Relationship Between the Values of Beech Timber (*Fagus* L.) and Tree Dimensions in Forest Thinning in Serbia

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Abstract

The planning and implementation of the majority of professional measures and activities in forest production management requires the knowledge of the basic quantitative elements (tree diameter, height, volume) and value elements (value of wood volume). In that sense, the aim of this research was to define the relationship between the value of timber and tree dimensions in beech forest thinning in Serbia (regression models, average growth rates, etc.). This will make it possible to predict in advance some value parameters, to raise the quality level of thinning operation planning, as well as to achieve better management of financial flows in the forestry sector (e.g. assessment of efficiency and profitability). The sample consisted of 7,815 beech trees harvested by thinning (5,973 in high forests and 1,842 in coppice forests), and the measurements included total volume and the volume and value of timber assortments.

The main scientific method applied in the study was the modelling method, and the analysis of causality between the study elements was performed using mathematical-statistical methods, such as descriptive statistics and regression and correlation analysis.

Based on the study results, the conclusions were as follows: (a) there is a high variability in timber value depending on forest origin and assortment category, (b) the effect of the diameter at breast height on timber value is stronger (the coefficient of linear regression R=0.52-0.83) than the effect of height (R=0.47-0.68), (c) the obtained regression models are a very good description of the relation between diameter at breast height and total timber value (R=0.58-0.97 in high forests and R=0.64-0.97 in coppice forests). An especially high quality model is the model which refers to the effect of diameter at breast height on the value per tree (R=0.97 in high forests and coppice forests), (d) all models show unequal distribution of the error along regression line (heteroskedasticity), but as this occurrence is more related to large trees, which are relatively few in thinning operations, this does not affect the accuracy of timber value assessment in thinning operations. The study conclusions point out that the timber value in beech forest thinning can be assessed with relatively high reliability.

The obtained models can be used when it is necessary to know the total value of thinned material (aiming at the determination of financial assessment of thinning efficiency), or when it is necessary to create the plans for selling the felled timber (estimation of the potential revenue).

Key words: diameter, height, timber value, beech, thinning, Serbia

Introduction

The planning and implementation of the majority of professional measures and activities in the management of production processes in forestry requires the knowledge of the basic quantitative elements (diameter, height, volume) and value elements (value of wood volume). The knowledge on the above elements should be based on a sufficiently large sample, professionally defined methods and procedures of basic data processing, consistent carrying out of all activities on data processing, precise analyses, and objective conclusions (Ranković and Vučković 2011). This study should be, inter alia, a contribution to such knowledge; it should provide good-quality information, but also point to the possibility of implementation of definite methodological procedures (Anon. 2011) in similar future studies.

State of beech forests in Serbia

In Serbia, forests occupy the area of 2,252,400 ha, with standing timber volume amounting to 362,487,418 m^3 and current volume increment 9,079,773 m^3. The dominant forest type in the growing stock are beech forests accounting for 29.3% per area (660,400 ha), 42.4% per volume (153,836,670 m^3) and 32.3% per volume increment (2,928,838 m^3) (Banković et al. 2009a, 2009b). Thanks to its adaptability to site conditions, beech has an exceptionally wide ecological valence in Serbia, both horizontal and vertical. Excepting the far north (AP Vojvodina), beech occurs throughout Serbia, at the altitudes between 100 and 1,700 m. It makes up about 50 different forest types with another 32 tree species, and 17 species belong to the categories of endemic, relic, rare and threatened species (Medarević and Milošević 2005). The prevalent category is high forests with 53.1% of the area, but there are a significant percentage of coppice forests (this is the consequence of historical circumstances - economic crisis caused by the frequent wars in the region and in connection with this cutting beech forests of high intensity over large areas, and errors resulting from the previously used system of forest management) with 46.9% of the area (Pantić et al. 2003). Correspondingly, devastated forests account for 2.8% of the area, insufficiently stocked forests 37.4%, and well-preserved forests 59.8% of the area. From the structural aspect, even-aged forests are dominant (78.4%), followed by all-aged forests (21.4%), and virgin forests occupy only 0.2% of the area. The distribution of even-aged forest area per age categories is quite unfavourable and accounts for: juvenile forests 3.7%, middle-aged 47.5% and maturing and mature forests 48.8%. The distribution of beech forest total volume per diameter categories (irrespective of structure) is balanced and accounts for: small-diameter trees 35.1%, medium-diameter trees 34.9% and large-diameter trees 30.0%. Currently, about 46,000,000 m^3 are in the category of large-diameter (mature) trees, and about 54,000,000 m^3 in the category of medium-diameter trees (Medarević et al. 2005, Banković et al. 2009a, 2009b).

The above data point to an exceptionally high ecological and economic significance of beech forests in Serbia. Hence, the research of this natural resource is an indispensable subject, particularly of socio economic disciplines. The resulting knowledge has both a theoretic and a practical significance, not only at the local, but also at the regional levels, taking into account the percentage of beech forests in Europe.

Aim, purpose and object of research and hypotheses

The basic aim of the research was to obtain good-quality numerical parameters of the relationship between timber value harvested by thinning in Serbia and some elements of tree dimensions (regression curves, average growth rates, etc.).

The basic purpose of the above aim was to evaluate the sums that can be used in the estimation of the market value of thinned material in beech forests in Serbia, and in creation of different future scenarios which comprise the data on timber value (e.g. in the calculation of insurance premiums (Holecy and Hanewinke 2006), timber selling (Anon. 2001, Anon. 2012), assessment of effectiveness of thinning implementation, estimation of total income from wood (Matthews 2003), value analysis (Anon. 2013) in wood supply chain (Uusitalo 2011), etc.). As some value parameters would be known in advance, this would increase the quality level of thinning operation planning, and create a reliable foundation for higher-quality management of financial flows in the forestry sector (e.g. assessment of efficiency and profitability).

The subject of the research was the dimensions (diameter at breast height and height) of beech trees removed by thinning, and beech timber value.

The basic hypotheses, which were to be confirmed, are the following:

- There are differences in the variability of the value of technical wood and cordwood per assortment classes and diameter classes;
- There is a strong correlation between the study parameters of timber value as a dependent variable, and diameter at breast height (*d*) and height (*h*), as independent variables;
- Effect of diameter (*d*) on the selected parameters of timber value (value of technical wood – M_t, value of cordwood – M_c, timber value per tree – M_{tr} and timber value per unit volume – M_V) is especially high, so such models can be successfully applied in the estimation of timber value.

Materials and methods

The main scientific method applied in the study was the modeling method, and mathematical-statistical methods, such as descriptive statistics and regression and correlation analysis, were used in the analysis of causality between the study elements.

Timber value was assessed by the method of assessment and prediction (Keča 2009), and correlation and regression analyses were used for the more accurate estimation (Ranković and Vučković 2011). The first step was the formation of a correlation matrix for the evaluation of the strength of linear correlation between individual variables of value structure and tree dimensions (diameter at breast height and height), and the next step was the formation of the corresponding regression models (Hadživuković 1991), used in the analysis of the relationship between timber value (*M*) and the diameter at breast height (*d*), and height (*h*).

The value of harvested wood volume was calculated based on the assortment structure of all felled trees (volume of each of the assortment classes), divided into two units based on the silvicultural forms of thinned forests (high forests and coppice forests).

This was followed by the calculation of timber value per assortment classes by the multiplication of the volume of each assortment category with the corresponding prices (PE "Srbijašume" Pricelist) in € (rate of exchange 21.03.2011) (this assessment operates with the gross value of wood and means that production costs were not deducted, then it would be net value, as it was the case in the document "Study of forest valuation and financing in Serbia" (Anon. 2007)). The value was expressed in four ways: total timber value (M) was first divided into the value of technical wood (M_t) and cordwood (M_c), and then the total timber value was presented per tree (M_{tr}) and per unit volume (M_V). Thus, the total value of wood (M) is the sum of technical wood (M_t) and firewood (M_c) without wastewood. In addition, the value of technical wood generates inside the value following assortments: F logs, L log, cordwood, logs of I, II, III classes and round sticks.

The main data were collected during regular thinning of even-aged (high and coppice) beech forests throughout Serbia (the territory of AP Kosovo and Metohija is not included, nor the territory of AP Vojvodina, where beech forests occupy only 1,626 ha) during 2009 (in 16 forest estates), at different altitudinal zones. Each tree was measured for diameter at breast height (d), and after felling and delimbing, total length (h) and trunk diameters were measured at 2 m sections. Branch diameters were measured in the middle of 1 m long sections. Trunk volume was calculated using a complex Smilian's equation, and branch volume was calculated using simple Huber's formula. Total volume of trees above 3 cm diameter (Banković and Pantić 2006) was calculated as the sum of the volume of the above two volumes. The volume of individual assortment classes was calculated based on the usual bucking of each felled tree, according to the standards for forest wood assortments and the assessed wood defects.

Total number of treated trees was 7,815, of which 5,973 in high forests and 1,842 in coppice forests (Table 1). As in 2009 in central part of Serbia (state-owned forests) 453,300 m^3 of beech timber was removed by thinning (Anon. 2010), and as his research deals with the volume of 11,392 m^3, it can be concluded that it is about 2.5% of the total felled volume. In that sense, from the quantitative and qualitative aspects, the sample structure can be considered as representative and, as such, it is a reliable base for drawing valid conclusions.

The basic analysis of assortment structure was performed using descriptive statistics (variability per diameter classes). Regarding the distribution of the number of trees per diameter classes, it was close to normal both in high forests and in coppice forests, with a mild left skewness (Figure 1). In high forests, the greatest number of trees was concentrated in diameter classes 17.5-37.5 cm, and in coppice forests in diameter classes 12.5-22.5 cm.

Table 1. Number of measured beech trees in thinning per regions in Serbia in 2009

Region	Forest origin		
	High forests	Coppice forests	Σ
East Serbia	1,234	94	1,328
Central Serbia	1,734	/	1,734
West Serbia	1,498	1,010	2,508
South Serbia	1,507	738	2,245
Σ	5,973	1,842	7,815

Source: original

As for volume distribution per diameter classes (Figure 2), the closeness to normal distribution was even more pronounced, with a mild left skewness in coppice forests. In high forests, the largest volume was concentrated in diameter classes 42.5-62.5 cm, and in coppice forests in diameter classes 22.5-32.5 cm.

Also, there was a similar situation in timber value distribution per diameter classes (Figure 3). In high forests, the highest timber value was concentrated in diameter classes 42.5-62.5 cm, and in coppice forests, in diameter classes 27.5-37.5 cm.

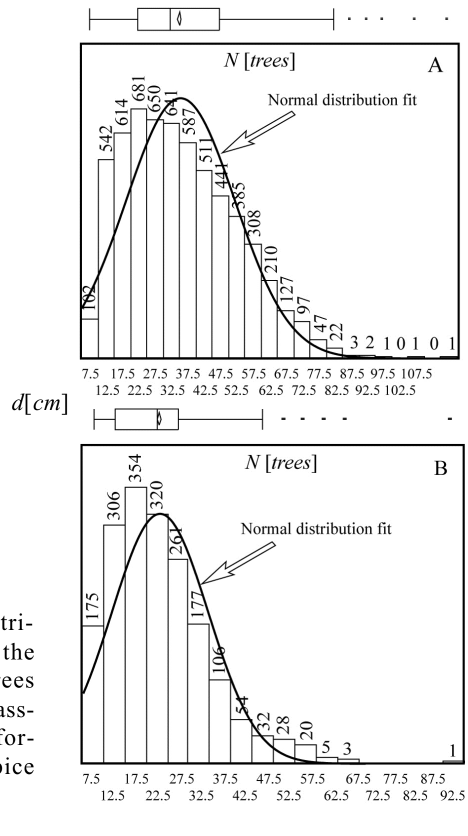

Figure 1. Distribution of the number of trees per diameter classes (A – high forests, B – coppice forests)

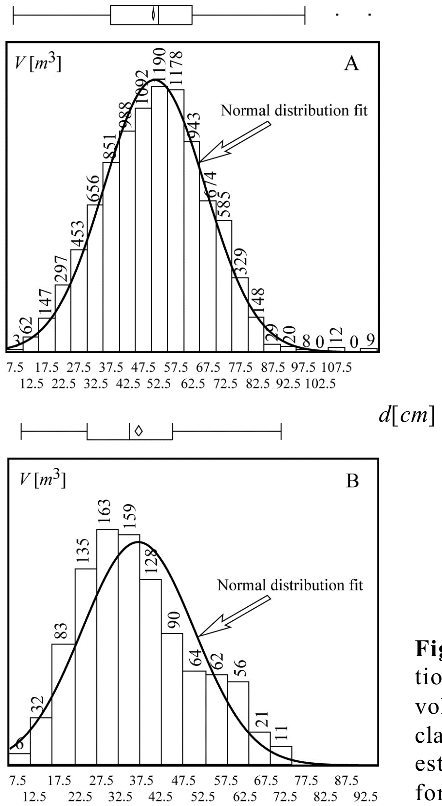

Figure 2. Distribution of total timber volume per diameter classes (A – high forests, B – coppice forests)

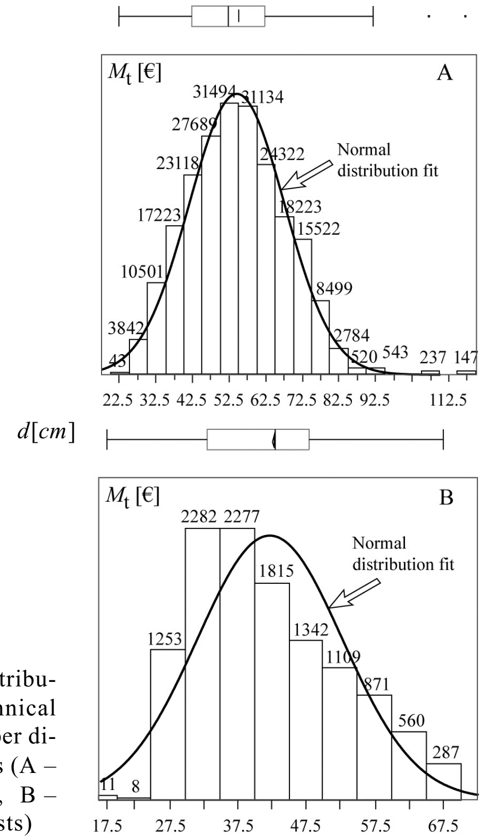

Figure 4. Distribution of technical timber value per diameter classes (A – high forests, B – coppice forests)

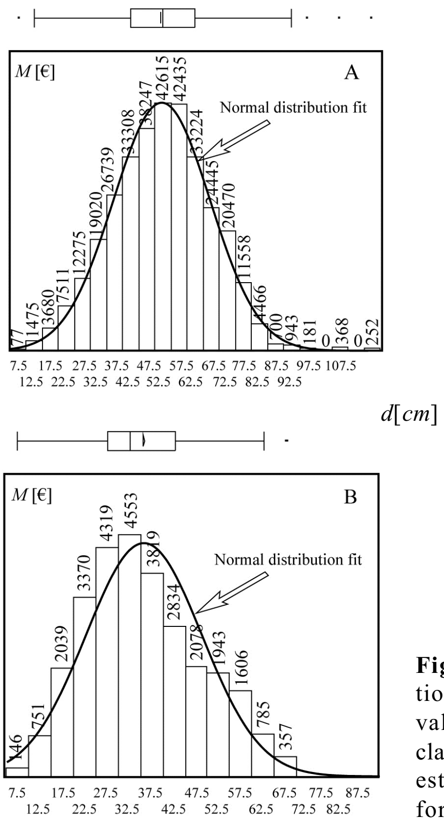

Figure 3. Distribution of total timber value per diameter classes (A – high forests, B – coppice forests)

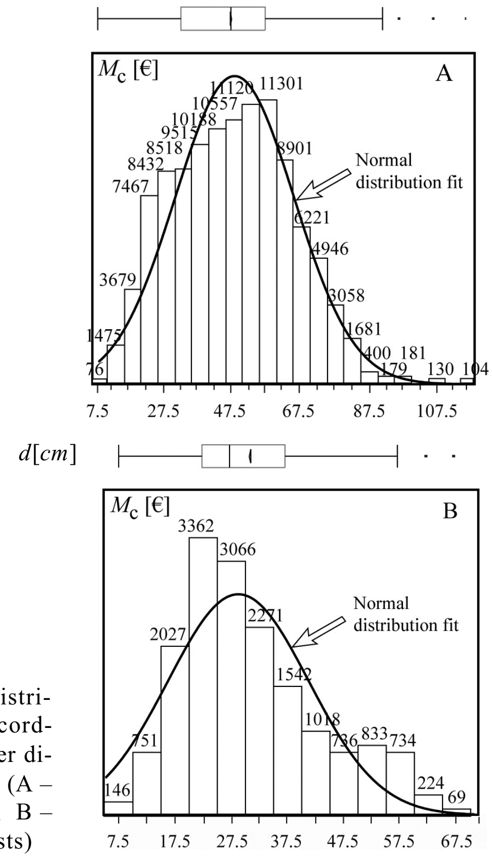

Figure 5. Distribution of cordwood value per diameter classes (A – high forests, B – coppice forests)

A very similar situation refers to the distribution of the values of technical wood and cordwood per diameter classes in high and coppice forests (Figures 4, 5). There is a somewhat higher deviation from normal distribution in coppice forests (both technical wood and cordwood). The value of technical wood of the trees in high forests is concentrated in diameter classes 47.5-62.5 cm, and in coppice forests it is concentrated in diameter classes 32.5-37.5 cm. Cordwood shows a considerably narrower range, so in high forests, the value is concentrated in diameter classes 37.5-57.5 cm, and in coppice forests in diameter classes 22.5-27.5 cm.

All the above facts prove that the basic data are rather regularly distributed per diameter classes, so they can be a rather reliable base (many statistical tests are based on the assumption of normality) for the estimation of timber value, on the one hand, and the assessment of the relationship between timber value and the elements of tree dimensions, on the other hand.

Results

The study results, which are based on the processing of the collected data, are grouped in accordance with the following segments (parallel for high forests and coppice forests):

- variability in the attained value within diameter classes;
- correlation between timber value (M_t, M_c, M_{tr} and M_V) and tree dimensions (d and h);
- regression models of the dependence of each of the above parameters of timber value (M_t, M_c, M_{tr} and M_V) and the diameter at breast height (d), i.e. the following regressions $M_t=f(d)$, $M_c=f(d)$, $M_{tr}=f(d)$ and $M_V=f(d)$.

Variability

The variability of the value of technical wood and cordwood per diameter classes is presented in the diagram (Figure 6).

Based on the presented variability of timber value per diameter classes, it can be seen that it is higher in technical wood, and lower in cordwood. Variability in technical wood value is higher in coppice forests (B), and variability in cordwood value is higher in high forests (A).

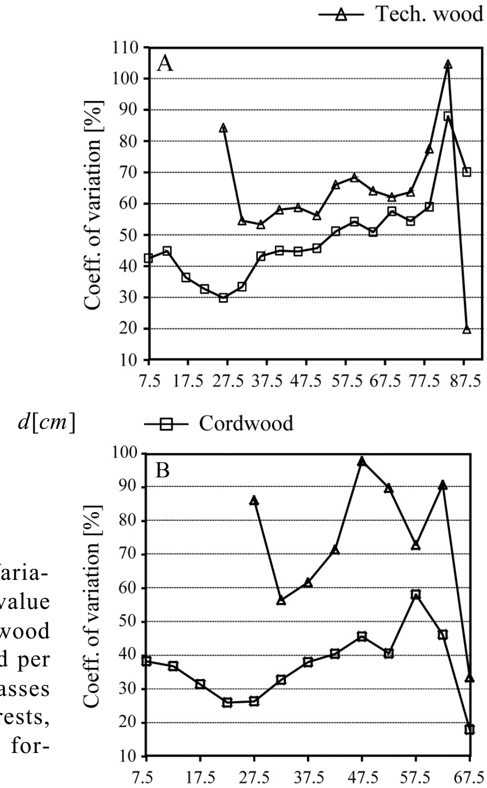

Figure 6. Variability of the value of technical wood and cordwood per diameter classes (A – high forests, B – coppice forests)

Correlation

The correlation of the study timber value parameters and elements of tree dimensions is shown in Table 2.

The data presented in the Table show that there is a high and significant linear correlation between the selected parameters of timber value and the elements of tree dimensions. Compared to height (h), the diameter at breast height (d) shows regularly a higher level of correlation with the parameters of timber value (M_t, M_c, M_{tr} and M_V).

Regression models

The base for a more in-depth research was defined by previous studies, so this time the focus is exclusively

Table 2. Pearson's product moment correlations of observed variables*

Parameter			High forests				Coppice forests			
			M_t	M_c	M_{tr}	M_V	M_t	M_c	M_{tr}	M_V
d	cm	Correlation	0.7422	0.7417	0.8323	0.5221	0.6577	0.8106	0.8097	0.5944
		p-value**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
h	m	Correlation	0.5939	0.5616	0.6575	0.5192	0.4667	0.6810	0.6137	0.5673
		p-value**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

* Sample size of high forests was 5,973 and sample size of coppice forests was 1,842.
** P-values below 0.05 indicate statistically significant non-zero correlations at the 95% confidence level.
Source: original

on the effect of diameter at breast height on timber value. The results of the tested dependences $M_t=f(d)$, $M_c=f(d)$, $M_{tr}=f(d)$ and $M_V=f(d)$ are presented in tabular form (Table 3) and in diagrams (Figures 7-10).

In the obtained regression models of timber value depending on the diameter at breast height, all parameters and correlation coefficients (*t*-test parameters, *F*-test correlation coefficients) are also statisti-

Table 3. Regression models for calculation of timber value (in parenthesis are t-statistics of regression parameters)

High forests	Coppice forests
Value of technical wood	Value of technical wood
$M_t=f(d)$ –>SQRT $M_t=f$(SQRT d)	$M_t=f(d)$ –>SQRT $M_t=f$(SQRT d)
SQRT M_t=–10.664+2.565·SQRT d	SQRT M_t=–5.749+1.493·SQRT d
(–80.69) (115.44)	(–39.88) (50.04)
R^2=0.69 R=0.83 $F_{(1, 5972)}$=13,326.67	R^2=0.58 R=0.76 $F_{(1, 1841)}$=2,503.50
$M_t=(-10.664+2.565\cdot\text{SQRT } d)^2$	$M_t=(-5.749+1.493\cdot\text{SQRT } d)^2$
Value of cordwood	Value of cordwood
$M_c=f(d)$ –>ln $M_c=f(\ln d)$	$M_c=f(d)$ –>ln $M_c=f(\ln d)$
ln M_c=–3.060+1.619·ln d	ln M_c=–3,990+1.910·ln d
(–79.76) (147.02)	(–67.27) (99.13)
R^2=0.78 R=0.89 $F_{(1, 5972)}$=21,615.49	R^2=0.84 R=0.92 $F_{(1, 1841)}$=9,826.11
$M_c=0.047\cdot d^{1.619}$	$M_c=0.019\cdot d^{1.91}$
Wood value per tree	Wood value per tree
$M_{tr}=f(d)$ –>ln $M_{tr}=f(\ln d)$	$M_{tr}=f(d)$ –>ln $M_{tr}=f(\ln d)$
ln M_{tr}=–5.944+2.658·ln d	ln M_{tr}=–5.595+2.516·ln d
(–195.56) (304.64)	(–120.49) (166.69)
R^2=0.94 R=0.97 $F_{(1, 5972)}$=92,802.23	R^2=0.94 R=0.97 $F_{(1, 1841)}$=27,784.76
$M_{tr}=0.003\cdot d^{2.658}$	$M_{tr}=0.004\cdot d^{2.516}$
Wood value per volume unit	Wood value per volume unit
$M_V=f(d)$ –>ln $M_V=f(\ln d)$	$M_V=f(d)$ –>ln $M_V=f(\ln d)$
ln M_V=2.473+0.255·ln d	ln M_V=2.654+0.184·ln d
(153.94) (55.33)	(167.81) (35.71)
R^2=0.34 R=0.58 $F_{(1, 5972)}$=3,061.46	R^2=0.41 R=0.64 $F_{(1, 1841)}$=1,275.45
$M_V=11.86\cdot d^{0.255}$	$M_V=14.21\cdot d^{0.184}$

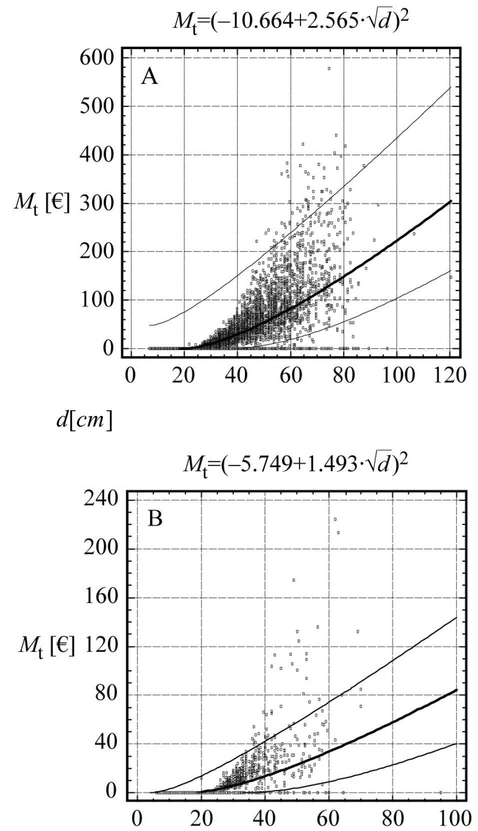

Figure 7. Regression model $M_t=f(d)$ to calculate value of technical wood (A – high forests, B – coppice forests)

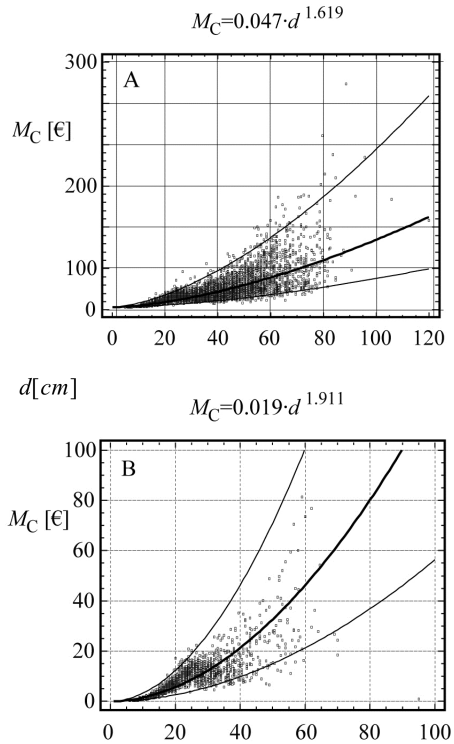

Figure 8. Regression model $M_c=f(d)$ to calculate value of cordwood (A – high forests, B – coppice forests)

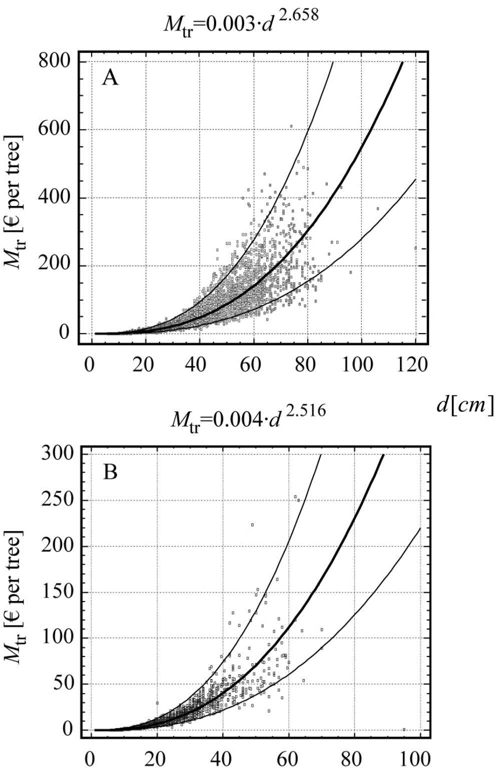

Figure 9. Regression model M_{tr}=*f*(*d*) to calculate wood value per tree (A – high forests, B – coppice forests)

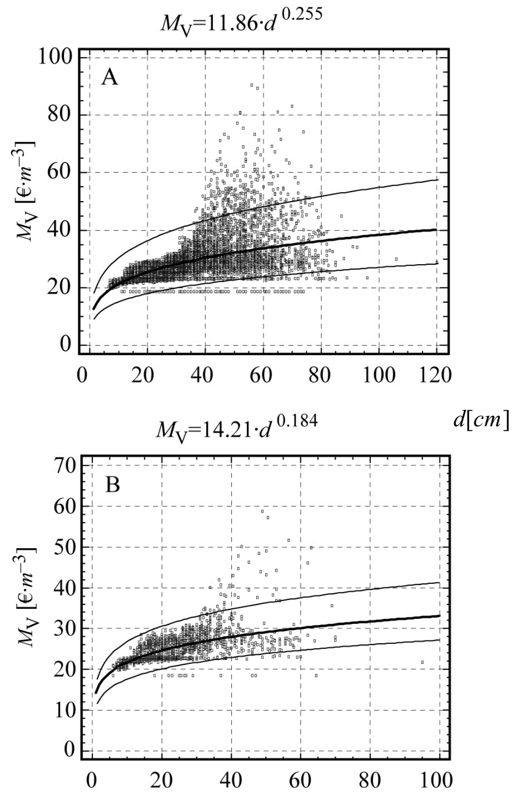

Figure 10. Regression model M_V=*f*(*d*) to calculate wood value per volume unit (A – high forests, B – coppice forests)

cally significant. This point to a conclusion that the study models can well be used in the assessment of timber value in beech forest thinning in Serbia (error below 5%).

Discussion and conclusions

The observed variability in the value of technical wood and cordwood in high forests and coppice forests can be explained by a simpler assortment structure of coppice forests (prevalence of cordwood), so the changes in tree value within the same diameter class are considerably lower. Based on the above regression models, in the design of beech forest thinning, despite the minor differences in variation, such a situation should not be a great obstacle to the assessment of the value of timber to be removed from the stand.

The study of the effect of *d* and *h* on timber value shows that the obtained linear correlation coefficients are mainly greater in high forests than in coppice forests (Table 1). This implies that also the estimation of timber value in future high forest thinning can be characterised as more reliable. However, this does not diminish the potential application of such estimations in coppice forests, because it is not the case of critical differences, especially if it is borne in mind that, in all tested cases, there was a high significance of correlation coefficients (error below 5%).

Regarding the regression models of the dependence of timber value on the change in diameter at breast height, it can be seen that all models, except the one related to technical timber, are potential forms (potential form produces even higher correlation coefficients than the linear form, which was used as the first step in the assessment of the effect of tree dimension elements on timber value, together with the already emphasised high significance per all elements) ($M=a\cdot d^{b}$). Thus, in cordwood, the increase in diameter at breast height by 1% would increase the value by about 0.16% in high forests, and by about 0.19% in coppice forests. The same increase in diameter at breast height could cause the timber value per tree to increase by about 0.27% in high forests and by about 0.25% in coppice forests. Regarding the timber value per unit volume, the change in diameter at breast height would increase the value by about 0.26% in high forests and by about 0.18% in coppice forests.

It can also be seen that the highest coefficient of determination (both in high forests and in coppice forests) occurs in the model which correlates the diameter at breast height (*d*) and timber value per tree (M_{tr}), which, together with a high significance per all tested elements, recommends this model for the assessment of timber value in beech forest thinning in Serbia. From the aspect of the assessment procedure, this practically means that it is necessary to measure the diameters of trees marked for thinning, then to calculate the timber value of each tree based on regression equations, and finally by adding all individual values, to estimate the total sum that can be expected from the selling of felled timber. In the procedure, disregarding the minor differences in parameter sizes, special equations should be used for high forests and coppice forests, because the potential error could be multiplied on account of the number of trees. Also, in this procedure, unequal distribution of regression error along regression line (heteroskedasticity) should be taken into account, which is clearly seen in the diagram (Figure 9). However, the elimination of the error was not carried out (Jovičić 1981), because it is assumed that the case in which the error could have a perceptible effect (high percentage of large-sized trees) is exceptionally rare in thinning.

The following conclusions can be drawn based on the study results:

- High variability in timber value depending on forest origin (high forests and coppice forests) and assortment category (technical timber and cordwood);
- High linear correlation between the study elements of tree dimensions (*d* and *h*) and timber value (M_t, M_c, M_{tr} and M_V);
- The effect of the diameter at breast height (*d*) on timber value is stronger than the effect of height (*h*), because linear correlation coefficients between timber value and diameter at breast height (R = 0.52-0.83) are greater than those between timber value and height (R = 0.47-0.68);
- The obtained regression models present a very good description of the relation between diameter at breast height (*d*) and timber value (M_t, M_c, M_{tr}, M_V) - R = 0.58-0.97 in high forests and R = 0.64-0.97 in coppice forests;
- Regression model which addresses the effect of diameter at breast height (*d*) on the value per tree (M_{tr}) is of very high quality – R = 0.97 in high forests and coppice forests;
- All models show unequal distribution of the error along regression line (heteroskedasticity), but as this occurrence is more related to large trees, which are relatively few in thinning operations, this does not jeopardise the accuracy of results in the procedures of timber value assessment in thinning.

The above conclusions point out that the assessment of timber value in beech forest thinning in Serbia can be performed with relatively high reliability. The focus should be on the application of the model which addresses the effect of diameter at breast height (*d*) on timber value per tree (M_{tr}). Thus, for example, starting from the fact that total harvested beech wood in 2009 in state forest thinning amounted to 453,300 m^3 (2010), it could be estimated that its value amounted to € 14.95 mil. To be exact, € 13.74 mil was harvested in high forests (90.5%), and € 1.21 mil in coppice forests (9.5%).

The obtained models should be used when it is necessary to know the total value of thinned material (aiming at the financial assessment of thinning efficiency), or when it is necessary to create the plans for selling of felled material (estimation of the potential revenue). In the latter case, advantage should be given to the models which treat separately technical wood (M_t) and cordwood (M_c), because the function of these two wood categories is different, which is reflected also on potential users, i.e. buyers.

Acknowledgements

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References

Anon. 2001. A landowner's guide to selling standing timber. Ontario Woodlot Association, Kempt Ville. 2-3, 6-10.

Anon. 2007. Study on forest valuation & financing in Serbia: the forest valuation sub-study. Project „Forest Sector Development in Serbia" (GCP/FRY/003/FIN), FAO & Helsinki University - Department of Forestry Economics, Rim - Helsinki – Belgrade. 7-12, 15-17. (in Serbian).

Anon. 2010. Forestry in Republic of Serbia 2009. Bulletin 521, Republic Institute for Statistics, ISSN 0354-3641, Belgrade. 1-64. (in Serbian).

Anon. 2011. What is my timber worth, and how do I sell it? SRS Forest Economics & Policy, US Forest Service, Washington D.C. (link: http://www.srs.fs.usda.gov/econ/data/prices/wannano.htm, visited: May, 2011).

Anon. 2012. PUU - Renewing wood product value chains and timber procurement solutions 2009-2013. Research Programme, Metla, Vantaa. (link: http://www.metla.fi/ohjelma/puu/esite-en.pdf, visited: September, 2012).

Anon. 2013. Selling trees & timber: questions & answers. Virginia Department of Forestry, Charlottesville (link: http://www.dof.virginia.gov/mgt/harvest/faq-selling-timber.htm, visited: January, 2013).

Banković, S., Medarević, M., Pantić, D. and Petrović, N. 2009a. The National Forest Inventory of the Republic of Serbia - The growing stock of the Republic of Serbia. Ministry of Agriculture, Forestry & Water Management of the Republic of Serbia - Forest Directorate, Belgrade, 238 pp.

Banković, S., Medarević, M., Pantić, D., Petrović, N., Šljukić, B. and Obradović, S. 2009b. The growing stock of the Republic of Serbia - state & problems. *Bulletin of the Faculty of Forestry*, University of Belgrade, Faculty of Forestry, Belgrade, 100: 7-30, DOI: 10.2298/GSF090007B. (in Serbian with English abstract).

Banković, S. and Pantić, D. 2006. Dendrometry. University of Belgrade - Faculty of Forestry, Belgrade, 556 pp. (in Serbian).

Hadživuković, S. 1991. Statistical methods. University of Novi Sad - Faculty of agriculture, Novi Sad, 584 pp. (in Serbian).

Holecy, J. and Hanewinke, M. 2006. A forest management risk insurance model and its application to coniferous stands in southwest Germany. *Forest Policy & Economics*, Elsevier Science B.V., Amsterdam, 8: 161-174.

Jovičić, M. 1981. Econometric methods. Savremena administracija, Belgrade, 306 pp. (in Serbian).

Keča, Lj. 2009. Cost-effectiveness of wood production in Poplar plantations at Ravni Srem. doctoral thesis - manuscript, University of Belgrade - Faculty of Forestry, Belgrade. (in Serbian).

Matthews, K.R. 2003. Timber stumpage values "Worth a closer look"!, electronic document (link: http://www.privateforestrysthnqld.com.au/wp-content/2008/09/timber-stumpage-values.pdf).

Medarević, M., Banković, S., Pantić, D. and Petrović, N. 2005. State of beech forest in Serbia. „Beech in Serbia", UŠITS & University of Belgrade - Faculty of Forestry, Belgrade, 47-71. (in Serbian).

Medarević, M. and Milošević, R. 2005. Types of beech forests in Serbia. „Beech in Serbia", UŠITS & University of Belgrade - Faculty of Forestry, Belgrade, 366-370. (in Serbian).

Pantić, D., Krstić, M., Danilović, M., Matović, B. and Marković, N. 2003. Tree development & productivity of beech coppice stands in the Crni Vrh region. *Bulletin of the Faculty of Forestry*, University of Belgrade - Faculty of Forestry, Belgrade, 87: 175-186. DOI 10.2298/GSF0387175P. (in Serbianwith English abstract).

Ranković, N. and Vučković, Ì. 2011. Wood dimensions and value in the Austrian pine plantations in forest estate „Sombor" - forest unit „Subotica". *Bulletin of the Faculty of Forestry*, University of Belgrade - Faculty of Forestry, Belgrade, 104: 155-172. DOI 10.2298/GSF1104155R. (in Serbian with English abstract).

Uusitalo, J. 2011. WOODVALUE: Value creation in wood supply chains. PowerPoint presentation from WoodWisdom-Net Seminar, The Finnish Forest Research Institute (METLA),Vantaa (link: http://www.woodwisdom.net/mm_files/do_889/20110201_WOODVALUE.pdf, visited: December, 2012).

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ВЗАИМООТНОШЕНИЕ КАЧЕСТВА ДРЕВЕСИНЫ И РАЗМЕРА БУКОВЫХ СТВОЛОВ, СРУБЛЕННЫХ ПРИ ПРОРЕЖИВАНИЯХ В ЛЕСАХ СЕРБИИ

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Резюме

Целью данного исследования было определение соотношения качества древесины и размера стволов в прореживаниях, проводимых в насаждениях бука в Сербии. Материалом послужили 7815 буковых стволов, срубленных при прореживании 5973 в высокоствольных лесах и 1842 в низкоствольных лесах, при этом определяя их общую кубатуру и кубатуру и качество отдельных сортиментов.

В качестве основного научного метода применялся метод моделирования, при чем в целях анализа причинно-следственной связи между исследуемыми элементами применялись также и соответствующие математические и статистические методы, такие как описательная статистика и регрессионный и корреляционный анализ.

На основе полученных результатов, можно сделать следующие выводы: (а) наблюдается четкая вариабельность качества древесины в зависимости от типа леса и категории сортиментов, (б) на качество древесины сильнее влияет диаметр ствола (коэффициент линейной регрессии R=0.52-0.83) чем его высота (R=0.47-0.68), (в) из полученных регресионных моделей хорошо видна связьмежду поперечником и качеством дерева вцелом (R=0.58-0.97 в высокоствольник and R=0.64-0.97 в низкоствольный лес), при чем особенно значительная модель, показывающая влияние поперечника на качество каждого отдельного ствола (R=0.97 в высокоствольник и низкоствольный лес), (г) во всех моделях наблюдается неодинаковое распределение количества ошибок на линии регрессии (гетероскедастичность), но, так как это явление более характерно для стволов большого размера, которые редко встречаются при прореживаниях, точность оценки качества древесины этим не уменьшается. Результаты исследования позволяют сделать вывод, что при прореживаниях и рубках ухода довольно точно можно оценить качество древесины в буковых лесах.

Полученные модели можно использовать при оценке общего качества древесины полученной при прореживаниях буковых лесов (в целях определения финансовой целесообразности применения прореживаний) или при планировании сбыта срубленного материала на рынке (оценка возможной прибыли).

Ключевые слова: диаметр, высота, значение древесины, бук, прореживание, Сербия