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Wood assortment tables of Norway spruce (*Picea abies* Karst.) for Canton 10 of Federation B&H

Sortimentne tablice smrče *(Picea abies* Karst) u Kantonu 10 Federacije BiH

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ABSTRACT - Sažetak

Current tables of wood assortments for the most important tree species in B&H were made almost 50 years ago. There is an indication that real forest wood assortments are different than the one derived from assortment tables in-use, both in terms of quality and dimensions. In the meantime, from the creation of the existing tables until today, the standards of production of forest wood assortments have changed, so that the fact of inaccuracy of the existing assortment tables is unquestionable.

This continually creates a variety of problems in the ongoing operations of forestry companies. The main aim of this paper is to create wood assortment tables whose assortment of wood products will correlate with the current market conditions. The research was conducted in the area of the Canton 10 in FB&H. A sample of 393 spruce trees was used as a database to produce this paper. The bucking of the sample trees was carried out in accordance with the valid norms and customer requirements with regards to the dimensions of forest wood products. Data processing was performed using methods of simple and multiple regressions, variance analysis as well as their combinations by the *Generalized Linear Models* method. Independent factors were breast diameter (DBH), technical quality class and the height of the trees. The share of wood assortments was determined through 10 different mathematical models, and it was found that all independent variables had a statistically significant influence on the dependent variables-volume of particular assortments or group of assortments. The share of logs is growing rapidly with the increase of tree diameter and decreases with decreasing of their technical quality. The influence of tree height primarily correlated with tree volume increase. Trees having better assortment quality, have tree heights higher than average for the same diameter class. The results of the research are presented in the form of tables as percentage share of wood assortment classes. The obtained results can be used as wood assortment tables in the research area.

Key words: *forest wood products, diameter, technical quality class, regressions*

INTRODUCTION - *Uvod*

Acknowledgement and evaluation of the forest quality is an essential information for establishing forestry policies and creating various plans in forestry and wood industry. Matić (1969) highlights that knowing the health condition of the forest and its technical applicability is of the same economic importance as knowing the areas of certain forest categories, their growing stocks and wood increment. He also states that perspective plans of forestry development, annual plans, development plans for certain objects of the wood industry

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etc. cannot be properly constructed if the assortment structure of the forest in focus cannot be determined beforehand. In reality, this can only be done by using assortment tables. Considering the huge importance of assessment (i.e. knowing the assortment structure of wood products in forest stands), numerous studies have been conducted both worldwide and locally, aiming to determine the assortment structure of the economically most important tree species. But, since all of the study results of assortment structure are greatly defined by the round-wood assortment system (standards), they often cannot be used for direct comparison due to obvious differences in classification criteria.

The first significant studies of wood assortment, and the assessing of the manner and size of certain influential factors on the assortment structure, was conducted by Flury (1916). These studies are also important because the author concluded that under the hypothesis of the same tree quality, even for the assortments that he formed (six assortment classes defined by the diameter at the thinner end and at minimum length), the tree height does not have an impact on the percentage share of these assortments in the tree volume (grown trees including bark). On the other hand, Gorskij (according to Pavlič 1973) obtained the results that confirm the impact of height on the percentage share of all assortments, concluding that tree height has an impact on the quantity of assortments. A great number of authors in Europe engaged in the research of the wood assortment structure and the creation of wood assortment tables (Mitscherlich 1939, Altherr 1953, Čermák 1982, Petráš and Nociar 1990, 1991 and many others). Nonetheless, the most interesting and the most important works definitely are the works of authors from the region of the former Yugoslavia, primarily due to the fact that they used the same round-wood normative (sorting) system.

Bojanin (1960) studied and analysed the share of some wood assortments, bark, and wood losses by diameter classes, as well as their interdependence. The author confirms a strong correlating dependence between the tree diameter at breast height and the researched characteristics, and presents the analytical expressions of these dependences.

Plavšić and Golubović (1963) studied the wood assortment share of the Silver fir (Abies alba L.) and conducted its classification based on the regulations of two standards (JUS 1955 and JUS 1962). They stated a strong correlation between the percentage share and the related diameter class for all assortments. They concluded that the change in regulation results in a significant difference between the percentage share of the most valuable assortments (1st and 2nd class sawlogs), which is 14%, according to the JUS 1955 standard, up to astounding 31% (due to the lowered quality and log thickness criteria), according to the JUS 1962 standard. These two authors stated that there were minor differences in the percentage ratio of wood assortments of the same diameter class in different height classes and different forest community, but they did not state the exact values. To finalize, they confirmed the forementioned hypothesis by Flury (1916), according to which the trees of the same diameter at breast height (DBH) and the same quality, but different heights, have the same percentage ratio of wood assortments, while their absolute values change along with the tree height.

The research in percentage share of the beech, spruce and fir assortments in monospecies and mixed stands in Bosnia and Herzegovina was conducted by Vukmirović (1971), Pavlič (1973) and Prolić (1975). As the result of those researches, the assortment tables for three economically most important tree species. Considering that a high variation of tree quality (i.e. technical usability) was determined, the authors created the so-called two-way assortment tables. The input values for the evaluation of the percentage share of assortments are the previously defined technical quality and diameter classes. As a part of this research, the impact of tree quality (expressed through technical quality classes) on percentage share of assortments is analysed for the first time. The better the tree quality, the higher the percentage share of the more valuable assortments — and vice-versa, regarding all of the researched tree species.

The assortment structure of the most important broadleaved species in Croatia was researched by Štefančić (1997, 1998). His conclusion was that tree height also affects the percentage share of wood assortments in merchantable tree volume (in addition to DBH). By analyzing this influence, he concluded that it is linear, hence, he presented the analytical expression of this dependence. The percentage share of timber rises with the increase of tree height (applies to all analyzed species), but the relation is inversely proportional for pulpwood.

Rebula (1996, 1998a, 1998b) made important contribution to knowledge of the wood assortment structure and the value of Silver fir trees. Using appropriate statistical methods, he determined the relation between the most important criteria of wood quality and its value. He concluded that tree's timber value depends on their diameter and natural defects (their amount and severity), with former being prevalent as the best individual criterion of their value.

Prka (2001, 2006a) has made intensive research on assortment structure of beech forests in Croatia determining a strong correlation between DBH and the percentage share of technical round wood i.e. stacked wood. Prka and Krpan (2007) pointed out the unreliability of the former approach of determining assortment structures of even-aged beech stands, while emphasizing the necessity of differentiating the assortment structure of stands from the assortment structure of felling method.

Koprivica et al. (2008) analysed the quality and assortment structure of tall beech stand volume in northern forest areas of Kučaj mountain range, revealing that the quality structure of the stands is extremely low. Percentage of technically applicable trees was staggering 34.7%, due to past mistakes in forest management.

In Europe, at the end of the last century, there were important changes in the field of standardization. Namely, the awareness that the diversity of national standards largely represents a serious goods trade obstacle for European industry and consumers, as well as the fact that it was obligatory to adjust national standards, led to the foundation of the European Committee for Standardization (CEN), i.e. the introduction of European Norms (EN). Efficient application of these standards requires, among others, the assortment structure research and the creation of applicable assortment tables according to the requirements regarding dimensions and quality. Therefore, numerous researches on assortment structure regarding European Norms have been conducted. (Šušnjar et al. 2005, Prka 2006b, Prka, 2008, Music et al. 2008, Prka and Poršinsky 2009).

Latest valid assortment tables for the most economically important tree species in BiH were made almost 50 years ago, based on previous standards (JUS) from 1968 and 1969, and the former state of wood industry. With a relatively fast technical and technological development in wood processing industry and usage, this previous standard was a matter of change throughout decades, while, regardless of that, it was not synchronized with the changes in other standards. In other words, the production plans of wood assortments and their immediate production were not adjusted because they had different grounds. As time passed, these differences grew. Lipoglavšek (1996) emphasized the unseemliness of these standards 25 years ago. Regarding that, it can be concluded that the produced and traded wood assortments today are much different than the ones that were produced at the time of creation of the above-mentioned assortment tables, which continuously creates various problems in the current business. If we consider the fact that the change of regulation (standards) results in a significant difference in percentage share of wood assortments (Plavšić and Golubović 1963), the need for creating assortment tables is imposed as a priority task. These assortment tables should include the wood assortment products which will as closely as possible correspond to the demands of the current wood industry market state, and their quality and dimensions should be attuned to the valid standards in the field of forestry and wood processing.

MATERIALS AND METHODS – *Materijal i metode*

From an economical and environmental aspect, spruce (*Picea abies* Karst) is one of the most important coniferous species in Europe. In Bosnia and Herzegovina, spruce represents one of the most significant forest tree species. Its share in the total wood stock is 16.1%, which makes it (after beech and fir) the third most important tree species in our forests.

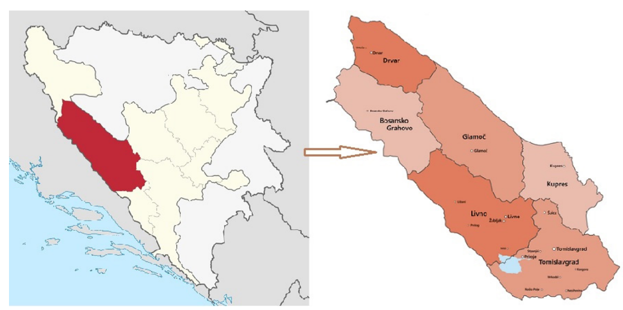

Figure 1. Research area – Canton 10 of the Federation of Bosnia and Herzegovina

Karta 1: Područje istraživanja – Kanton 10 Federacije Bosne i Hrecegovine

This research was conducted in the area of Canton 10 of the Federation of B&H (Figure 1) as part of the scientific-research project: *The creation of volume and assortment tables for fir, spruce and beech trees in the area of forests managed by FMC "Hercegbosanske šume Ltd. Kupres"*. In this canton, spruce is located at the south-western edge of its areal, in the area with the predominant moderately continental climate, in colder expositions and on higher altitudes.

The creation of assortment tables is methodologically a very complex task. In countries where the quality of assortments is influenced by other features (knots, taper, twist etc.) in addition to dimensions, assortment tables are usually created in two ways (Rebula 1996):

- Model trees are chosen using small samples (200-300 trees), based on the necessary features (dimensions and quality). Such an example can be found in *Sortimentačné tabuľky pre ihličnaté dreviny* (Hubač 1973)

and the current assortment tables in BiH (Vukmirović 1971, Pavlič 1973, Prolić 1975).
- Using large samples (1,000-1,500 trees) all the tree features are measured (dimensions and features), and then the assortment tables are computationally created by sample classification of the trees. Such an example can be found in *Sortimentačné tabuľky pre smrekovec, hrab a brezu* (Mecko et al. 1994).

Considering the huge amount of time spent for field work during data collection, as well as limited funds, the method applied in this paper is the so-called "small sample" method. Firstly, the locations for selecting model trees (representatives) were chosen in the research area, considering the fact that the chosen locations cover the forest area in Canton 10 as systematically as possible. Then the trees were selected based on DBH, height and quality. From 5 to 30 spruce trees were selected on every location depending on the spruce share in individual stands. While selecting the trees, it was taken care that the sample consisted of trees of all diameter and quality classes, whereat thicker trees were more represented since they have more variability regarding quality and potential of wood product assortment. Every selected tree had its DBH and height measured, and quality estimated. It is important to mention that some criteria of tree quality classifications (Matić 1964) were corrected or adjusted to the changes in standards and demands regarding dimensions and quality for the most important forest wood assortments (Musić and Lojo 2006). The structure of the sample trees is shown in Table 1.

Table 1. Number of trees in the sample per diameter and technical quality classes

Tabela 1. Broj stabala uzorka po debljinskim i tehničkim klasama

Diameters class (cm) *Debljinska klasa (cm)*	**No. of trees** *Broj stabala*	**Technical quality class** *Tehnička kvalitetna klasa*			
		I	**II**	**III**	**IV**
10-14.9	26	15	0	10	0
15-19.9	26	6	0	17	4
20-29.9	68	15	22	25	7
30-49.9	118	34	43	36	4
50-69.9	53	38	42	30	0
>70	44	20	15	9	1
Total	**393**	**128**	**122**	**127**	**16**

Following the felling of selected model trees, their volume was determined using the section model. Due to the irregular shape of the lower part of the stem, the volume of the first section was calculated using Ricke's formula while the volume of the other sections was calculated using Huber's formula. The diameter were measured at the middle of the section length, twice (cross-wise), with the precision of up to 1 mm, considering their average value as well. In the places where the diameter was measured, tree bark was also measured (mm). In addition, every felled tree was measured from the ground to the final terminal bud or height of the tallest branch including the height of the stump (height of tree). Following the log dimension measurement, their cutting was conducted according to the current standards for certain forest wood assortments and the current demands of the wood industry regarding the type of assortment and their dimensions, primarily the length. The dimension measurement of the produced wood assortments, with the purpose of determining their volume, was conducted according to the *JUS D.B0.022* (1984) standard with the addition of the appropriate length excess where the standard prescribes it.

Considering the crucial and dominant impact of tree diameter and quality on the percentage share of assortments, DBH and the technical quality class have to be taken as independent variables in all models, with the following two regression procedures:

1. Levelling the share of certain forest wood assortments for each quality class individually, by method of simple or multiple regression with the diameter at breast height appearing as an independent continual variable.
2. Levelling the share of certain forest wood assortments simultaneously for different quality classes and different tree diameters. This second procedure would have to combine category and continual variables simultaneously. Therefore, the use of *Generalized Linear Models* (GLM) analysis combining variance analysis and regression is the logical procedure.

Both procedures have their drawbacks which largely depend on the quality (size) of the sample, where the first procedure requires a significantly larger sample. Namely, although the changes in the forest wood assortments regarding diameter and quality are known for the researched feature (assortment structure), thus possible inconsistencies can easily be recognized, the sample analyzed in this paper is still relatively small, hence the gained results could have a strong impact on individual models of simple regression. Due to this drawback of the first procedure, the *Generalized Linear Models* (GLM) procedure was used in this paper. Its models are more flexible in solutions and offer more logical results in cases of missing trees in the sample. For the purpose of analyzing the impact of different factors on the tree volume and the volume of certain assortment, the Fischer LSD test and variance analysis were used. Statistical program STATGRAPHICS Centurion XVII was used for the processing of the data and the interpretation of the results.

RESULTS AND DISCUSSION – *Rezultati i diskusija*

After determining the volume of certain forest wood assortments, their percentage share in the volume of merchantable wood was calculated per diameter and technical quality classes. The obtained results, with some minor deviations, show a rather clear and logical distribution of data. The better the quality and diameter, the larger the share of more valuable assortments. Only the technical class IV is missing the data for diameter classes 10 - 15 cm and 50 - 70 cm. Although the data for this class is rather logical, the number of trees of the sample was too low to derive any reliable conclusions.

Therefore, the main aim of this paper is the creation of reliable functional models for the estimate of the percentage share for the volume of certain forest wood assortments in the volume of trees.

It was stated in a lot of conducted research that the height of coniferous trees (site quality class of the stand) does not have a significant impact on the percentage share of assortments (Flury 1916, Plavšić and Golubović 1963, Pavlić 1973, Prolić 1975). This was also confirmed through our preliminary data analyses while attempting to directly level the percentage share of the forest wood assortments in the volume of spruce trees through the GLM procedure. The direct usage of the percentage share of volumes of certain assortments or assortment groups as independent variables did not yield reliable results. Therefore, the indirect approach of levelling volumes of certain forest wood assortments and large spruce wood volume was used. The percentage shares were then calculated based on the tree volumes and volumes of certain forest wood assortments. A special problem was the fact that some assortments appear only above certain DBH of trees, i.e. that the change of percentage share of certain assortments does not have a continual – constant flow which could easily be expressed through some sort of functional form. Such was the case with logs of every quality. Namely, they appear in trees above a certain DBH, their percentage share significantly rises with the increase of tree diameter, and then that increasement slows down following a declining curve.

By using the GLM method for determining the model for the estimation of volume of certain forest wood assortments in tree volume using DBH as one of the continual variables, there was no result yielding a good quality distribution of residual deviation in every individual case. Because of that, the diameter class of 5 cm was used instead of DBH as an independent category variable.

Volume of merchantable wood - V_7 (model 1) – *Zapremina krupnog drveta V_7 (model 1)*

In order to secure the best relative relation between tree volume and the volume of certain assortments, the first thing to be done in this procedure was to make a tree volume evaluation model (of merchantable wood) based on the data. The main purpose of creating such a model is precise calculation of volume share of certain assortments for the purpose of this paper. That is why the model for evaluating the volume of merchantable wood has the same factors as the models for evaluating the volume of certain assortments or groups of assortments. The regression model for ascertaining the volume of merchantable wood includes the following independent category factors:

1. DBH_{cl} – diameter class of 5 cm width, based on the measured breast diameter,
2. TQ_{cl} - technical quality class of the tree, And for the quantitative factor, the following was taken:
3. H - tree height in meters.

With the aim of optimizing the model, the transformation of the dependent variable was conducted by using the Box-Cox (1964) procedure with the determined exponent $\lambda = 0.179096$. The resulting regression model has a high coefficient of multiple determination ($R^2 = 0.9878$), and the regression results are given in Tables 2 and Tables 3.

Based on the data from Tables 2 and 3, it is noticeable that each independent factor shows a considerable impact on the size of the dependent variable, while the impact of the technical class remains the smallest. According to the sizes of the parameters of the regression model alongside the quality classes, it can be concluded that the trees are of lower quality, and those of the same diameter, are somewhat slighter taper than better quality trees. The average volumes of spruce trees by diameter classes, with intervals of least significant difference around average sizes, are presented in Figure 2.

Table 2. The analysis of variance for the volume of trees (merchantable wood) – V_7

Tabela 2. Analiza varijanse zapremine stabala (krupno drvo) - V_7

Source *Izvor*	**Sum of Squares** *Suma kvadrata*	**Df**	**Mean Square** *Sredina kvadrata*	**F-Ratio** *F-odnos*	**P-Value** *P-vrijednost*
Model	868.857	18	48.2698	1685.60	0.0000
Residual	10.7101	374	0.0286366		
Total (Corrected)	879.567	392			

Table 3. Type III Sums of Squares

Tabela 3. Suma kvadrata tip III

Source *Izvor*	**Sum of Squares** *Suma kvadrata*	**Df**	**Mean Square** *Sredina kvadrata*	**F-Ratio** *F-odnos*	**P-Value** *P-vrijednost*
TQ_{class}	0.36893	3	0.122977	4.29	0.0054
DBH_{class}	51.2513	14	3.66081	127.84	0.0000
H	9.0211	1	9.0211	315.02	0.0000
Residual	10.7101	374	0.0286366		
Total (Corrected)	879.567	392			

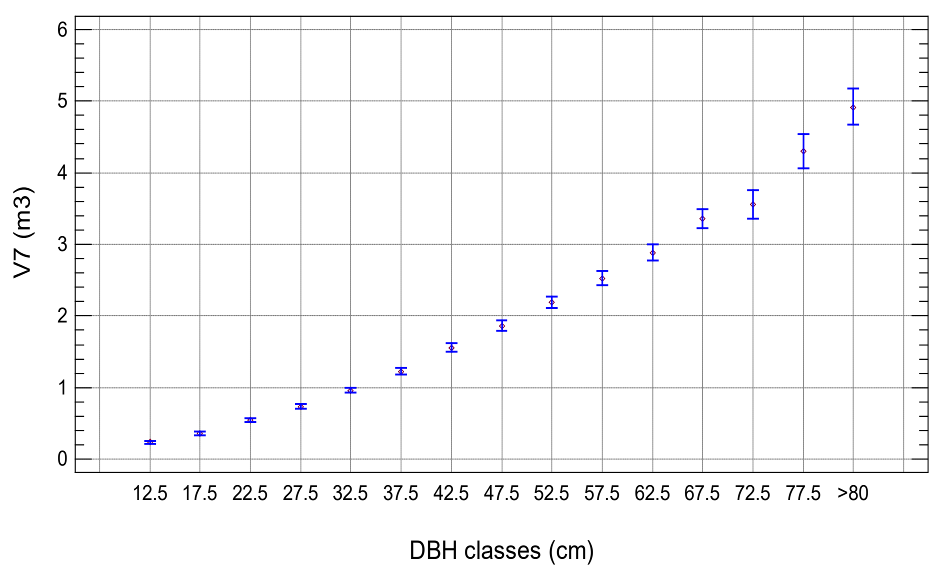

Figure 2. Average volumes of spruce trees (V_7) by diameter classes and least significant difference (LSD) intervals around average sizes

Grafikon 2. Prosječne zapremine stabala smrče (V_7) po debljinskim klasama i interval najmanjih značajnih razlika (LSD) oko prosječne vrijednosti

Analysis of residuals shows that they have no systematic deviation in any part of the domain of empirical data, with the exception of only two residuals leaving the ± 3 of the standard deviation.

The equation for the selected model is the following:

$$BoxCox\ (V_7) = -0.0958333 - 0.0267807 \cdot I1(1) + 0.0157342 \cdot I1(2) - 0.0513599 \cdot I1(3) - 2.06775 \cdot I2(1) - 1.66439 \cdot I2(2) - 1.25591 \cdot I2(3) - 0.929984 \cdot I2(4) - 0.626868 \cdot I2(5) - 0.338302 \cdot I2(6) - 0.0440483 \cdot I2(7) +$$

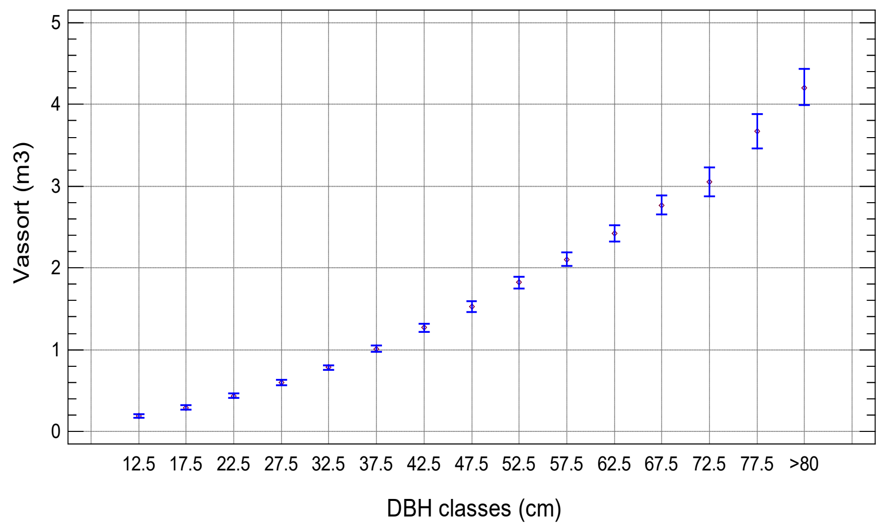

Figure 3. Average volumes of all asortments (V_{assort}) by diameter classes and least significant difference (LSD) intervals around average sizes

Grafikon 3. Prosječna zapremina svih sortimenata (V_{assort}) po debljinskim klasama i interval najmanjih značajnih razlika (LSD) oko prosječne vrijednosti

0.184114·I2(8) + 0.396691·I2(9) + 0.590793·I2(10) + 0.774412·I2(11) + 0.990616·I2(12) + 1.07565·I2(13) + 1.35434·I2(14) + 0.0661968·H

With:
BoxCox (V_7) = 1 + ($V_7^{0.179096}$-1)/(0.179096*1.20162$^{-0.820904}$)
I1(1) = 1 if TQ_{cl}=1; -1 if TQ_{cl}=4; 0 otherwise
I1(2) = 1 if TQ_{cl}=2; -1 if TQ_{cl}=4; 0 otherwise
I1(3) = 1 if TQ_{cl}=3; -1 if TQ_{cl}=4; 0 otherwise
I2(1) = 1 if DBH_{cl}=12.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(2) = 1 if DBH_{cl}=17.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(3) = 1 if DBH_{cl}=22.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(4) = 1 if DBH_{cl}=27.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(5) = 1 if DBH_{cl}=32.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(6) = 1 if DBH_{cl}=37.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(7) = 1 if DBH_{cl}=42.5; -1 if DBH_{cl}=80 and more; 0

Table 4. Average spruce tree height per diameter degrees for different technical quality classes

Tabela 4. Prosječne visine stabala smrče po debljinskim stepenima i tehničkim kvalitetnim klasama

Technical class *Tehnička klasa*	**Diameter of spruce trees (cm)** *Debljinski stepen (cm)*														
	12.5	**17.5**	**22.5**	**27.5**	**32.5**	**37.5**	**42.5**	**47.5**	**52.5**	**57.5**	**62.5**	**67.5**	**72.5**	**77.5**	**82.5**
	Tree height (m) *Visina stabla (m)*														
I	11.7	16.1	19.5	22.1	24.3	26.2	27.9	29.4	30.7	31.9	33.0	34.0	35.0	35.9	36.7
II	11.7	15.8	18.9	21.3	23.3	25.1	26.6	27.9	29.1	30.2	31.3	32.2	33.1	33.9	34.6
III	11.2	15.1	18.0	20.4	22.3	24.0	25.5	26.8	27.9	29.0	30.0	30.9	31.7	32.5	33.2
IV	10.4	14.0	16.5	18.4	20.1	21.4	22.7	23.7	24.7	25.6	26.5	27.3	28.0	28.7	29.3

otherwise
I2(8) = 1 if DBH_{cl}=47.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(9) = 1 if DBH_{cl}=52.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(10) = 1 if DBH_{cl}=57.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(11) = 1 if DBH_{cl}=62.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(12) = 1 if DBH_{cl}=67.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(13) = 1 if DBH_{cl}=72.5; -1 if DBH_{cl}=80 and more; 0 otherwise
I2(14) = 1 if DBH_{cl}=77.5; -1 if DBH_{cl}=80 and more; 0 otherwise

Volumes of all assortments – V_{assort} (model 2) – *Zapremina svih sortimenata - V_{assort} (model 2)*

The volume of all assortments was determined using the same procedure and the same independent variables as in the previous case. Also, the transformation of the dependent variable was conducted with the determined exponent $\lambda = 0.194387$. Every factor showed a significant influence on the dependent variable, and the chosen regression model has a high degree of explanation of the dependent variable's size (coefficient of multiple determination $R^2 = 0.9870$). The equation for the chosen model, its statistical parameters and the analysis of residuals are given in the supplement to this paper. Average volumes of all spruce tree assortments by diameter classes with intervals of least significant difference around average sizes are presented in Figure 3.

Average tree heights per diameter classes (model 3) – *Prosječne visine stabala po debljinski klasama (model 3)*

A significant correlation was established between the technical quality of trees and their height (for the same DBH), which is also logical since the trees in better stands are usually taller and have better trunks due to the faster clearing of branches. For this reason, and only for the purpose of creating assortment tables in this paper, we established mathematical models for estimating average heights of spruce trees in meters (H) depending on the DBH in cm. This was done separately for each technical class, and these were determined to be the best individual models of average tree height estimate:

TQ_{cl} =1: $H = -21.679 + 13.2165 \cdot \ln(D_{1,30})$; $R^2 = 94.03$
TQ_{cl} =2: $H = -18.7045 + 12.0706 \cdot \ln(D_{1,30})$; $R^2 = 80.76$
TQ_{cl} =3: $H = -19.5113 + 12.0537 \cdot \ln(D_{1,30})$; $R^2 = 85.99$
TQ_{cl} =4: $H = -16.998 + 10.6301 \cdot \ln(D_{1,30})$; $R^2 = 78.93$

Models were used to calculate the average heights per diameter classes and technical classes (Table 4). These heights were used to calculate the volumes of merchantable wood and the volumes of certain log types while creating the assortment tables.

Utilization degree of spruce in tree wood volume – *Stepen iskorištavanja u zapremini stabala smrče*

Using regression models 1, 2 and 3 the tree volumes were established as well as the volumes of all wood assortments per diameter and technical quality classes. Based on the established volumes, the percentage share of assortments in tree volumes was calculated, i.e. the percentage of utilization of tree volume into assortments. This data is presented in Table 5. The calculation of percentage share of individual assortments or group assortments in spruce tree volume was calculated in the same manner in the rest of this paper.

Table 5. Percentage share of all assortments in spruce tree volumes (degree of utilization)

Tabela 5. Procentualni udio svih sortimenata u zapremini stabala smrče (stepen iskorištenja)

Diameters class (cm) *Debljinska klasa (cm)*	**Technical quality classes** *Tehnička kvalitetna klasa*			
	I	**II**	**III**	**IV**
	% assort	**% assort**	**% assort**	**% assort**
10-14	75.6		73.9	71.1
15-19	80.2		78.7	75.9
20-29	81.2	80.7	79.9	77.4
30-39	82.8	82.4	81.8	79.5
40-49	82.7	82.3	81.9	79.8
50-69	83.9	83.6	83.4	81.6
>70	85.7	85.5	85.4	83.9

Volumes of all logs - V_{logs} (model 4) – *Zapremina svih trupaca V_{logs} (model 4)*

While analyzing the log volume, we excluded the trees under 20 cm DBH since, according to current standards, logs cannot be produced from these trees. For the procedure of creating the model, 341 trees were used. The volume of all spruce logs consists of the following:

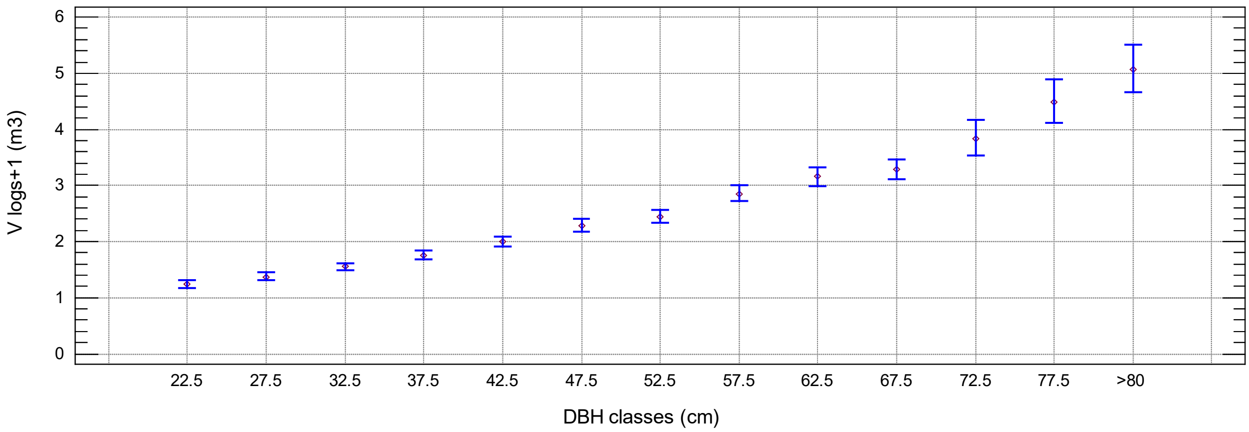

Figure 5. Average volume of all logs by diameter classes and least significant difference (LSD) intervals around average sizes

Grafikon 5. Prosječna zapremina trupaca po debljinskim klasama i interval najmanjih značajnih razlika (LSD) oko prosječne vrijednosti

VL – veneer logs
SL_I – I class saw logs
SL_2 – II class saw logs
SL_3 – III class saw logs

It is clear that levelling the volumes of all logs is far more reliable than the direct levelling of individual log types. For this purpose, the volumes, i.e. the percentage share of log types which are the least represented in tree volumes (VL and SL_I), were calculated as the difference between the volumes (percentage) determined for all logs together and the most represented log groups (SL_2 and SL_3).

This regression model included the same independent variables as model 1. In the regression procedure itself, the dependent variable was linearly increased by 1 (m^3) for each data (V_{logs}+1). This was done in order to enable the model optimization by transformation according to the Box-Cox procedure (eliminating zeroes from the data), while keeping in mind that this increase in dependent variable data has no impact on the quality of regression and its statistical parameters. It is understood that in the final calculation of volume, according to this model, it is necessary to deduct 1 (m^3) from the obtained values. All independent variables had a statistically significant impact on the dependent variable, and the regression model has a high level of explanation of the dependent variable's size (multiple determination coefficient R^2 = 0.9206). The equation for the chosen model, its statistical parameters and the analysis of residuals are given in the supplement to this paper. The average volumes of all spruce logs are presented by diameter and quality classes in Figure 4, while the least significant difference intervals around average sizes, are presented in Figure 5.

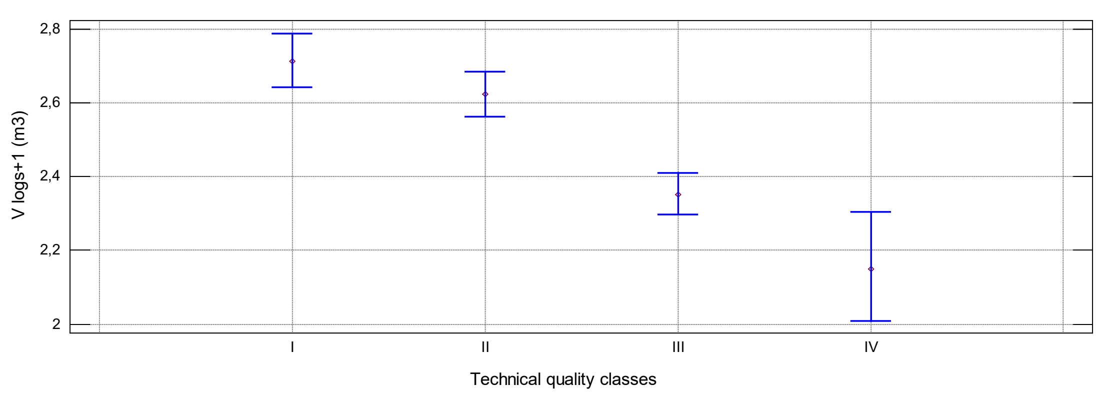

Figure 6. Average volume of all logs by technical quality classes and least significant difference (LSD) intervals around average sizes

Grafikon 6. Prosječna zapremina trupaca (V_{assort}) po tehničkim klasama i interval najmanjih značajnih razlika oko prosječne vrijednost

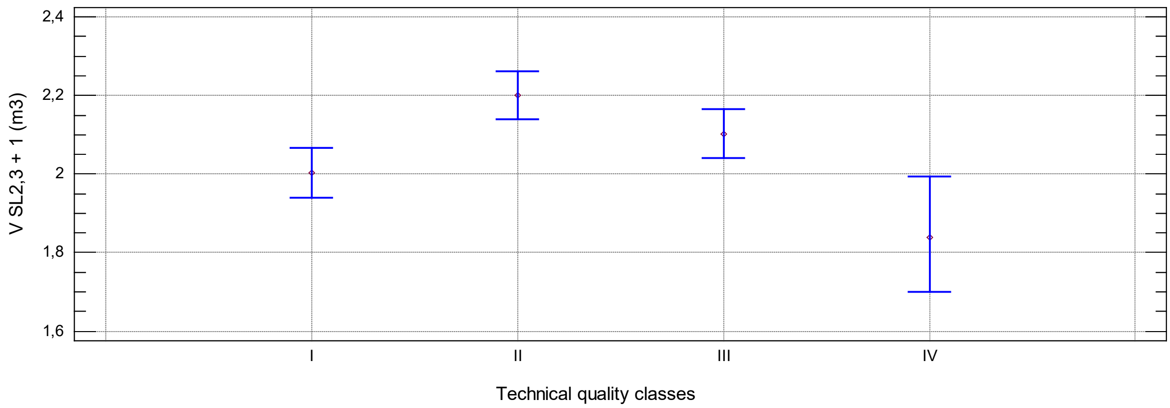

Figure 7. Average volume of sawlogs II and III class by technical quality classes and least significant difference (LSD) intervals around average sizes

Grafikon 7. Prosječna zapremina pilanskih trupaca II i III klase po tehničkim klasama i interval najmanjih značajnih razlika oko prosječne vrijednosti

Percentage log share in spruce tree volume – *Procentualni udio truapca u zapremini stabala smrče*

Based on models 1 and 4, spruce tree volumes and log volumes were calculated according to diameter classes, separately for each technical class. This procedure could not be conducted for the quality class IV since it lacks the best quality logs (VL and SL_1), thus the data obtained through the regression model in this part is unreliable. This problem will be solved by creating the model for estimating log volumes of classes SL_2 and SL_3 together. The percentage share of logs was then determined by simply dividing log volume and merchantable wood volume (both per diameter and technical classes).

Saw log volume for classes II and III - V $SL_{2,3}$ (model 5) – *Zapremina pilanskih trupaca II i III klase V $SL_{2,3}$ (model 5)*

The total share of these logs in the sample is over 50% of merchantable wood volume, with an average of 73% of all logs. In addition, this assortment group is greatly represented in all diameter classes (over 20 cm) and all technical tree classes. The conducted analysis showed that the model for determining the volume of saw logs from class II and III (combined) was more reliable (has fewer mistakes) than the model used to determine the combined volume of veneer and class I saw logs. During the optimization of the model, the Box-Cox transformation of the dependent variable with the exponent λ = -0.429777 was used. Here, just like with model 4, the dependent variable was increased by 1 (m^3) linearly for each data, for the previously explained reasons. The resulting regression model has a multiple determination coefficient of R^2 = 0.8471. The equation for the chosen model, its statistical parameters and the analysis of residuals are given in the supplement to this paper. The average volumes of analyzed logs by technical quality classes and least significant difference intervals around average sizes are presented in Figure 6.

The figure shows that the reliability interval around the average volume size of these logs in the technical class IV is significantly wider (larger) than for other classes. This points to the conclusion that the results for this class are rather unreliable, the main reason being the fact that only a few trees of this class contained logs that have been analyzed in the sample.

Saw log volume for class II - V SL_2 (model 6) – *Zapremina pilanskih trupaca II klase V SL_2 (model 6)*

In the sample tree volume, the volume of class II saw logs was larger and better distributed by diameter classes than the volume of saw logs in class III. Therefore, the model for the estimate of their volume is more reliable than the one for saw logs in class III, and that is why it is presented in this paper. Just like in previously described procedures, while creating this model, trees with DBH over 20 cm were used alongside the same independent variables (with already explained 1 (m^3) increase of the dependent variable). During the optimization of the model, the Box-Cox dependent variable transformation was applied with the exponent λ = -0.744052. The resulting regression model has a multiple determination coefficient of R^2 = 0.6309. The equation for the chosen model and its statistical parameters are given in the supplement to this paper. The average volumes of these logs by diameter classes and least significant difference intervals around average sizes are presented in Figure 7.

The following volumes were determined based on the previous regression models: tree volumes, the volumes of all wood assortments, volumes of all logs together, combined saw log volumes for classes II and III, and volume for saw logs of class II. The obtained sizes of volumes were used to calculate the percentage share of all assortments and/or assortment groups in the spruce tree volume.

Pit timber, pulpwood and firewood – *Rudno drvo, celulozno drvo i ogrjevno drvo*

This assortment group consists of assortments such as pit timber (PT), pulpwood (PW) and firewood (FW). Firewood was represented with only 0.23% in the sample, and in the volume of this assortment group with only 2.6%. Therefore, firewood is included in the volume of pulpwood in all the analyses. In practice, pit timber and pulpwood most often substitute each other, depending on the current demand on the market. Their percentage share has already been determined by previously defined percentage share of all assortments combined and the percentage share of all logs combined, and represents their difference: $PT + PW = V_{assort} - V_{logs}$ (%). The share of pit timber has, as opposed to pulpwood, shown a clear regularity of appearance according to diameter classes, thus it was easier to make a regression model for the estimate of its volume.

Pit timber share in tree volume (model 7) – *Udio rudnog drveta u zapremini (model 7)*

While searching for the optimal model for estimating pit timber volume, i.e. its share in spruce tree volume, it was noticed that direct levelling of percentage share in tree volume yielded the model with the largest multiple determination coefficient ($R^2 = 0.536$) and the best residual distribution around the estimate line. For the creation of the model, the same independent variables were used as in all previous models, and the ponder in calculating the equation parameters was merchantable wood volume (V_7). The equation for the chosen model is given in the supplement to this paper. The average percentage share of pit timber by diameter classes with least significant difference intervals around average sizes are presented in Figure 8. Based on previous models it is easy to obtain the percentage share of pulpwood and firewood: $PW + FW = V_{assort} - V_{logs} - PT$ (%)

Veneer log share in tree volume (model 8) – *Udio furnirskih trupaca u zapremini stabala (model 8)*

The share of veneer logs in the volume of large spruce tree wood is relatively small. The percentage share of veneer and class I saw logs combined (VL and SL_I) has already been determined as the difference of the share of all logs and saw logs of classes II and III combined. These assortments do not appear in the volumes of trees thinner than 30 cm, and their total share in the sample volume was only 1.21%. Due to insufficient data

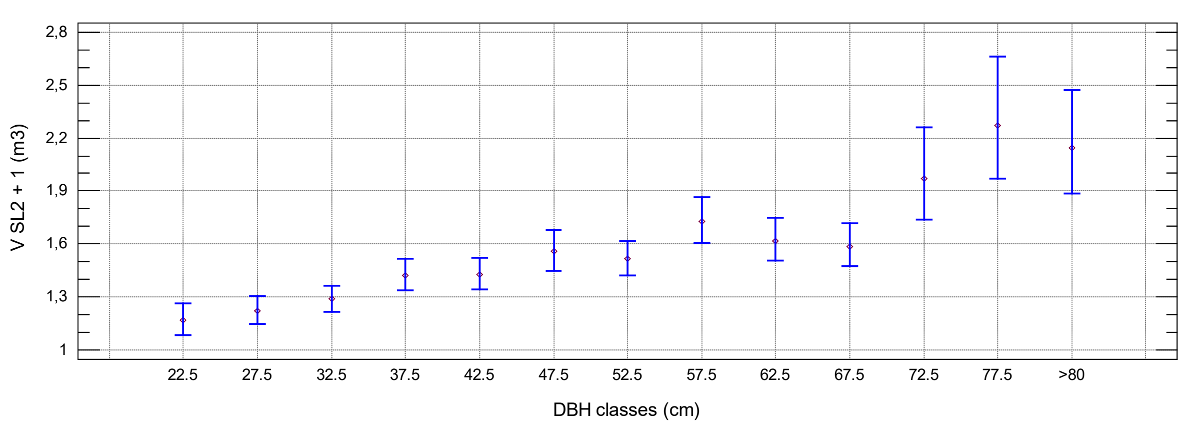

Figure 8. Average volume of class II saw logs by diameter classes and least significant difference (LSD) intervals around average sizes

Grafikon 8. Prosječna zapremina pilanskih trupaca II klase po debljinskim klasama i interval najmanjih značajnih razlika oko prosječne vrijednosti

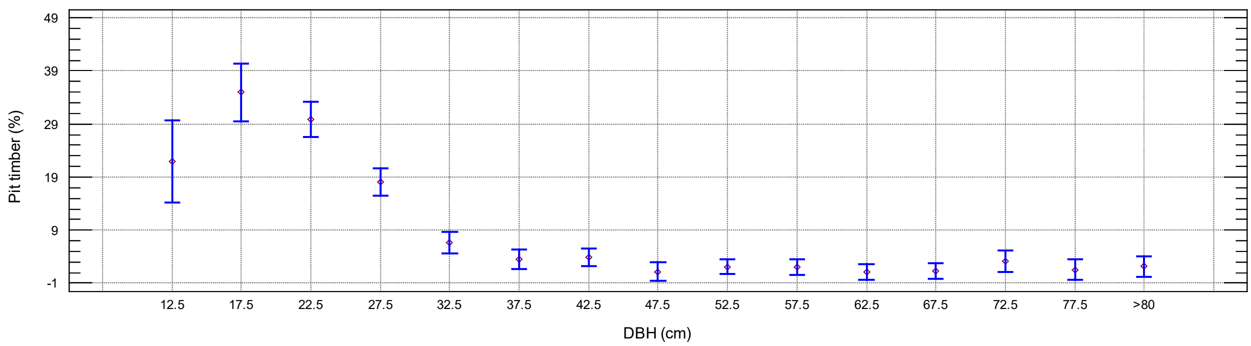

Figure 8. Average percentages of pit timber by diameter classes and least significant difference (LSD) intervals around average sizes

Grafikon 8. Prosječna procentualno učešće rudnog drveta po debljinskim klasama i interval najmanjih značajnih razlika (LSD) oko prosječne vrijednosti

and their variability by technical classes, there was no significant difference between veneer logs and saw logs of class I. Also, there were no significant differences in the percentage share of veneer logs by diameter classes. Therefore, the share of these logs in assortment tables was given together in the same group as class I saw logs ($VL + SL_I$) with the account of their relation by technical quality classes. The ascertained model for estimating the percentage share of veneer logs was of a very low explanation degree (only 12 %), and it is therefore not presented in this paper. The average percentages of veneer logs by diameter and quality classes, as well as the least significant difference intervals around average sizes, are given in the supplement to this paper.

The volumes of veneer and saw logs of class I - VL and SL_I (model 9) – *Zapremina furnirskih i pilanskih trupaca I klase VL and SL_I (model 9)*

Due to the regulations on minimal dimensions and quality of these logs, their share in tree volume is significantly lower than the saw logs of classes II and III, while this share increases with the increase in tree quality. For this reason, while creating the volume estimation model for these logs, only the trees over 30 cm DBH from first three diameter classes were taken into account. During the optimization of the model, the Box-Cox dependent variable transformation was applied with the exponent □ = -0.728027, as well as the linear increase in the dependent variable by 1 (m^3) for each piece of data. The equation for the chosen model and its statistical parameters is given in the supplement to this paper. The average volumes of these logs by technical quality classes and the least significant difference intervals around average sizes are presented in Figure 9.

The resulting model has an explanation degree of only 44.12% for the volume of these assortments. The main reason is their relatively small share (a lacking presence) i.e. high-volume variability by diameter classes. All the independent factors proved a significant impact on the volume of logs, but the factor of technical quality proved as most important. In other words, the volume (share) of these logs is significantly larger in better quality trees.

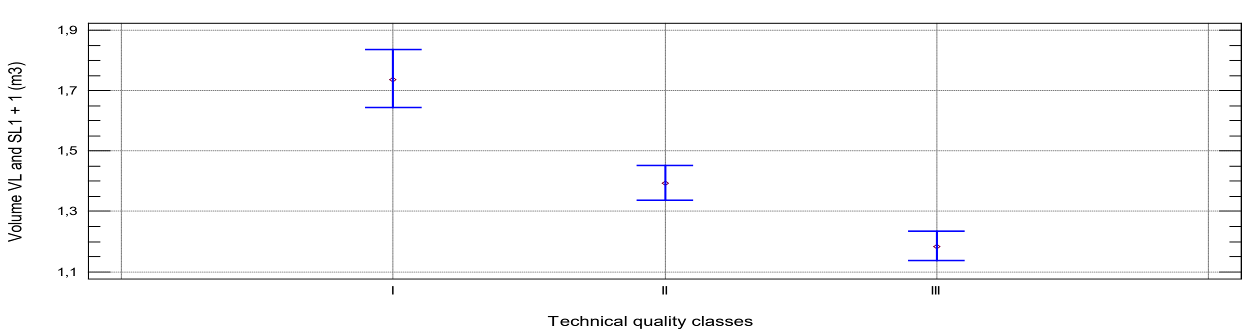

Figure 9. Average volume of veneer logs and class I saw logs per technical quality classes and least significant difference (LSD) intervals around average sizes

Grafikon 9. Prosječna zapremina furnirskih trupaca i pilanskih trupaca I klase po tehničkim klasama i interval najmanjih značajnih razlika (LSD) oko prosječne vrijednosti

Bark volume of spruce trees – *Zapremina kore stabala smrče*

Bark thickness and percentage share of bark in the volume of roundwood (section) in this area of research were already determined in the paper "Modelling bark thickness of Norway Spruce (*Picea abies* Karst)" (Musić et al. 2019). The results of this paper were used during the creation of wood assortment tables.

Percentage share of waste in spruce tree volume (W) – *Procentulani udio otpatka u zapremini stabala smrče (W)*

Waste usually consists of the following: different unproduced parts of merchantable wood and sawdust, and prescribed method of scaling round-wood, including deduction of the double bark thickness. Since the bark volume was determined in the paper, the waste share is calculated as the difference between the percentage share of merchantable wood volume (100%) and the percentage share of all assortments and bark.

Assortment tables – percentage share of assortments in the volume of spruce tree merchantable wood – *Sortimentne tablice – procentulani udio sortimenata u zapremini krupnog drveta stabala smrče*

The final data on determined percentage shares of certain forest wood assortments were obtained by correcting the data obtained using the presented regression models and the explained procedures. To clarify, it was necessary to correct the percentage shares of some assortments by diameter and technical classes in a manner that their sum matches the percentage share of all assortments combined i.e. the percentage share of merchantable wood (100%). The final results are presented in Tables 6-9.

Through the analysis of the obtained results on the percentage share of certain wood assortment and/or assortment groups, it can be stated that they are logical, and largely confirm the previously established relations (Rebula 1996, Rebula 1998a, Rebula 1998b, Plavšić and Golubović 1963, Pavlič 1973 etc.). Nonetheless, by comparing these tables with the current spruce assortment tables for spruce (Pavlič 1973), a significant increase in the most valuable assortments can be noticed (VL and SL_I), especially in the first technical and diameter class (20-30 cm). These differences are conditioned primarily by the changes in standards that have occurred in the meantime, regarding the lowering of quality criteria. Similar results can also be found in the research by Plavšić and Golubović (1963) of fir assortment share according to the regulations of two different standards. Comparisons with the results of authors from different countries, that also dealing with assortment structures, is not suitable, due to the differences in standards and classification systems of wood assortments, but it is confirmed that tree diameter and quality show a dominant impact on the percentage representation of wood assortments regardless of valid regulations and tree species.

CONCLUSIONS - *Zaključak*

Based on the acquired results from the conducted research and the discussion that followed, it is possible to select the following important conclusions:

- The influence of independent variables on all dependent variables was manifested and it is statistically significant.
- The width of the tree i.e. diameter at breast height is confirmed as a reliable indicator of tree quality i.e. its value. With the increase of the width, the share of the valuable assortments grows, and the share of less valuable assortments decreases in all technical classes, at the same time the level of wood volume usefulness increases.
- The increase in tree quality expressed through the qualification in certain technical quality classes (for the same diameters) results, principally, in a significantly larger share of the most valuable assortments.
- The influence of tree height on the volume of each assortment was, as expected, manifested through the increase in volume of trees and their belonging assortments, as well as through common influence with quality since better quality trees were of greater average height.
- The created assortment tables and their wood product assortment greatly correlate with the current state of wood industry, and they correspond to the valid standards in forestry and wood processing.

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Table 6. First technical class trees

Tabela 6. Stabla prve tehničke klase

DBH class	Veneer and saw logs I class VL + SL1	Saw logs II class SL2	Saw logs III class SL3	Saw logs II and III class SL2+SL3	All Logs	Pit timber PT	Pulp wood PW	PT+PW	All Assortments	Bark B	Waste W	Total merchantable wood
Debljinska klasa	*Furnirski i pilanksi trupci prve kalse VL + SL1*	*Pilanski trupci II klase SL2*	*Pilanski trupci III klase SL3*	*Pilanski trupci II i III klase SL2+SL3*	*Svi trupci*	*Rudno drvo PT*	*Celulozno drvo PW*	*PT+PW*	*Svi sortimenti*	*Kora B*	*Otpadak W*	*Ukupno krupno drvo*
cm	%	%	%	%	%	%	%	%	%	%	%	%
10-14	0.00	0.00	0.00	0.00	0.00	25.13	50.50	75.63	75.63	11.00	13.37	100.00
15-19	0.00	0.00	0.00	0.00	0.00	37.21	43.00	80.21	80.21	11.49	8.30	100.00
20-29	34.30	10.80	9.60	20.40	54.70	19.10	7.40	26.50	81.20	10.70	8.10	100.00
30-39	34.30	24.20	9.80	34.00	68.30	3.85	10.60	14.45	82.75	10.00	7.25	100.00
40-49	31.10	26.00	14.50	40.50	71.60	0.84	10.20	11.04	82.64	9.20	8.16	100.00
50-69	28.80	26.00	17.20	43.20	72.00	0.06	11.90	11.96	83.96	8.80	7.24	100.00
70-90	30.70	25.90	22.60	48.50	79.20	0.24	6.30	6.54	85.74	8.40	5.86	100.00
	(3.0 : 97.0)											

Table 7. Second technical class trees

Tabela 7. Stabla druge tehničke klase

DBH class	Veneer and saw logs I class VL + SL1	Saw logs II class SL2	Saw logs III class SL3	Saw logs II and III class SL2+SL3	All Logs	Pit timber PT	Pulp wood PW	PT+PW	All Assortments	Bark B	Waste W	Total merchantable wood
Debljinska klasa	*Furnirski i pilanksi trupci prve kalse VL + SL1*	*Pilanski trupci II klase SL2*	*Pilanski trupci III klase SL3*	*Pilanski trupci II i III klase SL2+SL3*	*Svi trupci*	*Rudno drvo PT*	*Celulozno drvo PW*	*PT+PW*	*Svi sortimenti*	*Kora B*	*Otpadak W*	*Ukupno krupno drvo*
cm	%	%	%	%	%	%	%	%	%	%	%	%
20-29	3.20	27.50	10.20	37.70	40.90	19.54	20.30	39.84	80.74	11.00	8.26	100.00
30-39	17.10	36.50	8.90	45.40	62.50	4.35	15.50	19.85	82.35	10.25	7.40	100.00
40-49	18.30	33.10	16.10	49.20	67.50	1.39	13.40	14.79	82.29	9.40	8.31	100.00
50-69	16.10	32.00	19.40	51.40	67.50	0.70	14.30	15.00	82.50	9.10	8.40	100.00
70-90	18.40	31.50	26.10	57.60	76.00	0.93	8.50	9.43	85.43	8.70	5.87	100.00
	(0.3 : 99.7)											

Table 8. Third technical class trees

Tabela 8. Stabla treće tehničke klase

BH class	Veneer and saw logs I class VL + SL1	Saw logs II class SL2	Saw logs III class SL3	Saw logs II and III class SL2+SL3	All Logs	Pit timber PT	Pulp wood PW	PT+PW	All Assortments	Bark B	Waste W	Total merchantable wood
Debljinska klasa	*Furnirski i pilanksi trupci prve kalse VL + SL1*	*Pilanski trupci II klase SL2*	*Pilanski trupci III klase SL3*	*Pilanski trupci II i III klase SL2+SL3*	*Svi trupci*	*Rudno drvo PT*	*Celulozno drvo PW*	*PT+PW*	*Svi sortimenti*	*Kora B*	*Otpadak W*	*Ukupno krupno drvo*
cm	%	%	%	%	%	%	%	%	%	%	%	%
10-14	0.00	0.00	0.00	0.00	0.00	25.80	48.10	73.90	73.90	11.40	14.70	100.00
15-19	0.00	0.00	0.00	0.00	0.00	38.00	40.70	78.70	78.70	11.90	9.40	100.00
20-29	0.00	2.20	23.60	25.80	25.80	20.00	34.10	54.10	79.90	11.00	9.10	100.00
30-39	7.10	23.10	20.80	43.90	51.00	4.80	26.00	30.80	81.80	10.40	7.80	100.00
40-49	11.10	24.10	24.90	49.00	60.10	1.90	19.90	21.80	81.90	9.50	8.60	100.00
50-69	11.90	24.10	27.40	51.50	63.40	1.20	18.70	19.90	83.30	9.20	7.50	100.00
70-90	13.10	24.20	33.00	57.20	70.30	1.50	13.60	15.10	85.40	8.80	5.80	100.00
	(0.0 : 100.0)											

Table 9. Fourth technical class trees

Tabela 9. Stabla četvrte tehničke klase

BH class	**Veneer and saw logs I class VL + SL I**	**Saw logs II class SL2**	**Saw logs III class SL3**	**Saw logs II and III class SL2+SL3**	**All Logs**	**Pit timber PT**	**Pulp wood PW**	**PT+PW**	**All Assortments**	**Bark B**	**Waste W**	**Total merchantable wood**
Debljinska klasa	***Furnirski i pilanksi trupci prve kalse VL + SL I***	***Pilanski trupci II klase SL2***	***Pilanski trupci III klase SL3***	***Pilanski trupci II i III klase SL2+SL3***	***Svi trupci***	***Rudno drvo PT***	***Celulozno drvo PW***	***PT+PW***	***Svi sortimenti***	***Kora B***	***Otpadak W***	***Ukupno krupno drvo***
cm	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
10-14	0.00	0.00	0.00	0.00	0.00	23.10	47.10	70.20	70.20	11.70	18.10	100.00
15-19	0.00	0.00	0.00	0.00	0.00	35.30	40.20	75.50	75.50	12.10	12.40	100.00
20-29	0.00	0.00	2.10	2.10	2.10	17.20	58.00	75.20	77.30	11.20	11.50	100.00
30-39	0.00	17.60	6.10	23.70	23.70	2.10	53.80	55.90	79.60	10.60	9.80	100.00
40-49	0.00	20.40	13.00	33.40	33.40	0.00	46.60	46.60	80.00	9.70	10.30	100.00
50-69	0.00	17.90	19.60	37.50	37.50	0.00	44.10	44.10	81.60	9.40	9.00	100.00
70-90	0.00	17.00	25.10	42.10	42.10	0.00	41.70	41.70	83.80	9.00	7.20	100.00
	(0.0 : 100.0)											

SAŽETAK

Postojeće tablice drvnih sortimenata za najvažnije vrste drveća u BiH napravljene su prije gotovo 50 godina. Postoje indikacije da se procentualno učešće šumskih drvnih sortimenata, prikazano u njima razlikuje od stvarnog, kako u pogledu kvaliteta tako i dimenzija. U međuvremenu, od stvaranja postojećih sortimentnih tablica do danas, promijenili su se standardi za proizvodnju šumskih drvnih sortimenata, tako da je neadekvatnost postojećih sortimentnih tablica neupitna.

Ta činjenica kontinuirano stvara razne probleme u operativnom poslovanju šumarskih preduzeća. Glavni cilj ovog rada je izrada sortimentnih tablica čiji će asortiman proizvoda od drveta biti u korelaciji sa trenutnim tržišnim uslovima. Istraživanje je provedeno na području Kantona 10 u FBiH. Uzorak od 393 stabala smrče korišten je kao baza podataka za izradu ovog rada. Sječa stabala izvedena je u skladu s važećim normama i zahtjevima kupaca s obzirom na dimenzije proizvoda od drveta. Obrada podataka izvršena je metodama jednostavne i višestruke regresije, analizom varijanse kao i njihovim kombinacijama metodom Generalizovanog linearnog modela. Nezavisni faktori bili su prsni prečnik stable (DBH), tehnička kvalitetna klasa i visina stabala. Udio drvnih sortimenata utvrđen je kroz 10 različitih matematičkih modela, u svakom od njih utvrđeno je da su sve nezavisne varijable imale statistički značajan uticaj na zavisne varijable - zapreminu pojedinih sortimenata ili grupe sortimenata. Udio trupaca značajno raste s povećanjem prečnika stabla, a smanjuje se smanjenjem njihovog tehničkog kvaliteta. Uticaj visine stabla na zapreminu sortimenata prvenstveno je povezan s većom zapreminom visočijih stabala istog prečnika, dok u procentualnom udjelu u zapremini stabala istog prečnika nema statistički značajan uticaj. Stabla iz uzorka, koja imaju veću zapreminu kvalitetnih sortimenata, u prosjeku imaju veću visinu stabala za istu klasu prečnika što je skriveni uticaj boniteta staništa na kvalitet stabala. Rezultati istraživanja predstavljeni su u obliku tabela za pojedine kvalitetne klase, kao procentualni udio drvnih sortimenata u pojedinim debljinskim klasama. Dobijeni rezultati mogu se koristiti kao sortimentne tablice u istraživanom području.