Determination of the Optimal Financial Rotation Period in Poplar Plantations

LJILJANA KEČA

Faculty of Forestry, University of Belgrade, Chair of Forestry Economics and Organisation, 1, Kneza Višeslava street, 11030 Belgrade, Serbia, Tel. +381641794648 and +381113053959, E-mail: ljiljana.keca@sfb.bg.ac.rs

Keča, L. 2017. Determination of the Optimal Financial Rotation Period in Poplar Plantations. *Baltic Forestry* 23(1): 673–682.

Abstract

Due to trends in the consumption of wood and particularly soft broadleaves, poplar cultivation has gained importance in Serbia and worldwide in the field of production, economics and environmental protection issues. The present study was performed to determine the optimal financial rotation lengths for hybrid poplar plantations (*Populus Euramericana* Gunier cv. I-214) in a selected area of Serbia. The aim of this study is to apply the method of assessment and calculation of the optimal production cycle length in order to determine the optimal production cycle length of poplar plantations in the localities of Serbia from a financial standpoint. The selected discount rate for the calculation is 6% (close to the maximum recorded internal rate of yield in the observed compartments). It was concluded that the production cycle length of poplar in the study area ranges from 12-19 years, depending on the soil type. The longest rotation is obtained for humofluvisol (alluvial semigley). The estimation based on the *NPV*s criterion determined a desired optimal production cycle length of about 16 years

Keywords: financial rotation, poplar, plantation, optimum

Introduction

Poplar plantations play one of the key roles in the industrial wood supply in countries such as China, France, India, Italy and Turkey, and each of them produces more than 1 million m^3 of poplar wood from specialised plantations (Spinelli and Magagnotti 2011). Managed on 10 to 30 years rotations, some of the clones can produce veneer logs (Hongyuan 1992).

Poplars are one of the most productive tree species in Serbia, which production complexity requires rational and well-planed management, whereby the site and species potentials would be maximally used (Keča and Pajić 2010). Conventional poplar growing in Serbia is characterized by the high costs of plantation establishment, as it is common to use the technology of full ground and soil preparation, with a lot of working operations (Keča and Pajić 2015). Alluvial plains along the rivers Danube, Sava, Tisa, Ibar and Morava Rivers are suitable for the growth of several broadleaved tree species (*Quercus robur* L., *Fraxinus angustifolia* Vahl., *Populus* spp.) (Keča et al. 2015). Serbia's forest reserves, which cover approximately 27% of the country's land area, or about two million hectares, are estimated to be containing 235 million m^3 of the standing inventory (Keča and Keča 2015). About 36.000 ha of poplar plantations are located in Vojvodina (Banković 2009).

The controversy of optimal forest management has a long history in forestry economics (Chladna 2007). Many studies applying different methodologies have been conducted in this area, and most of them are related to stochastic optimal rotation models (Willassen 1998, Alvarez and Koskela 2004). Nowadays, a lot of forest economists believe that the net present value approach is a true innovation in forest management and economics science. The fact that a total of 313 papers with this topic have been published since Faustmann speaks in favour of its importance. However, over two-thirds of these papers (211) have come since 1985 (Newman 2002).

In short rotation plantation forestry, high biomass productivity and economic profitability are given priority and harvest time usually coincides with the age when mean annual increment is the highest (Tullus et al. 2012). Therefore, the economic success of poplar plantations usually depends on obtaining the largest possible amount of top grade veneer logs, whose value can compensate the high establishment and management costs (Spinelli and Magagnotti 2011).

The aim of this research is to apply the method of assessment and the method of calculating the optimal production cycle length in order to determine the optimal production cycle length (Keča 2014) of poplar plantations in the studied localities from an economic standpoint.

The purpose of this research is to provide guidelines for forestry practices aimed at the improvement of the situation in the field of assessment of the optimal production cycle length in poplar plantations.

The research objects are: the number of trees, volume of trees and other elements that will be quantified and numerically analyzed.

Material and methods

The method of assessment was used in the article to prove the hypothesis that poplar achieved the best financial effects of production at the ages between 10 and 20 years. This problem comes down to the choice of the appropriate criterion in financial analysis and the monitoring of its trend for different lengths of the production cycle, as well as finding the age when the value of the selected criteria culminates. This is achieved by using regression and correlation analysis. If statistical significance of the regression model of the selected indicators' trend is provided, we find the maximum of curves and determine the time when the financial success is the highest.

The total net present value (NPV) and the average net present value (NPV_s) of wood production in the analyzed poplar plantations were selected as the criteria for the assessment of the financial effects, calculated according to the method of the present value and the resultant value and then expressed per unit area. The basic principle on which the method of the present value is based is that stand value is equated with the value of timber of the selected trees (in this case poplar), in the exact proportion that represented the assortment volume of categories that at the time of assessment are present in the market, reduced by the costs of forest utilization:

$$V_s = (V_1 \cdot P_1 + V_2 \cdot P_2 + \ldots + V_n \cdot P_n) - C_s$$

where: V_s-value of the stand, $V_{1,2,\ldots n}$- volume of the timber assortment categories, $P_{1,2,\ldots n}$ – prices of timber assortment categories, C_s – costs of forest utilization.

The investigated sample plots were established from *Populus* × *euramericana* cl. *I-214,* with a 6 × 3 m (555 trees per *ha*) planting spacing for technical wood production, and they were located in the Northern province of Vojvodina. Nineteen (19) compartments (52 stands) aged 24-42 years with a total area of 362.35 ha were investigated. Soil types in these plots are: α / β–β gley; alluvial semigley; fossil hydromorphic black soil on loess-alluvium and fossil hydromorphic black soil (humosemigley) on loess-alluvium. The research was carried out in poplar plantations located in the area of the Sava River during the 2002 – 2014 period. Data pertaining to costs during years 0-5 (soil preparation, planting, care and protection, etc.) were obtained from the archives of the forest enterprise which managed the studied plantations, and also the data from material books (Keča 2010a). The costs of ground preparation for afforestation are 2040.50 €/ha in the starting year. In the first year, the costs of maintenance and protection of plants are 209.44 €/ha. In the second year, afforestation with rooted cuttings and maintenance and protection of the plantation costs are 207.48 €/ha. In the third, fourth and fifth years, the costs of tending (inter-row treatment and weed control) amount to 305.45 €/ha. The costs in the sixth year are 825.91 €/ha, because of the costs of schematic thinning and cutting, processing and extraction of timber, and in the final year, the costs amount to 3397.0 €/ha. On the other hand, the revenues range between 11 088.3 – 23 676.36 €/ha. Since all the studied stands are state-owned and managed by the Public Forest Enterprise "Vojvodinašume", the value (cost) of the land (land rent) did not enter into the calculations (Keča et al. 2011).

Estimates were made separately for each soil type, bearing in mind the possibility that different surfaces can behave differently and the effects of financial trends observed. The criteria for the assessment of the financial effects were the selected total net present value (NPV) and the average net present value (NVP_s) of production of poplar wood in the analyzed plantations, calculated according to the method of the present value of felling ripeness, and the resultant value then expressed per unit area.

The chosen discount rate to be used in the calculation was 6%. This discount rate is very close to the maximum recorded internal rate of return in the observed stands, which amounts to 5.56% (Keča 2010, Tullus et al. 2012). The return on investment from the stands at a certain age should be equal to the available alternative rate of return on the capital invested (rather than percentage changes in costs). Stands or trunks are only in this case the "financial mature" (Duerr et al. 1956, Keča and Keča 2014). In forestry, the valuation of forests is performed with the interest rate of capitalization (it is the basis for the capitalization of rents, discounting and prolonging of financing rents). Therefore, the basis for determining interest rates in forestry is the rate of value growth. The higher increment of a stand, the higher the interest rate (Figurić 1996).

The assessment was made separately for each soil type in three variants. The first variant (**M0**) is based on real data on costs and revenues created in the compartments on the same ground, totally focused on them when calculating total and average net present value of production. Bearing in mind that in all cases it has reliable information at the beginning of the production cycle (establishment and care of plantations – costs) and its end (harvest and production assortments – revenues and associated costs).

The following two variants are created as an attempt to compile an expert assessment of data about possible values from the central segment of production cycle length. In that way, the obtained data were incorporated into the calculation. The assessment starts from the two typical cases which form two clearly visible contradictions. The second variant (**M1**) is based on an estimation that in the period of culmination of the financial effects there is no complex assortment structure, but at this age stacked wood usually dominates in the assortment structure of the produced volume of poplar wood. It was taken as an assumption that the entire realized production is of simple assortment structure and belongs to the category of cordwood.

The third variant (**M2**) is based on the assumption that the assortment structure may still affect movement of the culminating point of the observed criterion. However, at this moment there are no data related to complete final felling at these ages in sample plots, remaining as an opportunity to assess the income and expenses at these ages. The estimation of revenues from timber, in this case, is the most complex part of the assessment, and is made through the assortment structure obtained, based on the method of "model tailoring" of the trunks (Nikolić 1988). This method assumes that assortment structure depends only on the dimensions of trunks and does not take into account possible errors of the spindles of tree trunks that affect the result of cutting in practice. Such a developed assortment structure can be considered ideal, and (theoretically) as a result brings the highest revenues from the sales of wood.

In this way, there is the opportunity to compare the results of three assessments ("real" – lack of data from the central segment of the length of the production cycle, "minimalistic" – the actual data associated data, where income is assessed only on the basis of the least valuable assortments and "maximalistic" – the actual data associated – the data were obtained on the basis of a calculation of income based on the ideal assortment structure). Such access is provided to summarize the possible similarities or differences in results and provide a more precise definition of the age range at which the greatest financial effects can be expected.

To conduct the calculation of missing data on income in the variant M2, for stands at ages that are missing, in the field we required compartments to meet the requirement that they include trees of such ages (ranging between 9-23 years). Such departments are found in each category of soil, but their number is not the same in each of them. In the next step, data on the dimensions (diameter and height) of all trees from each of the selected compartments were collected and processed. The dimensions of trees in the selected classes were obtained from the Special plan of forest management of this area. During data processing, it was noticed that trees in the researched artificial poplar plantations at the same age (same compartment) have approximately the same dimensions (height variation coefficient is C_h = 5.23%, and the thickness of C_d = 4.31%) (Table 1). That means it can be operated with a single tree of average size ("mean tree" as a representative of all trees in the department in which the trees are of the same age (Banković and Pantić 2006).

Table 1. Coefficients of variations of dimensions of trees in plantations of poplar with a 6×6 *m* planting space; *T* – age of plantation, *N* – number of stands, C_d – coefficient of variations in diameter, C_h – coefficient of variations in height

T age	*N*	C_d %	C_h %
	1	7,5	4,8
15	2	6,8	5,1
	3	6,9	5,2
Average		**7,1**	**5,0**
	1	7,1	4,6
20	2	7,5	5,3
	3	5,2	4,2
Average		**6.6**	**4,7**
	1	5,8	4,1
25	2	7,0	4,4
	3	6,4	4,7
Average		**6,4**	**4,4**

"Model tailoring" based on the principle of maximum utilization (Nikolić 1988) was applied for the selected trees (Table 2), and a total of 33 trees of different ages (from 12-28 years) were chosen.

Table 2. Age and number of stands whose derived trees were used for the purposes of "model tailoring"

Soil Type	Age of the stands *year*	Number of stands
* α / β–β gley	12, 14, 16, 18, 19, 23, 26, 28	8
*RC	13, 14, 15, 16, 17, 19, 23, 25, 26, 27	10
	14, 15, 16, 18, 19, 22, 23	7
ASG	9, 12, 14, 15, 16, 18, 23, 24	8
Σ	/	33

*RC-fossil hydromorphic black soil (humosemigley) on loess-alluvium, AS ASG–alluvial semigley, LC-fossil hydromorphic black soil on loess-alluvium, α / β–β gley

As a result of the "model tailoring", "mean trees" by volume assortments were obtained in each selected department. These "mean trees" are the next step multiplied by the appropriate prices and the number of trees in each of these departments, in order to obtain the value of revenues by departments. These are dependent on the assortment structure, soil type and the age of stands. In the following calculation, the resulting value of income is divided by the surface area of each department to obtain the amount of revenue per hectare. So, as input data for the assessment of income, we used data on the number and size of trees in the selected departments on the ground (to obtain the average dimensions of trees and assess assortment structure), market prices assortments for 2014 (the valid price list PE "Vojvodinašume") and the area of the observed compartments. The wholesale prices of PE "Vojvodinašume" (VAT is excluded) for tree assortments are as follows: for class F, the price is 66.06 €/m³, class L 51.75 €/m³, class I 38.53 €/m³ and class II 30.28 €/m³.

The present value of the income and expenses (with a discount rate of 6%), total and average net present value were calculated on the basis of the database, and finally the time of their culmination was estimated. The assessment of culmination was done in a way that data were flat out (even) by a regression curve (cubic parable, i.e. polynomial of third-degree). After that, we found the maximum of the given function as the time of culmination of the total and average net present income for the 4 researched types of poplar forests.

Finally, the criteria for the greatest financial impacts were chosen. In order to compare the financial effects of the total and average net present values, it is necessary to reduce them to the same level. Therefore, procedures are multiplying the average net present value with the age at which the total net present value (t_{NPVmax}) culminates. After that, we compared the result obtained in that way between the results (NPV_t) and the total net present value (NPV), and the selected value that has a higher validity (Ranković 1996). The formula for such a calculation would have the following form:

$$NPV_t = NPV_s \cdot t_{NPVmax}$$

a choice when compared would be as follows:

• if the requirement that the $NPV_t \geq NPV$ is met, then further analysis related to the average net present value (NPV_s would be a criterion for observation and analysis);

• if the opposite condition ($NPV_t \leq NPV$) is fulfilled, then total net present value (NPV) is the criterion in relation to which further observation and analysis are to be performed.

Results

According to the available data from the field on α / β–β **gley** soil type, 8 stands aged 12, 14, 16, 18, 19, 23, 26 and 28 years (Table 3) were researched. They were evaluated in terms of the size of NPV and NVP_s presented by the regression curve trend (cubic parabola) (Figures 1, 2).

Table 3. Values of NPV and NPV_s in three variants of estimation

Age year	Variants of estimation					
	M_0		M_1		M_2	
	NPV	NPV_s	NPV	NPV_s	NPV	NPV_s
	€·ha⁻¹					
1	–2.040,48	–2.040,48	–2.040,48	–2.040,48	–2.040,48	–2.040,48
2	–2.238,06	–1.119,03	–2.238,06	–1.119,03	–2.238,06	–1.119,03
3	–2.422,72	–807,57	–2.422,72	–807,57	–2.422,72	–807,57
4	–2.516,46	–629,12	–2.516,46	–629,12	–2.516,46	–629,12
5	–2.593,22	–518,64	–2.593,22	–518,64	–2.593,22	–518,64
6	–2.665,63	–444,27	–2.665,63	–444,27	–2.665,63	–444,27
7	–2.227,16	–318,17	–2.227,16	–318,17	–2.227,16	–318,17
12	/	/	–1.270,07	–105,84	–1.392,15	–116,01
14	/	/	–1.131,06	–80,79	–1.133,42	–80,96
16	/	/	–1.129,19	–70,57	–843,70	–52,73
18	/	/	–1.077,86	–59,88	–273,23	–15,18
19	/	/	–1.005,04	–52,90	–427,12	–22,48
23	/	/	–1.117,19	–48,57	–784,25	–34,10
26	/	/	–1.039,30	–39,97	–597,52	–22,98
28	/	/	–1.144,09	–40,86	326,94	11,68
43	–1060,86	–24,67	–1.060,86	–24,67	–1.060,86	–24,67

On the basis of these elements, it can be stated that the estimation based on criteria NPV_s represents the required optimum length of the production cycle and it is 17 years (Table 4).

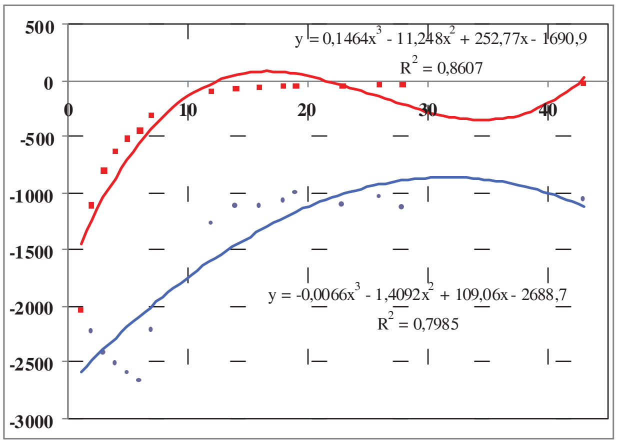

Figure 1. NPV and NPV_s in estimation variant M_1 (in all figures NPV is in red, and NPV_s is in blue)

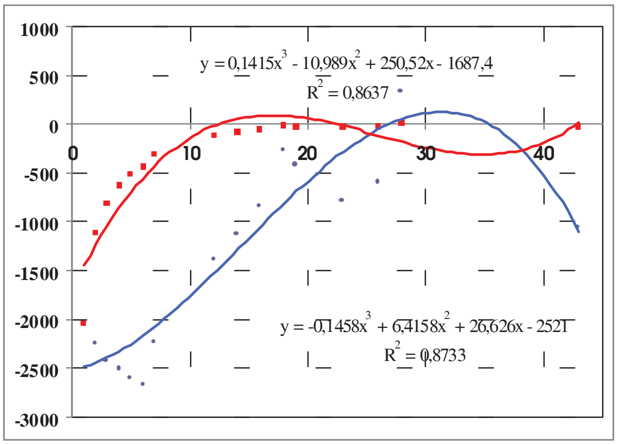

Figure 2. NPV and NPV_s in estimation variant M_2

Table 4. Optimal lenght of production cycle and the highest value of NPV and NPV_s

Variant of estimation	Time of culmination		Maximum value		Verification of criteria
	NPV	NPV_s	NPV_{max}	$NPVs_{max}$	$NPVs_{max} \cdot t_{NPVmax}$ (t_{NPVmax}=32)
	year		€·ha⁻¹		
M_0	/	/	/	/	/
M_1	32	17	–855,00	72,82	2.330,12
M_2	32	17	123,26	90,81	2.905,87

According to the data available from the field on **RC soil** type was researched 10 stands aged 13, 14, 15, 16, 17, 19, 23, 25, 26 and 27 years (Table 5) (Figures 3, 4, 5).

On the basis of these elements, it can be said that the estimation based on the NPV_s criterion represents the required optimum length of the production cycle, which is 15 years (Table 6).

According to available data from the field, on **LC soil** type was researched 7 stands of the following ages: 14, 15, 16, 18, 19, 22 and 23 years (Table 7) (Figures 6, 7).

Table 5. Values of NPV and NPV_s in three variants of estimation

Age year	Variants of estimation					
	M₀		*M₁*		*M₂*	
	NPV	*NPVs*	*NPV*	*NPVs*	*NPV*	*NPVs*
	€·ha⁻¹					
1	–2040,48	–2040,48	–2040,48	–2040,48	–2040,48	–2040,48
2	–2238,06	–1119,03	–2238,06	–1119,03	–2238,06	–1119,03
3	–2422,72	–807,57	–2422,72	–807,57	–2422,72	–807,57
4	–2516,46	–629,12	–2516,46	–629,12	–2516,46	–629,12
5	–2593,22	–518,64	–2593,22	–518,64	–2593,22	–518,64
6	–2665,63	–444,27	–2665,63	–444,27	–2665,63	–444,27
7	–2227,16	–318,17	–2227,16	–318,17	–2227,16	–318,17
13	/	/	–1141,62	–87,82	–1319,09	–101,47
14	/	/	–1141,99	–81,57	–608,60	–43,47
15	/	/	–1119,72	–74,65	–1083,78	–72,25
16	/	/	–903,19	–56,45	–1029,56	–64,35
17	/	/	–805,41	–52,65	144,58	8,50
19	/	/	–895,03	–61,04	–43,41	–2,28
23	/	/	–1159,81	–50,43	–396,38	–17,23
25	/	/	–1237,94	–49,52	–107,35	–4,29
26	/	/	–1205,75	–46,38	–443,79	–17,07
27	/	/	–1158,08	–42,89	–569,70	–21,10
29	–275,60	–9,50	–275,60	–9,50	–275,60	–9,50
30	38,24	1,27	38,24	1,27	38,24	1,27
32	–315,89	–9,87	–315,89	–9,87	–315,89	–9,87

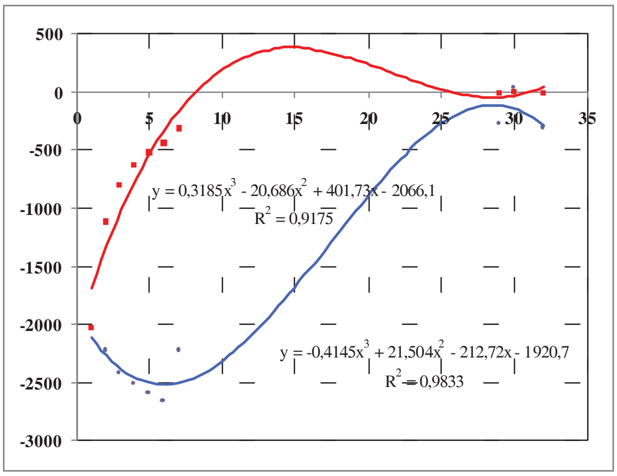

Figure 3. NPV and NPV_s in estimation variant M_0

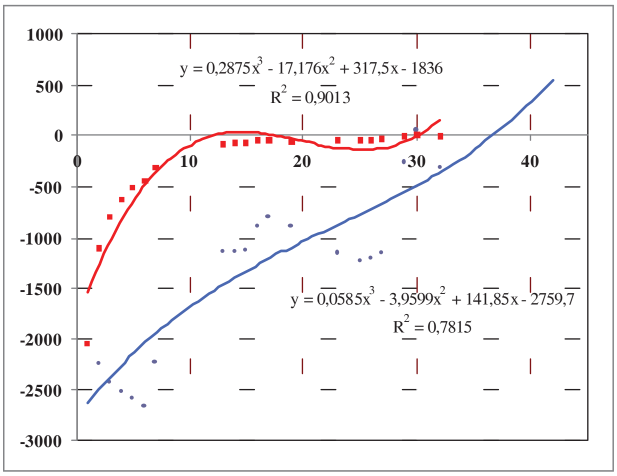

Figure 4. NPV and NPV_s in estimation variant M_1

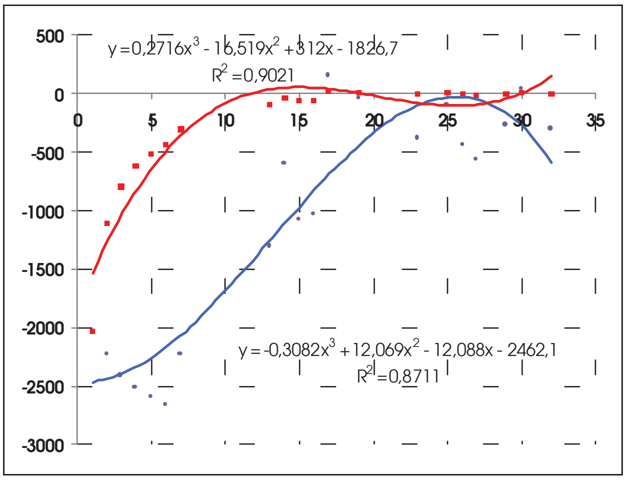

Figure 5. NPV and NPV_s in estimation variant M_2

Table 6. Optimal lenght of production cycle and the highest value of NPV and NPV_s

Variant of estimation	Time of culmination		Maximum value		Verification of criteria
	NPV	*NPVs*	*NPVmax*		*NPV*
	year		€·ha⁻¹		
M₀	28	15	–116,83	380,44	10.652,32
M₁	/	15	/	32,21	/
M₂	26	15	–34,67	53,18	1.382,55

Table 7. Values of NPV and NPV_s in three variants of estimation

Ages year	Variants of estimation					
	M₀		*M₁*		*M₂*	
	NPV	*NPVs*	*NPV*	*NPVs*	*NPV*	*NPVs*
	€·ha⁻¹					
1	–2.040,48	–2.040,48	–2.040,48	–2.040,48	–2.040,48	–2.040,48
2	–2.238,06	–1.119,03	–2.238,06	–1.119,03	–2.238,06	–1.119,03
3	–2.422,72	–807,57	–2.422,72	–807,57	–2.422,72	–807,57
4	–2.516,46	–629,12	–2.516,46	–629,12	–2.516,46	–629,12
5	–2.593,22	–518,64	–2.593,22	–518,64	–2.593,22	–518,64
6	–2.665,63	–444,27	–2.665,63	–444,27	–2.665,63	–444,27
7	–2.227,16	–318,17	–2.227,16	–318,17	–2.227,16	–318,17
14	/	/	–1.358,64	–97,05	–1.168,11	–83,44
15	/	/	–1.259,21	–83,95	–811,71	–54,11
16	/	/	–1.217,31	–76,08	–823,81	–51,49
18	/	/	–1.186,83	–65,94	–621,65	–34,54
19	/	/	–1.114,57	–58,66	804,19	42,33
22	/	/	–1.175,63	–53,44	341,51	15,52
23	/	/	–1.199,77	–52,16	339,48	14,76
25	–237,35	–9,49	–237,35	–9,49	–237,35	–9,49

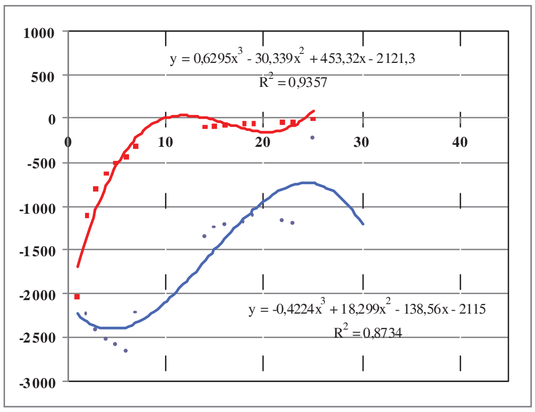

Figure 6. NPV and NPV_s in estimation variant M_1

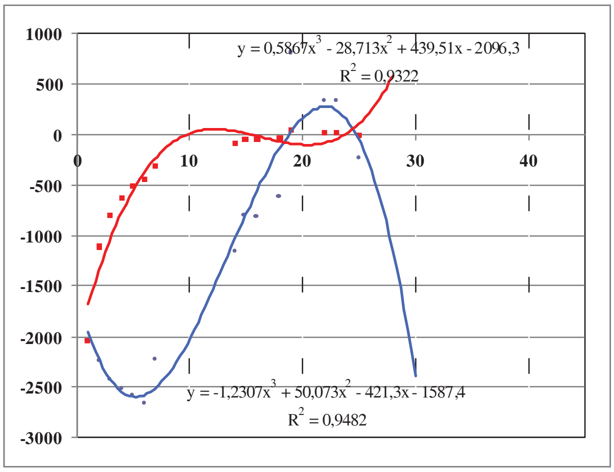

Figure 7. NPV and NPV_s in estimation variant M_2

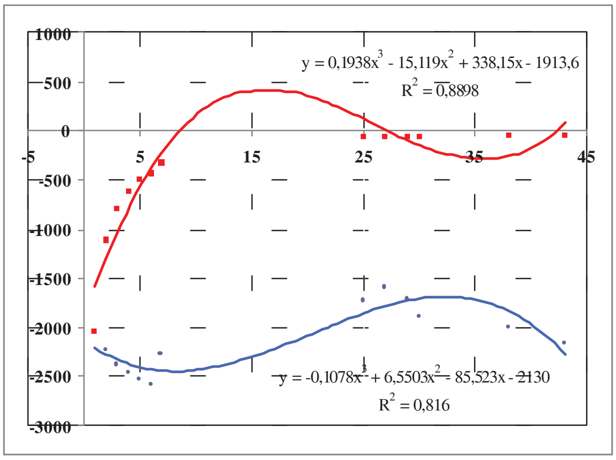

Figure 8. NPV and NPV_s in estimation variant M_0

Table 8. Optimal lenght of production cycle and the highest value of NPV and NPV_s

Variant of estimation	Time of culmination		Maximum value		Verification of criteria
	NPV	*NPV_s*	*NPV_{max}*		*NPV*
	year		*€·ha⁻¹*		
M₀	/	/	/	/	/
M₁	25	12	–742,13	37,50	937,50
M₂	22	12	274,84	56,97	1.253,34

On the basis of these elements, it can be said that the estimation based on the NPV_s criterion represents the required optimum length of the production cycle, which is 12 years (Table 8).

According to the data available from the field 8 stand at the **AS ASG soil type** of the ages: 9, 12, 14, 15, 16, 18, 23 and 24 years (Table 9), which were evaluated in NPV and NVP_s (Figures 8, 9, 10).

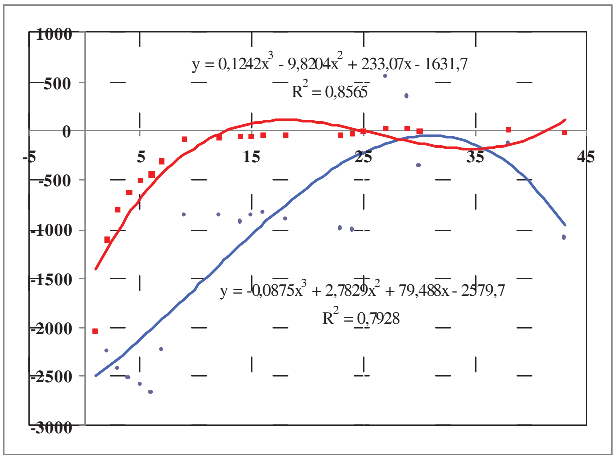

Figure 9. NPV and NPV_s in estimation variant M_1

Table 9. Values of NPV and NPV_s in three variants of estimation

Age year	Variants of estimation					
	M₀		*M₁*		*M₂*	
	NPV	*NPVs*	*NPV*	*NPVs*	*NPV*	*NPVs*
	€·ha⁻¹					
1	–2.040,48	–2.040,48	–2.040,48	–2.040,48	–2.040,48	–2.040,48
2	–2.227,48	–1.113,74	–2.238,06	–1.119,03	–2.238,06	–1.119,03
3	–2.392,88	–797,63	–2.422,72	–807,57	–2.422,72	–807,57
4	–2.472,35	–618,09	–2.516,46	–629,12	–2.516,46	–629,12
5	–2.533,93	–506,79	–2.593,22	–518,64	–2.593,22	–518,64
6	–2.588,92	–431,49	–2.665,63	–444,27	–2.665,63	–444,27
7	–2.273,80	–324,83	–2.227,16	–318,17	–2.227,16	–318,17
9	/	/	–856,69	–95,19	–1.881,25	–209,03
12	/	/	–859,78	–71,65	–1.646,98	–137,25
14	/	/	–943,98	–67,43	–1.444,57	–103,18
15	/	/	–854,08	–56,94	–800,30	–53,35
16	/	/	–833,39	–52,09	–411,19	–25,70
18	/	/	–899,12	–49,95	447,41	24,86
23	/	/	–1.011,41	–43,97	527,92	22,95
24	/	/	–1.021,35	–42,56	514,06	21,42
25	–1.743,02	–69,72	–237,35	–9,49	–237,35	–9,49
27	–1.609,37	–59,61	553,64	20,51	553,64	20,51
29	–1.725,41	–59,50	335,17	11,56	335,17	11,56
30	–1.896,30	–63,21	–363,49	–12,12	–363,49	–12,12
38	–1.999,57	–52,62	–124,02	–3,26	–124,02	–3,26
43	–2.161,99	–50,28	–1.097,84	–25,53	–1.097,84	–25,53

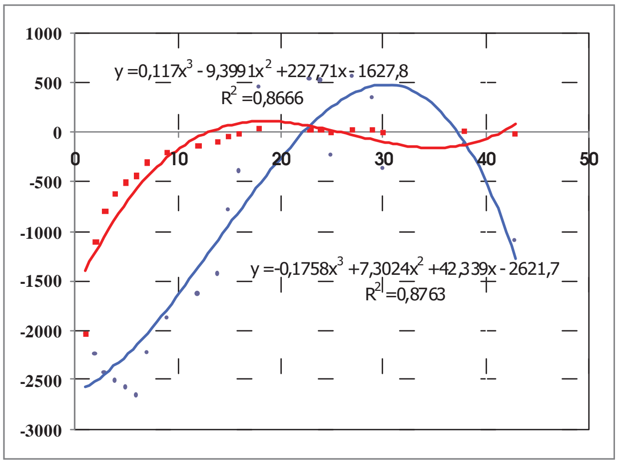

Figure 10. NPV and NPV_s in estimation variant M_2

Table 10. Optimal lenght of production cycle and the highest value of NPV and NPV_s

Variant of estimation	Time of culmination		Maximum value		Verification of criteria
	NPV	NPV_s	NPV_{max}		NPV
	year		€·ha⁻¹		
M_0	32	16	−1.692,62	420,14	13.444,48
M_1	31	18	–47,92	106,10	3.289,10
M_2	30	19	474,03	108,18	3.245,40

On the basis of these elements, it can be said that the estimation based on the NPV_s criterion represents the required optimum length of the production cycle ranging from 16 to 19 years (Table 10).

According to the available data from the field, 19 compartments of different ages (1-7, 25, 27, 29, 30, 32, 38 and 43) were available on all soil types together, and they were evaluated in the size of NPV and NVP_s. If we analyze the results of NVP_s for the researched soil types (Table 11) and evaluation methods, it can be concluded that the average value for all types of soil is 16 years. This suggests that the estimated optimal length of the production cycle is not dependent on the method of estimation. The culminating point of NPV_s is regularly the same, and does not depend on whether the whole harvested volume is treated as stacked wood (minimalistic variant) or used as assortment structure obtained by "model tailoring" (maximalistic variant). In other words, according to these findings, and used methods of evaluation of the revenues from timber, the time of NPV_s (optimal length of the production cycle) culmination is not sensitive to the assortment structure between the ages of 10 and 20, although it was found exactly at this segment of age (Figure 11).

Table 11. The estimated optimal length of the production cycle to NPV_s and coefficients of the regression of model

Soil type	Variant of estimation					
	M_2		M_0		M_1	
	NPV_s	R^2	NPV_s	R^2	NPV_s	R^2
* α / β–β gley	17	0,87	/	/	17	0,80
*RC	15	0,90	15	0,92	15	0,90
	12	0,93	/	/	12	0,94
ASG	19	0,87	16	0,89	18	0,86
Average	16	/	16	/	16	/

On the basis of these elements, it can be stated that the estimation based on the NPV_s criterion represents the required optimum length of the production cycle, which is 16 years (Table 12).

Discussion

Financial analysis is an objective means by which cost-intensive plantations can be compared to cultivating crops (e.g. agriculture) (Mitchell et al. 1999, Current et al. 1995, Sharma 1996, Sabadi 1986, 1997). This analysis can be used for project design, the selection of appropriate size of the project, optimization of the timing of activities and determination of the strategy of forest management. However, in addition to financial parameters, decision-making on plantation establishment must take other parameters into account, such as the interests of local communities, government policy and environmental protection (Neumayer 2011, Perez 2004). Forests are among the most valuable natural resources that humanity possesses, but it is difficult to make economic quantification of their values. There are benefits of forests, especially plantations, which cannot be quantified financially, such as their aesthetic, habitat, protective and anti-erosion functions.

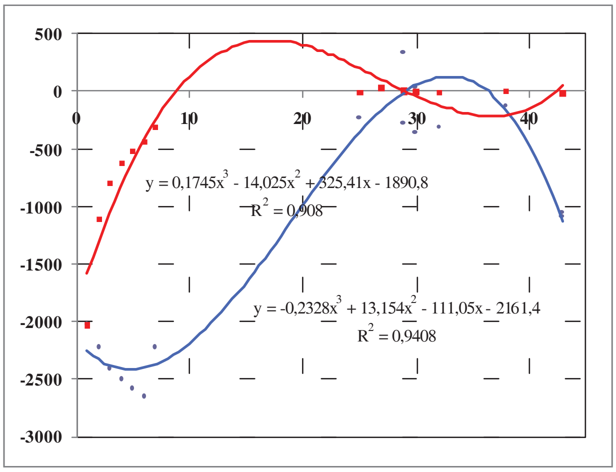

Figure 11. NPV and NPV_s in estimation variant M_o

Table 12. Optimal lenght of production cycle and the highest value of NPV and NPV_s

Variant of estimation	Time of culmination	Maximum value	Verification of criteria	Variant of estimation	Time of culmination
	NPV		NPV_s		
M_0	32	16	132,52	445,26	14.693,58
M_1	/	/	/	/	/
M_2	/	/	/	/	/

And finally, if a forest ecosystem has to fulfil all the requirements it is facing (especially environmental protection, reduction of CO_2 in the atmosphere (Holopainen 2008) and mitigation of the greenhouse effect), it is necessary to establish the sustainability of their management. According to some authors, for sustainable management it is necessary to size the plantations be at least several hundred hectares (Rose et al. 1981, Medarević 2006, Allen et al. 2008).

The optimal length of the production cycle in poplar plantations may be treated as short, compared to the production cycle of other economically important species such as beech, spruce, oak and others. The duration of a short rotation can be divided into three categories (Pope and Dawson, 2005): (I) 5-10 years - of intense culture for obtaining biomass; (II) 10-20 years - for receiving pulpwood (for paper, wood chips for the production of panels, firewood, pallets, certain chemicals such as ethylene glycol, and alcohols); (III) 20-40 years – for obtaining technical wood (for construction, peeled veneer, production of furniture). The largest poplar plantation areas are intended for the production of veneer, peeling and cutting logs, all of which (about 350,000 m^3 round wood $year^{-1}$) is processed in Serbia and used in the production of packaging, veneer, pallets, various types of board, furniture, and other articles (Keča et al. 2012). Short rotations (5-10 years) and the long ones (15 years) are different, both in terms of cost-efficiency, and energy efficiency. Short rotation plantations generate income earlier and more often. Due to shorter rotations, the risk of loss has not yet been so great, and the occurrence of damages was not so often. They allow the use of all technological advances and frequent introduction of newly selected hybrids in plantations (Rose et al. 1981). There are several factors that significantly affect the length of production cycle, but the most important are: the choice of the planting site, planting density, the costs of establishing plantations and the wood market conditions (Birler 1984).

The values obtained for the optimal length of the production cycle ranged in the interval from 16 to 19 years. The longest rotations in poplar plantations were obtained for alluvial semigley. This is the most suitable soil of all studied soils for the cultivation of poplar (Keča and Keča 2012), in addition to fluvisol and therefore the return that is achieved can bear financial burden with an interest rate of 6% (Keča et al. 2011). A shorter length of rotation was obtained on the black soil type. Similar results were obtained by Kohn J.P. (1994), except that in hybrid poplars with a 6 × 6 m planting space and different soil types this interval ranges from 11 to 17 years (Chapman and Meyer, 1947, Tahvonen and Seppo 1999). Researches conducted in Turkey estimated the length of financial rotation to 11 years (Engindeniz 2003). In the United States, there is legislation (Forest Practice Act of 2008) which exactly prescribes the production cycle length in 12-20 years old poplar plantations, depending on their purpose. In Canada, van Kooten (1999) stated that the optimal production cycle length for poplar ranged from 9 to 12 years.

It should be emphasized that the length of the economic and financial rotation, generally do not overlap (Anderson and Luckert 2006). The reason for this situation can be explained by the fact that the financial rotation usually varies depending on the price of poplar wood and interest rates (rate of interest), while the economic changes if there is a change in the productivity of land and habitat productivity (Kohn 1997).

Conclusions

The length of the production cycle for poplar in the project area ranges from 10-20 years. The values obtained for the length of financial rotation are in the range between 12 and19 years. The longest rotations were obtained for alluvial semigley and they ranged between 16 and 19 years, depending on the applied methods. The estimation based on the NPV_s criterion represents the required optimum length of the production cycle, which is about 16 years for poplar plantations in Serbia. However, it has been noted that the better soil for growing poplar (e.g. alluvial semigley) "suffers" a longer production cycle (19 years) in the case of NPV_s. According to the optimal length of the production cycle for Euro-American poplars, it is recommended to use the culmination of the average net present value. The statistical analysis shows that the obtained results for the two regression curves are characterized by high values of the coefficient of determination and the parameters are the most significant at the 0.05 level of significance, while the parameters in NPV_s in all variants are statistically significant, so that the observations and reasoning based on these regression models can be accepted as reliable. The level of statistical significance is high ($R^2 \geq 0{,}91$), and the correlation coefficient is precisely calculated ($F = 42.75$).

In the future, private forest owners can be advised to invest in such a production of poplar wood. On the other hand, there is a state interest in poplar plantations. Plantations are very efficient in CO_2 consumption, as shelterbelts, as well as in flood control, etc. Therefore, in the future the state can stimulate forest owners to invest in poplar production on river banks and on more quality soil types, which tends to be more profitable.

Acknowledgement

Gratitude for the implementation of this research authors suggest the Ministry of Education and Science of the Republic of Serbia, which financially supported this research within the project "Sustainable management of total resources of forests in the Republic of Serbia" – EVNo. 37008, and "Forest plantations in order to increase afforestation in Serbia" EVNo. 31041 COST Action FP1403 NON-NATIVE TREE SPECIES FOR EUROPEAN FORESTS: EXPERIENCES, RISKS AND OPPORTUNITIES (NNEXT)".

References

Allen, D., Fraleigh, S., McKenney, D. and Yemshanov, D. 2008. An Assessment of Short Rotation Coppice Woody Biomass to Heat Greenhouse in Southern Ontario, Canadian Forest Service (4).

Alvarez, L.H.R. and Koskela, E. 2004. Optimal Harvesting Under Resource Stock and Price Uncertainty. Discussion Paper, vol. 31. Helsinki Centre of Economic Research. Available at: http:// ethesis.helsinki.fi/julkaisut/eri/hecer/disc/31.

Anderson, J.A. and Luckert, M.K. 2006. Can hybrid poplar save industrial forestry in Canadas boreal forest?: A financial analysis and policy considerations, Western Forest Economist Meeting, Oregon, unpublished material (36).

Banković, S., Pantić, D. 2006. Dendrometrija, Beograd, Šumarski fakultet (556)

Banković, S., Medarević, M., Pantić, D., Petrović, N., Šljukić, B. and Obradović, S. 2009. The growing stock of the Republic of Serbia - State and problems. *Bulletin of the Faculty of Forestry* 100: 7-30 (in Serbian with English summary).

Birler, A.S. 1984. The profitability of poplar growing systems in Turkey, 17th Session of International Poplar Commission, Ottawa, Canada (http://www.fao.org/forestry).

Chapman, H.H. and Meyer, W.H. 1947. Forest Valuation, McGraw-Hill Book Company, Inc., USA (521).

Chladnį, Z. 2007. Determination of optimal rotation period under stochastic wood and carbon prices, *Forest Policy and Economics* 9.8: 1031-1045.

Current, D., Lutz, E. and Scherr, S. 1995. Costs, Benefits, and Farmer Adoption of Agroforestry, The World Bank, Washington, USA, DC 20433 (15).

Duerr, W.A., Fedkiw, J. and Guttenberg, S. 1956. Financial maturity: a guide to profitable timber growing, U.S. Dept. of Agriculture, p. 74.

Engindeniz, S. 2003. Determination of Economic and Financial Rotation Lengths of Hybrid Poplar Plantations: the Case of Turkey, *Pakistan Journal of Biological Sciences* 6 (4): 325-330.

Figurić, M. 1996. Uvod u ekonomiku šumskih resursa, Sveučilište u Zagrebu, Šumarski fakultet, Zagreb (247).

Hongyuan, X. 1992. The culture history and breeding strategy of poplar in Italy. *Journal of Forestry Research*, *3*(2): 95-100.

Holopainen, J. 2008. Financing Sustainable Forest Management, Tropenbos International, Wageningen, The Netherlans (176).

Keča, Lj. 2014. Determination of the optimal production cycle length from the financial aspect in poplar plantations on meadow semigley, *Bulletin of the Faculty of Forestry* 110: 87-104. DOI: 10.2298/GSF1410087K.

Keča, Lj. and Keča, N. 2012. Commercial Profitability of Poplar Plantation with Reference to the Damages Caused by Fungi, *SEEFOR, South-East European Forestry, International Scientific Journal in field of forestry*, 3(1): 23-31.

Keča, Lj. and Keča, N. 2015. Market potential dynamics for plantation-grown poplar forest products in Serbia. In: Ivetic V., Stankovic D. (eds.) Proceedings: International conference Reforestation Challenges. 03-06 June 2015, Belgrade, Serbia. Reforesta. pp. 33-41.

Keča, Lj., Keča, N. and Pajić, S. 2011. Investment Appraisal of Poplar Plantations in Serbia, *Baltic Forestry* 17(2): 268-279.

Keča, Lj., Keča, N. and Pantić, D. 2012. Net Present Value and Internal Rate of Return as Indicators for Assessment of Cost-efficiency of Poplar Plantations: a Serbian case study, *International Forestry Review* 14(2): 145-157.

Keča, Lj. and Pajić, S. 2010. Financial Aspects of Restoration in Poplar Plantations with Technology of Full Ground and Soil Preparation, Global Change, challenges for Soil Management, Advances in *Geoecology* No. 41. Editor: Miodrag Zlatić, Catena Verlag GMBH, (321-334)

Keča, Lj. and Pajić, S. 2015. Costs and revenues in poplar plantations established using full ground and soil preparation in Serbia. In: Ivetic V., Stankovic D. (eds.) Proceedings: International conference Reforestation Challenges. 03-06 June 2015, Belgrade, Serbia. Reforesta: p. 234-241.

Keča, N., Milenković, I. and Keča, Lj. 2015. Mycological complex of poplars in Serbia, *Journal of Forest Science*, 61(4): 169–174. doi: 10.17221/13/2014-JFS

Keča, Lj. 2010. Assessment of cost-efficiency for wood production in poplar plantations in Ravan Srem, based on internal rate of return. *Bulletin of the Faculty of Forestry* 102: 25-40.

Keča, Lj. 2010a. Estimation of cost-effectiveness of poplar wood production in Ravni Srem by applying the net present value method. *Bulletin of the Faculty of Forestry* 101: 81-100.

Keča, Lj. 2011. Estimation of cost-effectiveness of poplar wood production in poplar plantations in Ravni Srem based on the method of pay back period. *Bulletin of the Faculty of Forestry* 103: 41-56.

Keča, Lj. and Keča, N. 2014. Investment Appraisal in poplar Plantations in Serbia and its Relations with Sustainable Land Management, in „Challenges: Sustainable Land Management – Climate Change, *Advances in Geoecology* No. 43. Editors: Miodrag Zlatić and Stanimir Kostadinov, Catena Verlag GMBH, (287-297).

Kohn, J.P. 1997. The Ergonomic Casebook, CRC Press (240).

Medarević, M. 2006. Planiranje gazdovanja šumama, Šumarski fakultet u Beogradu [Forest management planning, Forest Faculty in Belgrade]: 149-151 (In Serbian).

Mitchell, C.P., Stevens, E.A. and Watters, M.P. 1999. Short-rotation forestry-operations, productivity and costs based on experience gained in the UK, *Forest Ecology and Management* 121: 123-136.

Neumayer, E. 2001. Greening trade and investment: environmental protection without protectionism. Earthscan (228).

Newman, D. H. 2002. Forestry's golden rule and the development of the optimal forest rotation literature. *Journal of Forest Economics* 8(1): 5-27.

Nikolić, S. 1988: Sortimentna struktura, *Šumarstvo*, *Časopis za šumarstvo, preradu drveta, pejzažnu arhitekturu i vodoprivredu erozionih područja* 2(3): 19-26.

Perez, O. 2004. Ecological sensitivity and global legal pluralism: rethinking the trade and environment conflict. Vol. 3. Hart Publishing.

Pope, P.E. and Dawson, J.O. 2005. Short-Rotation Plantations, Central Hardwood Notes, North Central Forest Experiment Station 5.09., Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana (6).

Ranković, N. 1996. Ekonomika šumarstva, Šumarski fakultet Univerziteta u Beogradu (362).

Rose, D., Ferguson, K., Lothner, D.C. and Zavitkovski, J. 1981. An economic and energy analysis of poplar intensive cultures in the Lake States, North Central Forest Experiment Station Forest Service, U.S. Department of Agriculture, USDA Forest Service, Research paper NC-196 (44).

Sabadi, R. 1986. Ekonomika šumarstva [Forestry economics]. Liber, Zagreb, 279 pp. (in Serbian).

Sabadi, R. 1997. Vrednovanje šuma u njihovoj ukupnosti [Evaluation of forests in their totality]. Hrvatske šume [Croatian forests], Zagreb, 40 pp. (in Croatian).

Sharma, K.K. 1996. Agroforestry in farming system development, Indian Forester 122(7), *Agroforestry Systems* 13: 235-257.

Spinelli, R., and Magagnotti, N. 2011. Strategies for the processing of tree tops from hybrid poplar plantations. *Baltic Forestry*, 17(1): 50-57.

Tahvonen, O. and Seppo, S. 1999. Optimal Forest Rotation within Situ Preferences. *Journal of Environmental Economics and Management* 37(1): 106-128.

Tullus, A., Lukason, O., Vares, A., Padari, A., Lutter, R., Tullus, T., Karoles, K. and Tullus, H. 2012. Economics of hybrid aspen (Populus tremula L.× P. tremuloides Michx.) and silver birch (*Betula pendula* Roth.) plantations on abandoned agricultural lands in Estonia. *Baltic Forestry*, 18(2): 288-298.

van Kooten, G.C. 1999. Economic Dynamics of Tree Planting for Carbon Uptake on Marginal Agricultural Lands, Working Paper 1999-18, For Internal Circulation Only Sustainable Forest Management Network. University of Alberta Edmonton, Alberta (19),

Willassen, Y., 1998. The stochastic rotation problem: a generalization of Faustmann's formula to stochastic forest growth. *Journal of Economic Dynamics and Control* 22 (573–596).

Received 23 October 2015
Accepted 24 February 2017