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Simulation Model for Prediction of Timber Assortment Price Trends in Croatia - a Case Study of Brinje Forest Office

Simulacija trendova cijena šumskih sortimenata u Hrvatskoj na primjeru Šumarije Brinje

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ABSTRACT • *This paper presents the results of a simulation model for the prediction of sale prices of common beech (Fagus sylvatica L.) and silver fir (Abies alba Mill.) assortments in the case study of Brinje Forest Office in Croatia. The survey covers the future time frame of 140 years (starting from the year 2013). The database of realized selling prices of assortments in the period from 1997 to 2013 was used in this research. On the basis of statistical analysis of realized selling prices in the past and using the Monte Carlo method, a simulation of future prices with 500, 100, 50 and 30 simulation repetitions was made. The result of this research is the methodological basis for future forest management economic planning in the case study of Brinje Forest Office, as well as in other case studies with similar forest management characteristics. Although, in this research, timber prices applicable in Croatia have been used, the same methods could be applied in other countries, too.*

Key words: *timber assortment price, price fluctuations, Monte Carlo simulation*

SAŽETAK • *Članak se bavi prognoziranjem prodajnih cijena sortimenata obične bukve (Fagus sylvatica L.) i obične jele (Abies alba Mill.). Istraživanje se odnosi na studij slučaja Šumarije Brinje u Republici Hrvatskoj i obuhvaća buduće vremensko razdoblje od 140 godina (počevši od 2013.). U istraživanju je prikupljena baza podataka o ostvarenim prodajnim cijenama sortimenata drva u razdoblju 1997. – 2013. Na temelju statističke analize ostvarenih prodajnih cijena u prošlosti te primjenom metode Monte Carlo, napravljena je simulacija budućih cijena s 500, 100, 50 i 30 simulacijskih ponavljanja. Rezultat ovog istraživanja svojevrsna je metodološka podloga za buduće ekonomsko planiranje gospodarenja šumama Šumarije Brinje, kao i za ostale studije slučaja sličnih šumskogospodarskih obilježja. Iako se cijene sortimenata drva odnose na Republiku Hrvatsku, prikazana se metodologija može primijeniti i u ostalim državama.*

Ključne riječi: *cijene sortimenata drva, prognoziranje cijena, simulacija Monte Carlo*

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1 INTRODUCTION
1. UVOD

The knowledge, i.e. a more precise estimate of possible future prices of goods and services is very important for the economics of forest management planning (Gong *et al.*, 2005, Linehan and Jacobson, 2005, Pukkala, 2015), similarly as for other economic branches. Adequate investment analysis is not possible without the involvement of elements of risk and uncertainty during the planning of a business process. Investing in the present is necessarily associated with a certain degree of risk and uncertainty that the expected effect of the project will not be achieved in the future or will be achieved with a certain degree of variability of results (Knoke *et al.*, 2001; Kangas *et al.*, 2008; Klemperer, 2003; Klemperer, 2001; Linehan and Jacobson, 2005; Gong *et al.*, 2005). Forest management plans, whose finances are based on the future price fluctuations, are more realistic than those with fixed future prices of products. Therefore, Knoke and Wurm (2006) and Hildebrandt and Knoke (2011) recommend using only this kind of planning. Price fluctuation of timber assortments in the future makes a specific background in studies dealing with long-term economic forest management planning, e. g. (Knoke *et al.*; 2001, Knoke and Plusczyk; 2001, Haight, 1990; Brazee and Mendelsohn, 1988; Knoke and Wurm, 2006; Beljan, 2015; Leskinen and Kangas, 1998). However, Knoke *et al.* (2001) and Knoke *et al.* (2005) emphasize that most of the research in forest economics do not take into account the risk of future price changes.

Under ideal conditions (market competition), the price of a product primarily depends on the relationship between supply and demand on the market (market-based approach). In most cases, the price changes are the result of a large number of other interactions on the market (Haight, 1990; Leefers and Ghani, 2014). In planned economy, prices will not fluctuate at all, while in market economy this is not the case. The forecast of future price of timber assortments is not a deterministic model and it is prone to certain deviations from the estimated value, while it depends on a large number of factors (Leefers and Ghani, 2014; Leskinen and Kangas, 1998). Based on the changes (fluctuations) of unit-prices of assortments in the past, it is possible, with certain degree of certainty, to assume the fluctuations of these prices in future (Knoke *et al.*, 2005; Knoke *et al.*, 2001; Clasen *et al.*, 2011; Beljan, 2015; Orsag and Dedi, 2011; Linehan and Jacobson, 2005; Pukkala, 2015). The risk of price changes is reflected in the standard deviation of past price fluctuations and it is a generally accepted measure of financial risk (Clasen *et al.*, 2011; Knoke and Wurm, 2006; Klemperer, 2003). The smaller the standard deviation, the lesser is the investment risk, and, therefore, the lower is the risk of price changes (fluctuations). For adequate analysis, it is first necessary to take into account a longer time series of timber sale prices from the past sorted by assortments. For this purpose, the Monte Carlo method is widely used to describe the future stochastic processes including the prediction of future timber assortment prices (Knoke *et al.*, 2001; Knoke and Plusczyk, 2001; Knoke *et al.*, 2005; Waller *et al.*, 2003).

The aim of this paper is the forecast of future selling prices of assortments of common beech (*Fagus sylvatica* L.) and silver fir (*Abies alba* Mill.) based on the example of Brinje Forest Office in the Republic of Croatia. The study includes the future time frame of 140 years (starting from the year 2013) and can serve as the basis for the long-term planning of forest management with the emphasis on economics.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Research site
2.1. Objekt istraživanja

The research site is located in the hilly area of Croatia (Brinje Forest Office) and covers an area of 18 019.36 ha divided into 7 Management Units. The forest is state owned and managed as selective beech-fir forest with average allowable cut of 45 016 $m^3 \cdot year^{-1}$ (the average in 1997-2013).

Table 1 shows descriptive statistical analyses of the data on selling prices for timber assortments of common beech and silver fir of Brinje Forest Office (Croatia) for the period 1997-2013. These data are owned by Croatian Forests Ltd. and are not shown in this research. It must be mentioned that in the research period the realized selling prices had notably small fluctuations with a tendency not to change. The most valuable timber assortments, according to the pricelist of Croatian Forests Ltd. (HŠ, 1997-2013), achieved the highest selling price. The analyzed time series of selling prices was limited to 17 years (data available for the 17-year period), but part of the data for individual assortments were made of 'shorter' time series because in certain years some assortments were not produced.

In the observed period (1997-2013), silver fir veneer logs achieved the highest selling price (114.55 $EUR \cdot m^{-3}$), while the lowest selling price was achieved for common beech firewood (OM) (12.61 $EUR \cdot m^{-3}$). The standard deviation for beech assortments (V, PV) is 19.18 $EUR \cdot m^{-3}$, while for silver fir assortments (TR) it totals 12.87 $EUR \cdot m^{-3}$. In total, standard deviation for common beech and silver fir assortments amounts to approx 3.75 $EUR \cdot m^{-3}$ (Table 1).

2.2 Applied methods
2.2. Metoda rada

The simulation of future price fluctuations is based on the assumption of normal distribution, where the variability of results, described with standard deviation and the average price in the past, are observed (Clasen *et al.*, 2011; Knoke *et al.*, 2001; Beljan, 2015; Orsag and Dedi, 2011). Past price fluctuations for every assortment separately are linked with feedback connections that have to be respected in future simulations (Knoke *et al.*, 2001; Knoke *et al.*, 2005; Beljan, 2015; Pukkala, 2015; Leskinen and Kangas, 1998). In other words, if the prices of certain assortments were simu-

Table 1 Results of descriptive statistics of selling prices of silver fir and common beech (1997-2013) for Brinje Forest Office (middle exchange rate of Croatian National Bank on 7/10/2015 1 EUR=7.62 HRK)
Tablica 1. Rezultati deskriptivne statistike ostvarenih prodajnih cijena jelovine i bukovine (1997. – 2013.) za Šumariju Brinje (srednji tečaj HNB-a 7, listopada 2015 : 1 EUR = 7,62 HRK)

Species *Vrsta drva*	**Assortment*** *Sortiment*	**Time series** *Vremenska serija* years / *god.*	**Average** *Prosječna vrijednost* EUR·m^{-3}	**Minimum** *Najmanja vrijednost* EUR·m^{-3}	**Maximum** *Najveća vrijednost* EUR·m^{-3}	**Standard deviation** *Standardna devijacija* EUR·m^{-3}
Fagus sylvatica L. Common Beech *bukva*	*V*	15	104.13	80.31	154.66	19.09
	PV	17	81.28	53.41	117.71	19.18
	I	17	55.12	51.97	58.66	1.75
	II	17	40.67	40.01	41.73	0.53
	III	17	28.88	25.98	30.10	1.08
	TR	17	29.31	17.99	33.07	4.91
	LM	17	21.23	12.61	30.97	4.85
	OM	10	20.80	12.34	29.66	5.09
	altogether	17	30.85	24.92	39.07	3.76
Abies alba Mill. Silver Fir / *jela*	V	7	114.55	109.58	117.05	2.49
	I	17	67.66	57.52	74.67	4.18
	II	17	48.87	43.17	52.49	2.69
	III	17	31.17	29.17	32.81	1.32
	TR	8	23.74	14.57	54.47	12.87
	LM	11	18.30	10.70	25.07	4.01
	OM	6	22.57	13.65	27.69	6.18
	altogether	17	35.31	26.25	40.81	3.75

*V – Veneer / *furnirski trupci*, PV – Peeled veneer (beech) / *trupci za ljušteni furnir*, I – 1st class sawlogs / *pilanski trupci I. klase*, II – 2nd class sawlogs / *pilanski trupci II. klase*, III – 3rd class sawlogs / *pilanski trupci III. klase*, TR – Thin roundwood / *tanka oblovina*, LM – Long-meter firewood / *višemetarsko ogrjevno drvo*, OM – One-meter firewood / *jednometarsko ogrjevno drvo*

lated in the future independently of each other, in their ultimate sum (at some point in the future), wrong values would be obtained. Therefore, first it is necessary to mathematically describe feedback connections (univariate linear regression) between one type of assortment of one tree species in relation to all other assortments of both tree species (Knoke *et al.*, 2001; Knoke *et al.*, 2005; Beljan, 2015). The assortment that is taken as standard (independent variable) is, in principle, one of the most produced, and its distribution of achieved selling prices is described by normal distribution (Knoke *et al.*, 2001; Knoke *et al.*, 2005; Clasen *et al.*, 2011). Shapiro-Wilks test (Shapiro and Wilk, 1965) was used for a test of normality and Durbin-Watson (Durbin and Watson, 1971) test for a test of autocorrelation. After the definition of the independent variable, a univariate linear regression analysis was made in relation to other types of assortments of both tree species.

Univariate linear regression analysis was done with *Statistica 8* software (StatSoft, 2007) using the expression according to Knoke *et al.* (2005):

$$p_{\text{assort}} = a + b \cdot p_{\text{indep. variable}} \qquad (1)$$

p_{assort} – achieved selling price of assortment
$p_{\text{independent variable}}$ – achieved selling price of beech long-meter firewood (LM) assortment
a,b – univariate linear regression analysis coefficient

In this way, the feedback connections between the independent variable and other common beech and silver fir assortments (dependent variables) were determined.

Future simulated price fluctuation was made by using Monte Carlo simulation in Excel 2007. This method used an assumed normal distribution, a series of random numbers, the arithmetic mean and standard deviation from past data (Knoke *et al.*, 2005; Waller *et al.*, 2003; Hildebrandt and Knoke, 2011; Nana and Lu, 2013). The expression according to Clasen *et al.* (2011) was used:

$$p_{\text{independent variable}} = NORMINV\,(probability;\ mean;\ SD) \qquad (2)$$

$p_{\text{independent variable}}$ – simulated price of beech long-meter firewood (LM) assortment
NORMINV –function name
probability --> RAND( ) – function that generates random numbers
mean - arithmetic mean
SD - standard deviation

Part of the function *probability* is replaced with function *RAND( )* to generate random numbers. The arithmetic mean and standard deviation refer to past prices, and Monte Carlo simulations assume their future values.

The process was first completed for the beech long-meter firewood (LM) assortment (Equation 2). In the same way, in the second step the simulation of prices for other assortments was made, but the feedback connections (the results of univariate linear regression analysis) were included in the Monte Carlo simulation using the expression according to (Clasen *et al.*, 2011):

$$p_{\text{assort}} = NORMINV\,(RAND(\,);\ a + b \cdot p_{\text{indep. variable}};\ SD) \qquad (3)$$

p_{assort} – simulated price of assortment
RAND( ) – function that generates random numbers
$p_{\text{independent variable}}$ – simulated selling price of beech long-meter firewood (LM) assortment

a,b – univariate linear regression analysis coefficient
SD – standard deviation

The process of price simulation of each assortment was repeated 500, 100, 50 and 30 times and, on this basis, an adequate number of simulations were selected. Using the described method, the expected selling price of each assortment in every future period (for each year) was obtained.

Investigation time frame was 140 years since, according to Beljan (2015), this is the minimum time needed to establish a normal (theoretical) forest and to economically and adequately compare two basic forest management practices (even aged and selective) in the case study of Brinje Forestry Office.

3 RESULTS
3. REZULTATI

The normal distribution (Gauss, 1809) was compared with the distribution of the past selling prices of all assortments of common beech and silver fir. The distribution of selling prices of common beech long-meter firewood (LM) is closest to the normal distribution, which can be seen from *p* values (significance level $p<0.05$) (Figure 1). Also, Durbin-Watson two-sided test showed that there was no first-order autocorrelation problem for common beech long-meter firewood (DW=1.7595, $p= 0.4505$).

Figure 1*a* shows the LM assortment of common beech as the best representative of the normal distribution and its deviation from the normal distribution using *Normal P-Plot* (Figure 1*b*). The price values are expressed in Kunas, and not in Euros, for the purpose of a more detailed sorting in price classes. The distribution of the above mentioned common beech LM assortment is "closer" to the normal distribution than that of any other assortment. The assortment of one tree species, superior in production quantity to all others and with the distribution of selling prices nearest to the normal distribution, was used as an independent variable for univariate linear regression analyses for comparison with other assortments of the respective species (common beech) and all assortments of the other species (silver fir). Therefore, the assortment of common beech long-meter firewood (LM) is used for this purpose (independent variable). In gross production share for the period 1997-2013, this assortment accounts for 54.71 % to 63.69 %.

Coefficients (a, b) were obtained by univariate linear regression analyses between LM of common beech (independent variable) and all other assortments of common beech and silver fir (dependent variable) (Table 2). Although the LM price data set is not equal to other assortments in terms of quantity, the "missing value" option was used, which uses only data with given independent and dependent variable in regression analyses. Coefficient of determination r^2 varies between 0.34 and 0.79 depending on the assortment (Table 2). By goodness of fit ($Pr> F$), it is evident that only few assortments do not satisfy predefined null hypothesis (Table 2). The same table shows that some of *b* coefficients are negative. Those assortments are in negative correlation with common beech long-meter firewood. In this sense, Monte Carlo simulation is not limited. For future timber price simulation, Monte Carlo can be used with positive and/or negative correlation as well, e.g. Knoke *et al.* (2005).

The coefficients of univariate linear regression pre-testing were then defined. The aim of pre-testing was to define the appropriate number of simulation processes (repetitions). Pre-testing was made for beech long-meter firewood (Figure 2). Pre-testing includes four groups of simulation processes, which are defined by the number of repeated simulations. The larger the number of repetitions of simulation results, the lower is the variability of prices, and vice versa (Figure 2). Therefore, the simulation process of 500 repetitions resulted in noticeably little variability of arithmetic mean of prices (Figure 2), so there was no need to repeat the process with 1000 repetition in pre-testing, because its variability would be negligible. In Figure 2 and Figure 3, darker area shows higher frequency of overlapping and, therefore, greater probability, i.e. the value of the

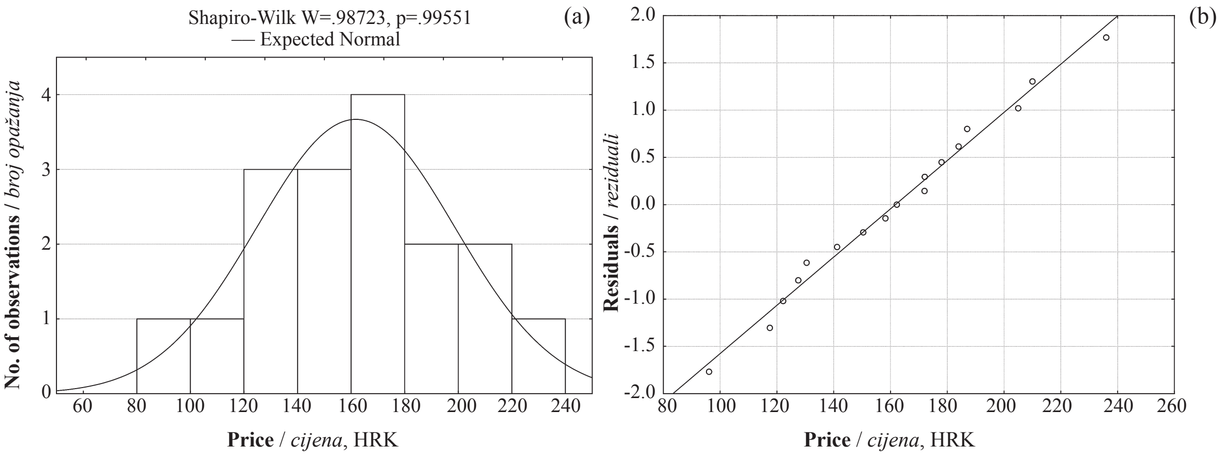

Figure 1 Results of Shapiro-Wilks test for common beech long-meter firewood (a). Deviations from normal distribution are shown by P-Plot chart (b)
Slika 1. a) Rezultati Shapiro-Wilkova testa za višemetricu bukve; b) odstupanja od normalne distribucije prikazana P-Plot grafikonom

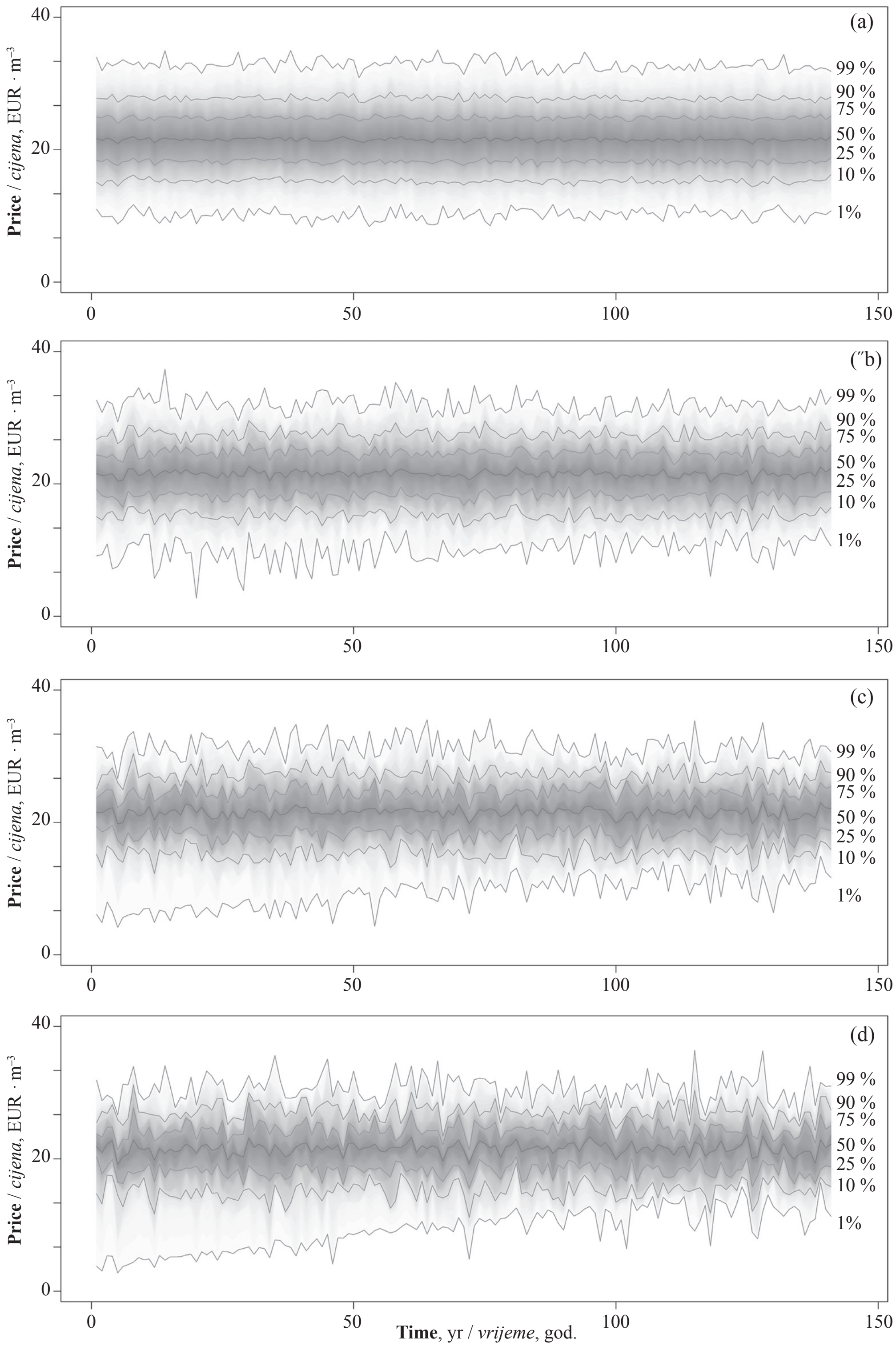

Figure 2 Pre-testing simulation of future prices repeated 500 (a), 100 (b), 50 (c) and 30 (d) times on the example of common beech long-meter firewood with average price of 21.23 EUR·m^{-3} and standard deviation 4.85 EUR·m^{-3} for the period of 140 years (darker area shows a higher frequency of overlapping)
Slika 2. Predtestiranje simulacije budućih cijena ponovljenih 500 (a), 100 (b), 50 (c) i 30 puta (d) na primjeru višemetrice obične bukve prosječne cijene 21,23 EUR·m^{-3} i standardne devijacije od 4,85 EUR·m^{-3} za razdoblje od 140 godina (tamnije područje prikazuje veću frekvenciju preklapanja)

most frequent overlapping of repeated simulations is shown in thick solid line.

The variability of prices over time is not regular and it varies depending on average selling price and standard deviation of each assortment in the past. The comparison of one simulation of achieved selling prices (Figure 3) shows that the Monte Carlo process drastically deviates from the arithmetic mean of thirty simulation repetitions.

The reason is that one Monte Carlo simulation regularly generates marginal selling prices. Only one simulation creates sudden price changes in a relatively short period of time, which cannot be expected in the actual conditions. Simulation repetition of thirty times

Table 2 Results of univariate linear regression analyses between common beech long-meter firewood and all other assortments of silver fir and common beech
Tablica 2. Rezultati univarijatne linearne regresijske analize između višemetrice bukve i svih ostalih sortimenata jele i bukve

Species *Vrsta drva*	**Assortment*** *Sortiment*	**Time series** *Vremenska serija* year / *god.*	**Coefficient** *Koeficijent*		r^2	*Pr >F*
			a	*b*		
Fagus sylvatica L. Common Beech / *bukva*	V	15	1168.918	-2.38514	0.61	0.000001
	PV	17	1122.703	-3.11171	0.79	< 0.000001
	I	17	440.0068	-0.123691	0.34	< 0.000001
	II	17	316.0228	-0.037867	0.35	< 0.000001
	III	17	222.7339	-0.016533	0.74	< 0.000001
	TR	17	156.1193	0.415658	0.41	0.001275
	OM	10	106.6529	0.332205	0.37	0.053188
Abies alba Mill. Silver Fir / *jela*	V	7	1000.401	-0.865067	0.87	0.000001
	I	17	451.0274	0.399157	0.46	< 0.000001
	II	17	337.0305	0.218366	0.39	< 0.000001
	III	17	218.9987	0.114495	0.42	< 0.000001
	TR	8	-104.923	2.190761	0.44	0.067840
	LM	11	7.9517	0.726147	0.69	0.086863
	OM	6	143.0897	0.149279	0.75	0.050195

*V – Veneer / *furnirski trupci*, PV – Peeled veneer (beech) / *trupci za ljušteni furnir*, I – 1st class sawlogs / *pilanski trupci I. klase*, II – 2nd class sawlogs / *pilanski trupci II. klase*, III – 3rd class sawlogs / *pilanski trupci III. klase*, TR – Thin roundwood / *tanka oblovina*, LM – Long-meter firewood / *višemetarsko ogrjevno drvo*, OM – One-meter firewood / *jednometarsko ogrjevno drvo*

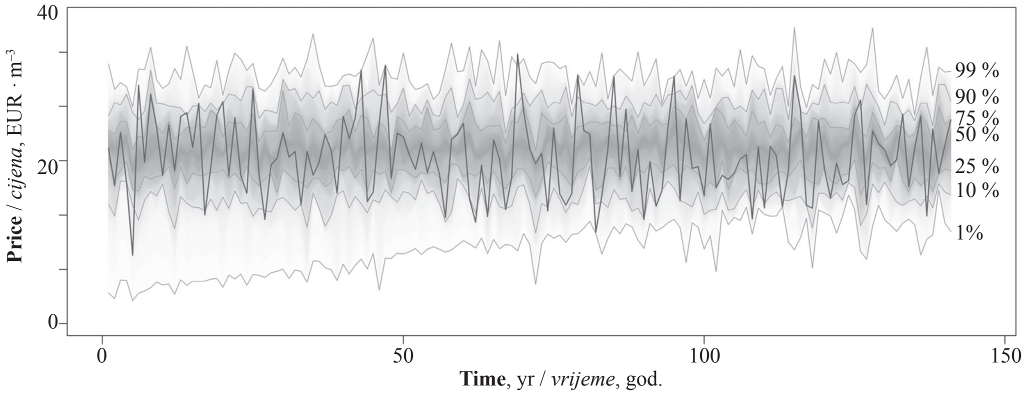

Figure 3 Comparison of one simulation (solid line) and arithmetic mean of 30 repetitions on the example of common beech long-meter firewood (grey area).
Slika 3. Usporedba jedne simulacije (debela linija) i aritmetičke sredine od 30 ponavljanja na primjeru višemetrice bukve (sivo područje)

was taken as a reference and used in simulations for all other assortments of common beech and silver fir. The end result of this research was the simulation of selling prices of all assortments of common beech and silver fir timber for the next 140 years (starting with the year 2013) including their mutual feedback connections. Because of the large quantity of simulations for other assortments (dependent variables), only the result of the simulation for common beech LM assortment was presented in this paper (Figure 2d).

4 DISCUSSION
4. RASPRAVA

It is normal for prices to increase over time at least for the money inflation rate. Based on the analysis of collected data on selling prices for the case study Brinje, it is obvious that the price of timber assortments did not increase in the period 1997-2013. Quite the contrary, the prices of some assortments were even reduced. The situation is similar on the entire market of timber assortments in the Republic of Croatia (Posavec and Beljan, 2013). The situation is also similar in other European countries, e.g. in Austria, where the prices showed the constancy (stability) in the period 2001-2008 (Statistik_Austria, 2009) and 2008-2012 (Dundović, 2013), respectively. In many cases, the state governments regulate politically the prices of timber on the domestic market (Leefers and Ghani, 2014). This is also the case in Croatia, where an organized market, based on relationship between demand and supply, does not exist. Statistical data (CBS, 2015) show that, although the prices of other energy sources increased in the period 1997-2013, the price of timber remained the same. It can be assumed that the establishment of timber stock exchange would cause the change of timber prices with an increasing tendency. The prices of timber assortments were not constant in Croatia. Nenadić (1922) described the increase of timber assortments prices that would be expected during the 20th century due to the population growth and greater demand for timber, which was also confirmed by Sabadi (1982). This can be confirmed by an almost triple increase in oak timber prices in the period 1881-1928, as stated by Nenadić (1929). The present situation (the last 25 years) on the timber assortment market in the Republic of Croatia has the characteristics of small fluctuations and this situation will probably remain the same due to the lack of changes in forest policies.

The overlapping of 30 simulation repetitions (Figure 2d) shows the most probable development trends of the future prices. Some authors, like Knoke and Wurm (2006) and Knoke *et al.* (2001), use simulations with 1000 repetitions for this purpose. It is clearly the responsibility of the decision maker or the investor to decide about an adequate number of simulation repetitions. If the market is more stable, it is possible to apply a greater number of repetitions and get fewer fluctuations. A similar procedure is applied when choosing the adequate forest interest rate for a certain area (Figure 2) and the comparison of single and thirtyfold repetition (Figure 3) show that referent simulation repetition (30 times) adequately describes the risk of future price changes. Although this research deals with price simulation for distant future, it is appropriate when calculating e.g. Net Present Value to use risk-adjusted discount rate (Klemperer, 2001; Klemperer, 2003; Price, 1997; Brukas *et al.*, 2001; Snowdon and Harou, 2013; Hahn *et al.*, 2014; Pukkala, 2015), which amounts to 2 % for the Croatian forestry (Beljan, 2015). However, some authors like Hahn *et al.* (2014) use for this purpose the fixed assortment price with a certain discount rate. Both methods are correct, but it is important to stress that higher discount rates should be used with fixed prices.

In this paper, only one of numerous available methods was used for the identification of price change risks. Univariate linear regression, which describes the feedback connections between the prices of timber assortments, can be replaced by a more complex mathematical function and thus increase the level of its explanation. Linehan and Jacobson (2005) stated that linear regression should be used for short and medium periods. The methodology of price definition in the future is a complex process prone to deviations from the forecasted value (Leskinen and Kangas, 1998; Linehan and Jacobson, 2005; Gong *et al.*, 2005, Pukkala, 2015). It is, however, indispensable for a more relevant economic analysis of forest management planning.

5 CONCLUSION
5. ZAKLJUČAK

For successful planning of management of forest resources, it is particularly important to predict the trends of timber assortment prices. The fluctuations of past prices of timber assortments can be simulated in the future for a time frame required by the forest management planning and provide opportunity for decision-makers to have insight into economic results of future scenarios of forest management. It is up to the decision-maker and investor to determine the risk level (the number of simulation repetitions) of price changes and select the interest rate and this decision depends on various factors. Simulation repetition of thirty times describes optimally the risk of price changes in the future for this case study.

In the last 20 years, the prices of timber assortments in Croatia have been stable and this is the result of help provided by the state to a powerful state company aimed at supporting the domestic wood industry. According to the results of predictions, stable prices can also be expected in the future especially for assortments of widely used timber species (common beech and silver fir).

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