0007246	–	–	–	0.0000416	0.0008142	0.0002179
	p(F)	0.0000	t	0.6405384	–	–	–	7.9587065	-4.1603364	11.0982873
			p(t)	0.5226750	–	–	–	0.0000000	0.0000501	0.0000000
total weight	R	0.9418	b	-1.2920462	0.8487995	-0.0812481	–	0.4281081	-3.9142891	3.0179155
	F	266.73	SE(b)	1.0345319	0.3291022	0.0375427	–	0.0537008	0.9666060	0.2571599
	p(F)	0.0000	t	-1.2489187	2.5791363	-2.1641501	–	7.9721010	-4.0495189	11.7355622
			p(t)	0.2134119	0.0107511	0.0318482	–	0.0000000	0.0000779	0.0000000
total volume	R	0.9354	b	-0.0014801	0.0009017	-0.0000844	–	0.0003996	-0.0036713	0.0029846
	F	237.85	SE(b)	0.0010883	0.0003462	0.0000395	–	0.0000565	0.0010169	0.0002705
	p(F)	0.0000	t	-1.3599907	2.6044517	-2.1364602	–	7.0725727	-3.6104252	11.0323729
			p(t)	0.1756337	0.0100170	0.0340725	–	0.0000000	0.0004020	0.0000000

Table 4. Regression models for estimating biomass variables of holm oak (*Quercus ilex*). General linear model follows equation $y = b_0 + \Sigma\, b_{ij} x_i^j$, $i = 1$ to 3, $j = 1$ to 2, where y is biomass variable (foliage, wood or total weight or volume) b_0 and b_{ij} are empirical parameters, x_i is independent variable. ns is number of stems, h is height (m), cd is crown diameter (m) and 2 indicates quadratic term. Weights are in kg and volumes are in m^3. R is regression coefficient. F is the ratio between regression mean square and residual mean square and p(F) is respective probability. SE(b) is standard error of respective empirical parameter (b). The t-value and respective p-value are used to test the hypothesis that respective empirical parameter (b) is equal to zero. Underlining indicates insignificance of the respective regressor after the model optimisation using the backward stepwise method.

	model statistics			intercept	ns	ns2	h	h2	cd	cd2
foliage weight	R	0.8596	b	0.7907485	-0.2551758	0.0172938	-	-	1.0962462	0.6127596
	F	111.12	SE(b)	0.2118195	0.0607074	0.0046453	-	-	0.3855214	0.2166722
	p(F)	0.0000	t	3.7331252	-4.2033724	3.7228201	-	-	2.8435417	2.8280488
			p(t)	0.0002640	0.0000440	0.0002741	-	-	0.0050556	0.0052942
wood weight	R	0.8551	b	1.6876990	-2.1318486	0.1676267	-	0.2918539	8.5565468	-
	F	106.79	SE(b)	1.0297446	0.3098426	0.0237578	-	0.0491038	0.6343839	-
	p(F)	0.0000	t	1.6389491	-6.8804242	7.0556646	-	5.9436119	13.4879634	-
			p(t)	0.1032263	0.0000000	0.0000000	-	0.0000000	0.0000000	-
foliage volume	R	0.8599	b	0.9156739	-0.2960958	0.0200528	-	-	1.2675272	0.7167410
	F	111.4	SE(b)	0.2460426	0.0705157	0.0053959	-	-	0.4478092	0.2516794
	p(F)	0.0000	t	3.7216072	-4.1990030	3.7163134	-	-	2.8305075	2.8478333
			p(t)	0.0002753	0.0000448	0.0002807	-	-	0.0052556	0.0049913
wood volume	R	0.8521	b	1.5622983	-1.9074992	0.1496515	-	0.2645198	7.6061093	-
	F	104.01	SE(b)	0.9327242	0.2806499	0.0215193	-	0.0444773	0.5746136	-
	p(F)	0.0000	t	1.6749842	-6.7967216	6.9542784	-	5.9472932	13.2369119	-
			p(t)	0.0959280	0.0000000	0.0000000	-	0.0000000	0.0000000	-
total weight	R	0.8690	b	2.0428597	-2.3677672	0.1836296	-	0.3016420	10.6363190	-
	F	121.08	SE(b)	1.1494962	0.3458750	0.0265206	-	0.0548142	0.7081580	-
	p(F)	0.0000	t	1.7771783	-6.8457312	6.9240342	-	5.5029898	15.0196978	-
			p(t)	0.0774751	0.0000000	0.0000000	-	0.0000001	0.0000000	-
total volume	R	0.8689	b	1.9698692	-2.1811567	0.1682015	-	0.2758336	10.0249328	-
	F	120.93	SE(b)	1.0776346	0.3242524	0.0248626	-	0.0513875	0.6638870	-
	p(F)	0.0000	t	1.8279565	-6.7267257	6.7652283	-	5.3677231	15.1003603	-
			p(t)	0.0694543	0.0000000	0.0000000	-	0.0000003	0.0000000	-

REFERENCES

Attiwill, P.M. and Ovington, J.D., 1968: Determination of forest biomass. Forest Science, 14: 13 - 15.

Baskerwille, G.L., 1965. Estimation of dry weight of tree components and total standing crop in conifer stands. Ecology 46: 867-869.

Cunia, T., 1986: Estimating Tree Biomass Regressions and Their Error. Tutorial Papers: 1 -106. Proceedings of the Workshop on Tree Biomass Regression Functions and their Contribution to Error of Forest Inventory Estimates (26-30 May 1986) USDA-Forest Service, NEFES: NE-GTR-117, Syracuse - New York, 303 pp.

Ott, R.L., 1993. An introduction to statistical methods and data analysis. Duxbury press, Belmont, 1051 pp.

Lukić, N. and Kružić, T., 1996: Estimating biomass of common beech biomass in Pannonian Croatia (in Croatian with English summary). In: Unapređenje proizvodnje biomase šumskih ekosustava (Ed. B. Mayer). Forestry Faculty Zagreb and Forestry Institute Jastrebarsko, Zagreb. 131-136.

Topić, V. and \upe, D., 1996: Grazing and browsing of goats in the sub-Mediterranean shrublands of the Croatian Karst (in Croatian with English summary). In: Unapređenje proizvodnje biomase šumskih ekosustava (Ed. B. Mayer). Forestry Faculty Zagreb and Forestry Institute Jastrebarsko, Zagreb. 377-384.

Whittaker, R.H. and Woodwell, G.M., 1968: Dimension and production relations of trees and shrubs in the Brookhaven Forest, New York. Journal of Ecology 56: 1 - 25.

REGRESIJSKI MODELI PROCJENE BIOMASE HRASTA MEDUNCA (*QUERCUS PUBESCENS* WILLD.), HRASTA SLADUNA (*QUERCUS FRAINETTO* TEN.) I HRASTA CRNIKE (*QUERCUS ILEX* L.) U PANJAČAMA

Razvoj modela za brzu procjenu biomase dominantnih mediteranskih vrsta drveća i grmlja važan je dio dugoročnoga istraživanja kompeticije između šumarstva i stočarstva u Hrvatskoj. Ovaj rad uvodi regresijske modele za procjenu biomase iznad površine tla u panjačama, razvijene za hrast medunac (*Quercus pubescens* Will.), hrast sladun (*Quercus frainetto* Ten.) i hrast crniku (*Quercus ilex* L.). Uzorci su prikupljeni u Dalamciji. Biomasa lišća i drveta je odvojeno mjerena kao težina i volumen. Nezavisni procjenitelji bili su promjer krošnje te visina i broj izbojaka iz panja. Generalno linearno modeliranje korišteno je za razvoj modela. Dobiveni su modeli prikladni za brzu i pouzdanu procjenu biomase populacije (lisnu i/ili drvenastu) u panjačama.

Ključne riječi: volumen i težina lišća, mediteranski hrastovi, panjača, volumen i težina drveta