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VOLUME TABLES OF EVERGREEN OAK (*Q. ilex* L.)

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Abstract: Double-entry and single-entry volume tables (tariffs) of evergreen oak (*Quercus ilex* L.) were produced for the territory of the Republic of Croatia. They were based on 425 model trees for large wood above 7 cm in diameter and a total volume above 3 cm in diameter. To determine the volume of trees, the Schumacher-Hall function was selected. Its regression model for the total volume (above 3 cm) is $v=0.000072412 \cdot d^{2.033282} \cdot h^{0.796658}$, with multiple regression coefficient R=0.991 and coefficient of determination R^2=98.2%, and for the volume of large wood (above 7 cm): $v=0.000025565 \cdot d^{2.467343} \cdot h^{0.699012}$, with multiple regression coefficient R=0.977 and determination coefficient R^2=95.5%. The arithmetic mean of the form factor is 0.674, and the values range from 0.409 to 1.081. Single-entry volume tables (tariffs) were generated based on the parameters of double-entry tables and construction of height curves.

Keywords: evergreen oak, volume tables, double-entry volume tables, single-entry volume tables, large wood, total volume, data analysis

ZAPREMINSKE TABLICE HRASTA CRNIKE (*Q. ilex* L.)

Izvod: Za područje Republike Hrvatske izrađene su dvoulazne i jednoulazne (tarife) volumne tablice hrasta crnike (*Quercus ilex* L.), na temelju 425 modelnih stabala za krupno drvo iznad 7 cm promjera i ukupan volumen iznad 3 cm promjera. Za određivanje volumena stabala odabrana je Schumacher-Hall-ova funkcija čiji je regresijski model, za ukupni volumen (iznad 3 cm): $v=0.000072412 \cdot d^{2.033282} \cdot h^{0.796658}$, uz multipli koeficijent regresije R=0.991 i koeficijent determinacije R^2=98.2%, a za volumen krupnog drva (iznad 7 cm): $v=0.000025565 \cdot d^{2.467343} \cdot h^{0.699012}$, uz multipli koeficijent regresije R=0.977 i koeficijent determinacije R^2=95.5%. Aritmetička sredina obličnog broja je 0,674, a vrijednosti se kreću od 0,409 do 1,081. Jednoulazne volumne tablice (tarife) rađene su na osnovi parametara dvoulaznih tablica i konstrukcije visinskih krivulja.

Ključne riječi: hrast crnika, volumne tablice, dvoulazne volumne tablice, jednoulazne volumne tablice, krupno drvo, ukupan volumen, analiza podataka

1. INTRODUCTION

Volume tables are based on the fact that trees of the same tree species, diameters at breast height and heights that have grown under approximately the same environmental conditions have the same volume in an average of a large number

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of trees and a fairly large area (Grundner-Schwapach, 1928). In double-entry tables, the diameter at breast height and tree height are used to calculate the volume. The tables are almost always made for a particular tree species although their application does not depend primarily on the tree species but the homogeneity of characteristics (height, diameter, form factor).

The use of electronic computers has significantly simplified and accelerated the construction of tables so that today they are made only in the form of electronic equations. The tabular presentation of volume has been increasingly losing its importance today. With the electronic construction of tables, it is sufficient to determine the empirical equation, i.e. the mathematical model of the sample tables.

According Pranjić, A., Lukić, N. (1997), the most important equations were developed by Stoate (1945), Spurr (1952), Ogaya, Nässlund (1947), W. H. Meyer (1932). Takata (1958), and Schumacher-Hall (1950). It is both necessary and important to plan the experiment and choose the type and intensity of the sample properly. The choice depends on the requirements of the research, reliability and possibilities. In addition, when creating volume tables, it is necessary to collect as much information as possible about the factors that affect (directly or indirectly) the growth and development of trees and stands (geological, pedological, orographic, climatological, etc.). Regarding the karst area, tables require data on trees below the estimation limit, i.e. trees of the species with such diameters. This is because some species whose trees attain such small diameters are cut down and sold in the market.

The development of tariffs is based on the assumption that single diameter degrees have constant heights, and grading can be achieved according to height classes or constant height curves.

Single-entry volume tables (tariffs) estimate the volume of the mean tree of a single diameter degree (within the stand) using only one entry (diameter at breast height, circumference, basal area). They can be either general or local. General tariffs can be used for all tree species or classes (broadleaved and coniferous) and all site classes. Local single-entry tables are made separately for each tree species by height categories. As tariffs express the dependence of volume only on the diameter at breast height, heights are taken into account directly or indirectly. Depending on the method applied, tariffs can use normal height curves and double-entry volume tables (wood mass tables, volume tables), series of form height quotients, and series of normal (standard) volume lines (mass lines).

Local single-entry tables are based on the assumption that trees of the same tree species and diameter degree tend to achieve the same height and form factor in a given site class. However, the height curves of even-aged stands of the same site class change their position over time. Therefore, a tariff series of volume in a certain site class corresponds to an even-aged stand of a specific age.

Changes in height curves and form factor curves should certainly be taken into account in the construction of tariffs of even-aged stands (Pranjić, A., Lukić N., 1997).

This research aimed to produce domestic volume tables for evergreen oak that will be used to estimate the volume of wood in practice (tree marking, forest estimation). So far, domestic tables of the tree species with similar morphology and physiology have been used for this purpose.

Furthermore, the aim was to study and monitor structural factors of evergreen oak (diameter at breast height, tree height, tree volume, form factor) in Istria and the northern Adriatic, and to examine the homogeneity of these characteristics, both within the species and between individual sites and to introduce several factors that affect the growth and development of trees and stands (geological, pedological, climatological). Another goal was to introduce a new approach to research and production of volume and similar tables.

2. RESEARCH METHODS

2.1. Object of research

The evergreen oak (*Quercus ilex* L.) is a tree 8–12 m tall, sometimes up to 20 m. However, continuous grazing often results in a bushy growth form. The crown is usually large and rounded, and the trunk is short. The bark is gray and thin when young. As the tree ages, it becomes dark gray, cracked, and develops fine scales. There is no colour differentiation between sapwood and heartwood. The border between the rings is barely visible and wavy, which makes rings difficult to count. The evergreen oak has diffuse-porous brown wood. The wood rays are large and numerous. The pore volume is 35.5%, and the wood volume 64.5%. Evergreen oak wood is very heavy (t_{15} = 1080, t_0 = 970 kg/m^3, very hard (1131 bar, or daN/ cm^2), firm, elastic and quite durable. It shrinks heavily (α_p = 0.57). The wood is hard to process and prone to cracking if 1-2 years after being in the water, it is not seasoned with care.

Evergreen oak wood is used for charcoal and firewood. If the texture is irregular, it can be used in carpentry. There are no special regulations for assortments. It is brought to the market in small logs. By-products include bark and tanbark caused by *Cynips tinctoria* Ol. var. *nostra* Destefani. The tanbark can be found in Istria and the surroundings of Gorica. It contains 41% tannin. The bark contains 15% tannin and is used for sole tanning. According to the colour of the inner side of freshly peeled bark, there are three types of evergreen oak bark: *écorce blanche, rouge or noire,* and *jaune or grise*. The black type is the best.

In the Republic of Croatia, evergreen oak occurs in six forest communities:

- EVERGREEN OAK FOREST WITH MYRTLE (*Myrto-Quercetum ilicis* /H-ić1956/ Trinajstić 1985)

Of all forms of evergreen oak forests and maquis on the Croatian Coast, the forests and maquis of evergreen oak with myrtle are the most thermophilic (zonal and local) community that develops everywhere where environmental conditions are suitable for its development. This primarily refers to the winter temperature trends;

- EVERGREEN OAK AND FLOWERING ASH FOREST (*Fraxino orni-Quercetum ilici*s H-ić / 1956/1958)

Mixed forests and maquis of evergreen oak and flowering ash are distributed throughout the northern Mediterranean. In some areas, they spread further south, for example, Calabria, Sicily, and Sardinia, but at higher altitudes. On the Croatian Coast, these forests and maquis are limited to its northern part, and their most beautiful stands can be found on the islands of Rab and Veli Brijun. They also develop as forests although other parts of the Coast are predominated by maquis, as is the case in some parts of Istria, on the islands of Krk and Cres, around Posedarje, on the island of Ugljan, the slopes of Kozjak above Split, and many other places;

- EVERGREEN OAK AND EUROPEAN HOP-HORNBEAM FOREST (*Ostryo-Quercetum ilicis* Trinajstić/ 1965/ 1974)

In higher positions, evergreen oak builds mixed stands with European hop-hornbeam (*Ostrya carpinifolia*), which points to relatively cold and wet environmental conditions. In the post-war period, these stands regenerated, so that today we find them mainly in the form of low forests, less often in the form of maquis, although they have been preserved only in some places, from the island of Cres in the northwest to the island of Korčula in the southeast, while they are relatively rare in the coastal area;

- ALEPPO PINE AND EVERGREEN OAK FOREST (*Querco ilicis-Pinetum halepensis* Loisel 1971)

Mixed Aleppo pine forests with a greater or lesser share of evergreen oak are widespread throughout the Mediterranean, where in the range of the general xerothermic climate, they occupy wetter microsites. On the Coast of Croatia, these forests occupy relatively large areas, especially on the Adriatic islands of Hvar, Korčula, Lastovo and Mljet. They are the most important type of Aleppo pine forests in Croatia;

- MIXED FOREST OF EVERGREEN OAK AND LIVE OAK (*Quercetum ilicis-virgilianae* Trinajstić 1983)

This forest is a distinct community of the Croatian Coast limited to its southern part. It occupies relatively large areas of more or less flat terrain with numerous sinkholes and karst fields from the Klek and Pelješac Peninsulas to the south and southeast. It was particularly well developed in Konavle and Župa Dubrovačka, in some Lastovo fields, and very probably on Lokrum Island. Because it grows in deep soils, it has been mostly cleared for agricultural land. Lately, it has been gradually regenerating, which can be easily noticed in many places on the Pelješac Peninsula;

- DALMATIAN BLACK PINE FOREST WITH EVERGREEN OAK (*Querco ilicis-Pinetum dalmaticae* Trinajstić 1986)

The area of distribution of Dalmatian black pine (*Pinus nigra* ssp. *dalmatica*) is limited to the Coast of Croatia. There, it builds several forest communities (Trinajstić 1986). In the area of distribution of Mediterranean black pine forests, it builds mixed forests with evergreen oak that can be considered a climax stage, caused by the degradation of either pure or mixed evergreen oak forests. The largest areas are on the island of Brač, and all stands of Dalmatian black pine on the island of Korčula belong to this forest community. The Brač stands of the Dalmatian black pine are magnificent forests of trees of different ages, based on which we can assume that the pine (as a pioneer) gradually filled the clearings. The pine itself builds the upper storey, and evergreen oak trees the understorey (lower storey). Korčula stands are mostly limited to the localities of Idrovo and Klupac (Jovančević 1961; Trinajstić, I. 1971). It must be emphasised that the numerous artificially established forest stands (cultures) of Dalmatian black pine on the Pelješac Peninsula show the direction of succession towards the community of Dalmatian black pine and evergreen oak.

2.2 Research area

These volume tables were made on the basis of data measured in five research areas, i.e. 16 localities (Figure 1): LABIN (2 localities); PAG (2 localities); POREČ (6 localities); PULA (3 localities); RAB (3 localities).

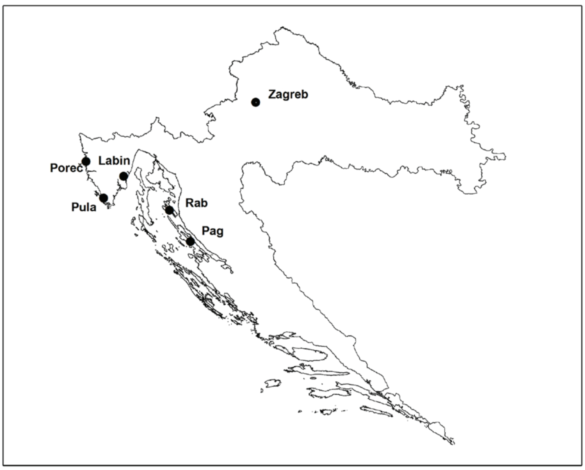


Fig. 1 Location of the research area
Slika 1. Situacija istraživanih objekata

LABIN

This research area has two localities.

- **Locality 1**

Soil type: Red soil, leached, medium deep ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 20 m

- **Locality 2**

Soil type: Brown soil on limestone, typical, shallow
Soil profile structure: Aoh-(B)rz-R
Elevation: 30 m

PAG
This research area has two localities.
- **Locality 3**

Soil type: Red, typical, medium deep, leached ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 25 m
- **Locality 4**

Soil type: Red soil, typical, medium deep, ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 25 m

POREČ
This research area has six localities.
- **Locality 5**

Soil type: Luvisol, anthropogenised on limestone
Soil profile structure: Ap-E-Bv-C
Elevation: 55 m
- **Locality 6**

Soil type: Red soil, typical, shallow ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 15 m
- **Locality 7**

Soil type: Red soil, typical, shallow ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 30 m
- **Locality 8**

Soil type: Red soil, typical, shallow ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 20 m
- **Locality 9**

Soil type: Red soil, typical, shallow ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 45 m
- **Locality 10**

Soil type: Red soil, typical, shallow ("terra rossa")
Soil profile structure: Aoh-(B)rz-R
Elevation: 15 m

PULA
This research area has three localities.
- **Locality 11**

Soil type: Brown soil on limestone, colluvial
Soil profile structure: Aoh-(B)rz-C
Elevation: 45 m

RAB

This research area has three localities.

- **Locality 14**

Soil type: Brown soil on limestone
Soil profile structure: Aoh-(B)rz-C
Elevation: 15 m

- **Locality 15**

Soil type: Brown soil on limestone, leached
Soil profile structure: Aoh-(B)rz-C
Elevation: 35 m

- **Locality16**

Soil type: Brown soil on limestone, in sinkhole
Soil profile structure: Aoh-(B)rz-C
Elevation: 65 m

2.3. Method of work

The research was planned at the level of tree analytics. It was planned to measure the described factors on 400-500 felled trees in several localities of the coastal area. The research plan was identical to the research plan schematically presented and published (Benko, M. *et al*., 1999). Trees of approximately normal age, without damage, were chosen as model trees. Trees with a diameter at breast height of 7–80 cm were sectioned. The total length of a felled tree was measured from the ground (stump height was taken into account) to the last bud (tree height). The diameter at breast height was measured at 1.30 m above the ground. The portion of the trunk below the breast diameter was divided into two sections. The first was 0.3 m long (stump), and the second 1m. In the first section, two cross diameters were measured at the end of the section, i.e. at 0.3 m above the ground. In all subsequent sections, two cross diameters were measured at the midpoint. From the diameter at breast height onwards, the sections were generally 2 m long, unless there was some irregularity in the trunk or branch or the section was shorter because it was at the end of the branch or trunk. The diameter of the trunk and branches was measured above 2.5 cm at the thin end of the section. Basic data on the research areas are shown in Table 1.

Table 1 Basic data about plots
Tablica 1. Osnovni podaci o plohama

Objekt istraživanja *Research area*	Starost u godinama *Age in years*	Količina modelnih stabala / kom. *Number of model trees / units*
Labin	31-67	92
Pag	42-70	35
Poreè	44-57	115
Pula	31-78	159
Rab	35-60	24
Ukupno/ Total	31-78	**425**

Most of the data were processed using a ready-made computer program, and only for some data, formulas were written or programs made. The data were processed in a matrix formed by the EGTRH database, in such a way that the data measured on a single tree were entered in the rows of the matrix, while the columns represented individual attributes: locality; diameter at breast height (d); tree height (h) and tree volume (c). Before creating the volume tables, all measured data were described in detail. The tree volume of was calculated as the sum of the volumes of the sections determined as the volume of cylinders,

$$v = \frac{d_s^2 \cdot \pi}{40000} \cdot l$$

It is in forestry known as Huber's formula (Pranjić, A., 1977) where v designates the volume of a section, d_s is the diameter at the appropriate spot of the section, and l is the length of the section. The total volume of a tree equals the sum of the volumes of all sections, i.e. it is calculated by the complex Huber's formula (Pranjić, A., Lukić, N., 1997). Regarding the form factor, f is the designation of the form factor, v is the sectional volume of the tree, v_v is the volume of the cylinder whose length is equal to the height of the tree, and the diameter is equal to the diameter at breast height of the tree.

$$f = \frac{v}{v_v}$$

The height curves were estimated by the Mihaylov function.

$$h = a_0 \cdot e^{-\frac{a_1}{d}} + 1.3$$

A Schumacher-Hall model was selected to determine the volume tables:

$$v = a_0 \cdot d^{a_1} \cdot h^{a_2}$$

where v is the volume of the tree, d is the diameter at breast height, h is the height of the tree, a_0, a_1 and a_2 are unknown parameters estimated on the basis of experimental data.

3. RESEARCH RESULTS AND DISCUSSION

The estimate of the parameters of the variable distribution (diameter at breast height, tree height, form factor, and tree volume) for all 425 trees is shown in Table 2. A high standard deviation of the diameter at breast height (3.4) can be observed, which indicates high variability of this variable. Tree heights range from 6.2 to 16.6 m, and the average height of all trees is 10.9 m. This variable has noticeably high variability. The variability of the total tree volume (above 3 cm) and the volume of large wood (above 7 cm) is low. The form factor also has low variability.

Table 2 Distribution of model trees
Tablica 2. Razdioba modelnih stabala

Visinski stupanj *Height degree*	Debljinski stupanj *Diameter degree*								
m	cm								
	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	Total
6	1	1	0	0	0	0	0	0	2
7	5	3	2	1	0	0	0	0	11
8	5	18	16	4	0	0	0	0	43
9	1	30	36	6	3	0	0	0	76
10	0	12	40	26	1	0	0	0	79
11	0	2	15	20	6	1	0	0	44
12	0	0	10	24	15	2	1	0	52
13	0	0	13	24	9	5	1	0	52
14	0	0	3	15	8	11	3	0	40
15	0	0	0	3	12	4	2	1	22
16	0	0	0	0	3	0	0	0	3
17	0	0	0	0	0	1	0	0	1
Total	12	66	135	123	57	24	7	1	**425**

Table 3 Estimate of parameters of studied variables
Tablica 3. Procjena parametara razdiobe proučavanih varijabli

Varijable *Variable*	Broj stabala *Number of trees*	Aritmetièka sredina *Arithmetic mean*	Standardna devijacija *Standard deviation*	Standardna pogr. prosj. *Standard error even*	Raspon - *Range*	
					min.	max.
Prosjeèni prsni promjer (cm) *Aver diameter breast height*	425	12.7	3.64	0.18	4.9	25.1
Visina stabla (m) *Tree heigh*	425	10.9	2.18	0.11	6.2	16.6
Volumen stabla (m3) *Tree volume*	425	0.11	0.08	0.003	0.009	0.478
Volumen krupnog drva iznad 7 cm *Volume of largewood above 7 cm*	425	0.09	0.07	0.003	0	0.424
Oblièni broj *Form factor*	425	0.67	0.07	0.004	0.409	1.081

3.1. Double-entry tables

3.1.1. Total volume (above 3 cm)

Multiple regression of the wood volume of trees above 3 cm for all localities together, with input variables of breast diameter and tree height, is shown in Table 4. The correlation coefficient is very high (0.991) as well as the determination coefficient (0.982). The significance of the parametric equations of the line is almost one.

The regression model of volume equation by Schumacher-Hall function reads:

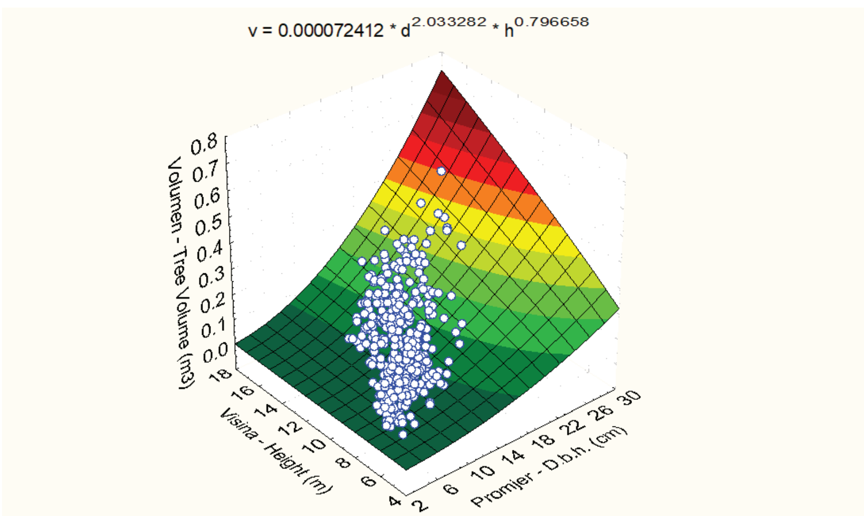
$$v = 0.000072412 \cdot d^{2.033282} \cdot h^{0.796658}$$

Mayer's correction factor is 1.01379.

Table 4 Multiple regression of the total tree volume
Tablica 4. Multipla regresija ukupnog volumena stabla

LNH – natural logarithm of tree height – independent variable
LND – natural logarithm of diameter at breast height – independent variable

Dotjerani R2 *Adjusted R2*	0.982	R	0.991		
Standardna greška *Standard error*	0.098	R2	0.982		
Analiza varijance *Variance analysis*	DF	Suma kvadrata *Sum of squares*	Sredina kvadrata *Mean squares*	F	
Regresija *Regression*	2	228.398	114.199	11836.382	
Ostatak *Residual*	422	4.072	0.00964		
Znaèajnost *Significance*	0				
Varijable u jednadžbi - *Variables in equation*					
Varijable *Variables*	B	Std. E B	Beta	t	Sig t
LNH	0.796658	0.036096	0.216928	22.070463	0
LND	2.033282	0.024458	0.817119	83.134455	0
Konstanta *Constant*	-9.53314	0.056349		-169.181	0



Graph 1 Equation of the total volume (above 3 cm) using the Schumacher-Hall function
Grafikon 1. Izjednačenje ukupnog volumena (iznad 3 cm) Schumacher-Hall-ovom funkcijom

3.1.2. Volume of large wood (above 7 cm)

Multiple regression of the large wood volume (above 7 cm) for all localities together, with input variables of breast diameter and tree height, is shown in Table 5. The correlation coefficient is very high (0.977) as well as the coefficient of determination (0.955). The significance of the parametric equations of the line is almost one. The regression model of large wood volume equation by Schumacher-Hall function reads:

$$v = 0.0000025565 \cdot d^{2.467343} \cdot h^{0.699012}$$

Mayer's correction factor is 1.01159.

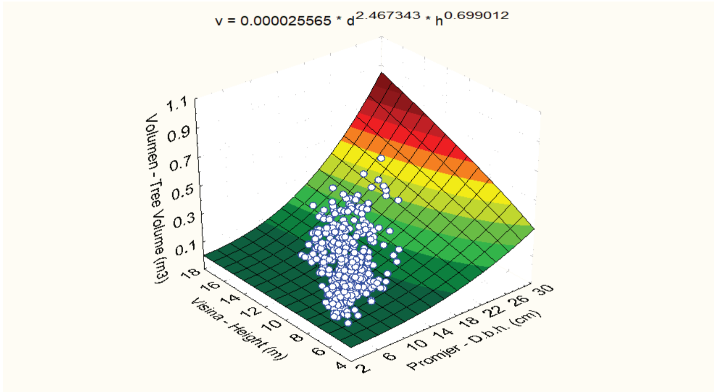
Table 5 Multiple regression of the volume of large wood (above 7 cm)
Tablica 5. Multipla regresija volumena krupnog drva (iznad 7 cm)

Dotjerani R2 *Adjusted R2*	0,955	R	0,977
Standardna greška *Standard error*	0,174	R2	0,955

Analiza varijance *Variance analysis*	DF	Suma kvadrata *Sum of squares*	Sredina kvadrata *Mean squares*	F
Regresija *Regression*	2	267,072	133,536	4404,059
Ostatak *Residual*	415	12,583	0,03032	
Značajnost *Significance*	0			

Varijable u jednadžbi - *Variables in equation*

Varijable *Variables*	B	Std. E B	Beta	t	Sig t
LNH	0,699012	0,064231	0,167830	-102,306	0
LND	2,467343	0,044932	0,846853	54,913151	0
Konstanta *Constant*	-10,5743	0,103359		-102,306	0



Graph 2 Equation of the volume of large wood using the Schumacher-Hall function
Grafikon 2. Izjednačenje volumena krupnog drva Schumacher-Hall-ovom funkcijom

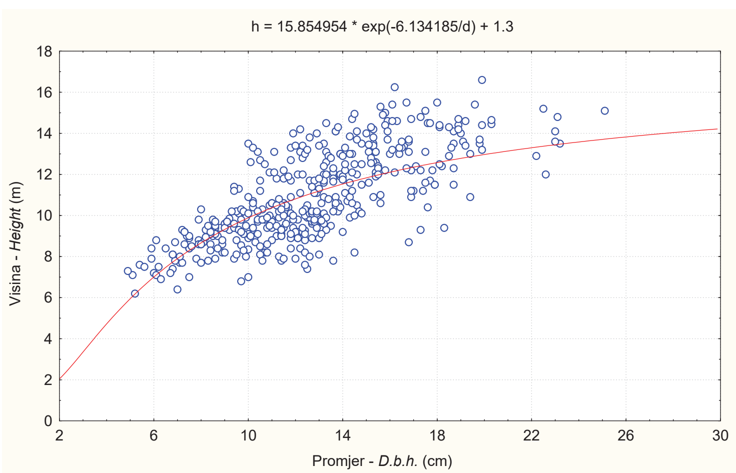
3.2. Single-entry tables (tariffs)

A common height curve was produced for all model trees (Graph 3).

Table 6 shows the parameters of the regression model of tree height depending on the breast diameter, according to Mihaylov. The regression model of the height curve for all trees reads:

$$h = 15.854954 \cdot e^{-\frac{6.134185}{d}} + 1.3$$

The coefficient of correlation between the tree height and diameter at breast height is 0.736, and the coefficient of determination is 54%. The significance of parameters a_0 and a_1 is <0.001. The spectral representation of the relation between volume and diameter at breast height by height classes is shown in Graph 4.



Graph 3 Height curve for all trees
Grafikon 3. Visinska krivulja za sva stabla

Table 6 Regression of tree height for all trees
Tablica 6. Regresija visine stabala za sva stabla

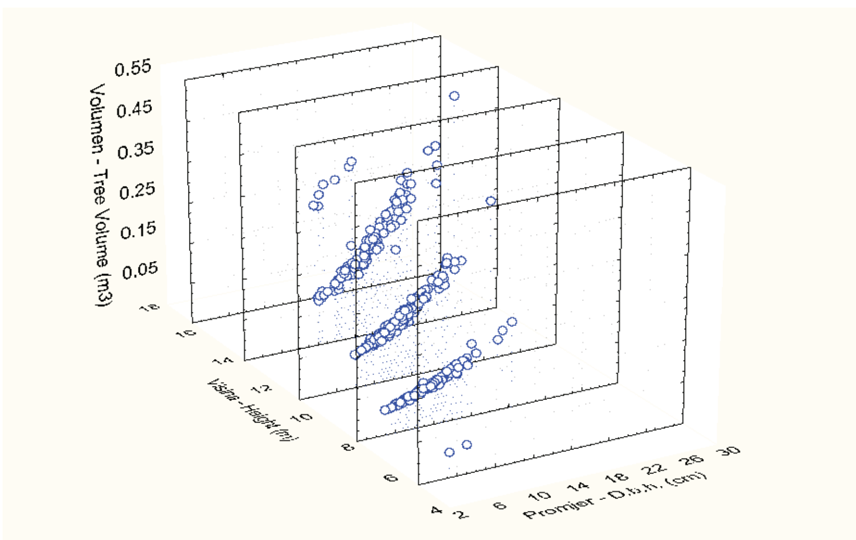
Dotjerani R2 *Adjusted R2*	0,540	R	0,736
Standardna greška *Standard error*	0,1562	R2	0,541

Analiza varijance *Variance analysis*	DF	Suma kvadrata *Sum of squares*	Sredina kvadrata *Mean squares*	F
Regresija *Regression*	1	12,184	12,184	499,134
Ostatak *Residual*	423	10,326	0,02441	
Značajnost *Significance*	0			

Varijable u jednadžbi - *Variables in equation*

Varijable *Variables*	B	Std. E B	Beta	t	Sig t
D	-6,134185	0,275	-0,736	-22,341	0
Konstanta *Constant*	2,763482	0,025		111,382	0

D – prsni promjer / *D* – diameter at breast height



Graph 4 Spektralni prikaz odnosa volumena i prsnog promjera po visinskim razredima
Grafikon 4. Spectral representation of the relation between volume and diameter breast height by height classes

4. CONCLUSIONS

The following conclusions can be drawn from the research:

- the biometric analyses of the four variables (*d, h, v*, and *f*) clearly show that there are differences between them;
- the measurements and analyses performed in the research reveal the complexity of the issue of volume estimation, i.e. the production of volume tables, both regarding the possible sampling issues and regarding the selection of relevant factors that can limit such research;
- the arithmetic mean of the form factor is 0.674, and the values range from 0.409 to 1.081;
- the values of evergreen oak volume (*Quercus ilex* L.) were equated by the Schumacher-Hall function whose regression model for the total volume (above 3 cm) is:

$$v = 0.000072412 \cdot d^{2.033282} \cdot h^{0.796658}$$

and for the volume of large wood (above 7 cm):

$$v = 0.000025565 \cdot d^{2.467343} \cdot h^{0.699012}$$

- to estimate tree volume, preference should be given to double-entry volume tables in regression form;
- due to relatively small diameters at breast height and the number of trees selected for felling, it is recommended to use a caliper with a centimeter division and to apply the most appropriate tables;
- the necessity of a comprehensive analysis of all relevant factors in the production of volume tables is confirmed, not only by the usual univariate methods but also by multivariate ones.

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ZAPREMINSKE TABLICE HRASTA CRNIKE (*Q. ilex* L.)

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Rezime

U radu su prikazana istraživanja vezana za izradu dvoulaznih i jednoulaznih volumnih tablica (tarife) hrasta crnike (*Q. ilex* L.), na području Republike Hrvatske. Istraživanja su izvršena na temelju 425 modelnih stabala za krupno drvo iznad 7 cm promjera i ukupan volumen iznad 3 cm promjera, na pet objekata: Poreč, Labin, Pula, Rab i Pag. Obavljena mjerenja i analize ukazuju na složenost problematike procjene volumena, tj. stvaranja volumnih tablica, kako s gledišta mogućeg problema uzorkovanja, tako i sa gledišta izbora relevantnih činilaca koji potencijalno omeđuju takva istraživanja. Aritmetička sredina obličnog broja je 0,674, a vrijednosti se kreću od 0,409 do 1,081. Za određivanje volumena stabala odabrana je Schumacher-Hall-ova funkcija čiji je regresijski model, za ukupni volumen (iznad 3 cm):$v=0.000072412 \cdot d^{2.033282} \cdot h^{0.796658}$, uz multipli koeficijent regresije R=0.991 i koeficijent determinacije R^2=98.2 %, a za volumen krupnog drva (iznad 7 cm): $v=0.000025565 \cdot d^{2.467343} \cdot h^{0.699012}$, uz multipli koeficijent regresije R=0.977 i koeficijent determinacije R^2=95.5 %. Jednoulazne volumne tablice (tarife) rađene su na osnovi parametara dvoulaznih tablica i konstrukcije visinskih krivulja. Sprovedena istraživanja ukazala su na visoku standardnu devijaciju prsnog promjera (3,4), što ukazuje na veliku varijabilnost te varijable. Visine stabala kreću se u rasponu od 6,2 do 16,6 m, a prosječna visina svih stabala iznosi 10,9 m. Primetna je veća varijabilnost ove varijable. Varijabilnosti ukupnog volumena stabla (iznad 3 cm) i volumen krupnog drva (iznad 7 cm), malih su vrijednosti. Vrijednosti obličnog broja imaju malu varijabilnost. Za procjenu volumena stabala prednost treba dati dvoulaznim volumnim tablicama, i to u regresijskom obliku. U radu je potvrdjena opravdanost svestrane analize svih relevantnih činilaca pri izradi volumnih tablica, i to ne samo uobičajenim univarijantnim metodama analize, nego i multivarijantnim.