Economics of Hybrid Aspen (*Populus tremula* L. × *P. tremuloides* Michx.) and Silver Birch (*Betula pendula* Roth.) Plantations on Abandoned Agricultural Lands in Estonia

ARVO TULLUS[1,2 *], OLIVER LUKASON[3], AIVO VARES[4], ALLAR PADARI[1], REIMO LUTTER[1], TEA TULLUS[1], KALLE KAROLES[1,5] AND HARDI TULLUS[1]

[1]*Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Kreutzwaldi 5, 51014 Tartu, Estonia*

[2]*Department of Botany, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu, Lai 40, 51005 Tartu, Estonia*

[3]*Institute of Business Administration, Faculty of Economics and Business Administration, University of Tartu, Narva mnt 4-A307, 51009 Tartu, Estonia*

[4]*Seed and Plant Management Department, State Forest Management Centre, Rõõmu tee 2, 51013 Tartu, Estonia*

[5]*Estonian Environment Information Centre, Rõõmu tee 2, 51013 Tartu, Estonia*

**Corresponding author: Arvo Tullus, tel.: +372 7313 795; fax: +372 7313 156; e-mail address: arvo.tullus@emu.ee*

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.

Abstract

We analysed the economics of hybrid aspen and silver birch which are both fast-growing deciduous trees recommended for the establishment of plantations on abandoned agricultural lands in Northern Europe. If managed during one rotation period the internal rate of return (IRR) of hybrid aspen plantations was 4.4-7.3% and the IRR of silver birch plantations was 4.7-6.7%. The highest value of IRR of 8.1% was estimated for the two-rotation (26+26 years) hybrid aspen management scenario in excellent site conditions. Higher IRR values were reached at excellent quality sites whereas hybrid aspen was more sensitive to site quality. With land cost included in the analysis, 1.1-1.7% lower IRR values were obtained compared to the case where land cost was excluded from the analysis, but the ranking of scenarios did not change. The financial maturity ages of one-rotation scenarios corresponding to maximum expected IRR values were 26 or 34 years for hybrid aspen in excellent or good to moderate sites respectively, whereas the maturity age did not change with the inclusion of land in the analysis. The maturity ages for different silver birch scenarios varied in the range of 34-45 years. The land expectation values (LEV) remained positive in case of 1-5% discount rates. In case of 3% discount rate, LEVs of all scenarios were roughly comparable to the current median agricultural land price. We conclude that the establishment of plantations with both studied hardwoods can be a profitable investment in Northern Europe and to ensure greater profitability such plantations should be managed under shorter rotations than traditionally used for birch and aspen forests in the region.

Key words: abandoned agricultural lands, afforestation, deciduous trees, forest economics, hybrid aspen, internal rate of return, land expectation value, plantation forestry, short-rotation forestry, silver birch

Introduction

Silver birch (*Betula pendula* Roth.) and hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantations have recently been established for the afforestation of abandoned agricultural lands in the Baltic countries (Daugaviete et al. 2003, Vares et al. 2003, Liepins 2007, Tullus et al. 2007, Kund et al. 2010) and in Fennoscandia (Karlsson et al. 1997, Johansson 1999, Beuker 2000, Yu et al. 2001, Rytter 2006). This has been driven by the need to find alternative uses for large abandoned agricultural areas that exist in the region (e.g. Peterson and Aunap 1998) as well as by the steadily increasing demand for industrial timber (FAOSTAT 2011). Silver birch is commercially the most important deciduous tree species in the region (Vakkari 2009, Hynynen et al. 2010) and hybrid aspen is considered to be the most promising tree for short-rotation forestry in boreal areas (Weih 2004, Rytter 2006, Tullus et al. 2012). Since the 1980ies, the main aim of birch and aspen plantations has been the production of pulpwood with the recent additional emphasis on offering a potential resource for energy wood (Rytter 2006, Di Fulvio et al. 2011). The growth and yield dynamics in birch and aspen plantations have been previously studied (e.g. Johansson 1999, Johansson 2007, Rytter and Stener 2005), showing the very high mean annual volume increment of hybrid aspen at a young age, reaching up to 20 m^3 ha^{-1} yr^{-1} during 25 years (Tullus et al. 2012), while the respective value reaches about 10 m^3 ha^{-1} yr^{-1} in the case of silver birch (Karlsson et al. 1997). However, birch timber is currently more highly valued in the market than aspen timber and a certain amount of expensive veneer logs can be expected from fast-growing birch plantations in addition to pulpwood, saw logs and energy wood, whereas only the latter three assortments are usually marketed from aspen timber. In addition, aspen wood is lighter than birch wood; a specific gravity of 350–370 kg m^{-3} has been estimated for hybrid aspen (Heräjärvi and Junkkonen 2006, Tullus et al. 2012) and 419–650 kg m^{-3} for silver birch, increasing with stand age (Kasesalu 1965, Repola 2006, Johansson 2007) in the region. This reduces the superiority of aspen over birch in biomass productivity terms. Thus an economic comparison of hybrid aspen and silver birch plantations is needed to provide not only theoretical knowledge, but also practical recommendations for land owners who aim to establish large-scale commercial plantations with these hardwoods in the region. Previously only a few studies have analysed economics of hybrid aspen (Rytter et al. 2011) and silver birch (Niskanen 1999) plantations on abandoned agricultural lands.

In short-rotation plantation forestry, high biomass productivity and economic profitability are given priority and harvest time usually coincides with the age when the mean annual increment is the highest. Thus much shorter rotation lengths are recommended for plantation forests compared to traditional forestry with the same species, where total production, outcome of more expensive assortments and environmental considerations determine the felling age. As plantation forestry with aspens and birches is still quite a new practice in Northern Europe, determination of felling ages for plantations with these hardwoods is a scantily studied topic.

The aim of the present study was to compare the economics of conventional management systems that are recommended for hybrid aspen and silver birch plantations established for the afforestation of abandoned agricultural lands. We will clarify whether the maximum profitability from hybrid aspen and silver birch plantations could be expected earlier than the commonly known maturity ages of European aspen and silver birch stands. We will compare the economics of plantations with both mentioned hardwoods growing on excellent and on good to moderate sites. The paper also outlines land expectation values at different discount rates.

Materials and methods

Studied plantations and growth model

As long-term growth data from commercial hybrid aspen and silver birch plantations on abandoned agricultural lands in the region are incomplete, growth functions suggested for silver birch and European aspen on forest land were used to predict the timber volumes and their distribution into assortments at harvests.

Empirical growth data from the oldest (12-year-old) existing hybrid aspen (n = 15) and silver birch plantations (n = 10) in Estonia were used as a starting point for growth modeling (Table 1). Hybrid aspen plantations were established with one-year-old micropropagated plants belonging to 27 clones originally selected in Finland; average planting density was 1,300 trees ha^{-1} (Tullus et al. 2007). Silver birch plantations were established with one-year-old bare-rooted seedlings of local provenance; planting density varied from 2,500 to 3,300 trees ha^{-1} (Kund et al. 2010). Growth characteristics of all trees were measured in 0.1 ha permanent sample plots in the studied plantations.

Additionally we present the results for sites with excellent (site group A) and good to moderate (group B) fertility for the mentioned trees. Plantations were grouped into fertility classes according to average height of the trees at the age of 12 years (Tables 1 and 2). As we did not include plantations with poor growth, the selection included fertile previous field soils (Table 2) which are generally recommended for hybrid aspen and silver birch in Estonia (Tullus et al. 2007, Kund et al. 2010). In all experimental plots, nutrient content in the A-horizon had previously been analysed. Plantations of site group A were growing on soils with higher P concentration and more favourable N:P ratio in the A-horizon (Table 2).

The previously published method by Padari et al. (2003, 2009) was used for growth simulation and assortment production assessment. The growth of height and diameter of trees in stands was simulated year by year using the difference models by Kiviste et al. (2006, 2009).

The simulation programs also determined the thinning regime according to stand density and consistent with the official norms by using the models by

Table 1. Growth characteristics and estimated yield (M) of 12-year-old hybrid aspen (HA) and silver birch (SB) plantations, letters denote statistically significant differences in group means according to Fisher LSD test

Plantation ID[a]	Tree species	Site group	*H*, m	DBH, cm	*n* trees ha^{-1}	*M*, m^3 ha^{-1}
125/HHB49	HA	A	16.5	12.6	1210	117
109/HHB18	HA	A	15.9	13.2	1050	121
124/HHB47	HA	A	15.9	14.1	930	109
116/HHB34	HA	A	15.9	13.8	1010	114
122/HHB42	HA	A	15.4	11.9	1030	84
104/HHB10	HA	A	15.3	12.6	1330	131
102/HHB5	HA	A	14.9	12.1	1280	103
Mean ± S.E. (*n* = 7):			15.9 ± 0.2 a	13.0 ± 0.3 a	1120 ± 57 b	109 ± 5 a
123/HHB43	HA	B	14.7	12.2	1210	100
120/HHB40	HA	B	14.7	11.8	1270	98
126/HHB50	HA	B	14.0	10.8	1050	65
116/HHB32	HA	B	13.3	12.0	1050	77
121/HHB41	HA	B	12.8	12.7	850	67
123/HHB44	HA	B	12.7	10.5	980	53
125/HHB48	HA	B	12.1	10.8	1130	62
116/HHB35	HA	B	11.8	10.3	790	39
Mean ± S.E. (*n* = 8):			13.3 ± 0.4 b	11.4 ± 0.3 b	1041 ± 59 b	70 ± 7 bc
409/LP21	SB	A	12.7	11.5	1375	91
402/LP14	SB	A	11.8	8.7	1960	70
405/LP17	SB	A	11.5	9.2	2070	81
408/LP20	SB	A	11.2	8.3	2870	90
410/LP22	SB	A	10.9	7.7	2860	75
Mean ± S.E. (*n* = 5):			11.6 ± 0.3 c	9.1 ± 0.7 c	2227 ± 286 a	81 ± 4 b
406/LP18	SB	B	10.7	8.4	2450	76
401/LP13	SB	B	10.7	8.6	1340	44
407/LP19	SB	B	10.6	8.8	1800	61
404/LP16	SB	B	10.3	6.8	1780	35
403/LP15	SB	B	9.7	8.1	1740	47
Mean ± S.E. (*n* = 5):			10.4 ± 0.2 d	8.1 ± 0.4 c	1822 ± 178 a	53 ± 7 c

[a] Identification number/experiment number according to NOLTFOX online database (http://noltfox.metla.fi)

Table 2. Soil type and chemical soil properties of the A-horizon in the studied hybrid aspen (HA) and silver birch (SB) plantations (data from Soo et al. 2009; Kund et al. 2010), letters denote statistically significant differences in group means according to Fisher LSD test

Plantation	Tree species	Site group	Soil type (WRB)	Soil A-horizon		
				N, mg kg^{-1}	P, mg kg^{-1}	N/P
125/HHB49[a]	HA	A	*Leptic Podzol*	1550	291	5
109/HHB18	HA	A	*Gleyic Planosol*	1050	98	11
124/HHB47	HA	A	*Cambic Arenosol*	1025	176	6
116/HHB34	HA	A	*Mollic Planosol*	1175	88	13
122/HHB42	HA	A	*Cumuli-Cambic Arenosol*	725	72	10
104/HHB10	HA	A	*Buried-gleyic soil*	1300	105	12
102/HHB5	HA	A	*Mollic Planosol*	1000	186	5
Mean ± S.E. (*n* = 7):				1118 ± 98	145 ± 29 ab	9.0 ± 1.3 a
123/HHB43	HA	B	*Gleyic Albeluvisol*	1225	97	13
120/HHB40	HA	B	*Gleyic Albeluvisol*	2225	22	101
126/HHB50	HA	B	*Gleyi-Mollic Planosol*	900	33	27
116/HHB32	HA	B	*Mollic Planosol*	975	145	7
121/HHB41	HA	B	*Mollic Planosol*	1475	60	24
123/HHB44	HA	B	*Eutric Gleysol*	1175	29	40
125/HHB48	HA	B	*Mollic Planosol*	1075	132	8
116/HHB35	HA	B	*Mollic Gleysol*	2850	39	73
Mean ± S.E. (*n* = 8):				1488 ± 244	70 ± 17 bc	36.7 ± 11.9 b
409/LP21	SB	A	*Dystric Gleysol*	1250	155	8
402/LP14	SB	A	*Eutric Podzoluvisol*	950	106	9
405/LP17	SB	A	*Glossic Podzoluvisol*	1400	36	39
408/LP20	SB	A	*Calcaric Cambisol*	1775	147	12
410/LP22	SB	A	*Mollic Gleysol*	2900	403	7
Mean ± S.E. (*n* = 5):				1655 ± 338	169 ± 62 a	15.0 ± 6.0 ab
406/LP18	SB	B	*Dystric Gleysol*	1125	27	42
401/LP13	SB	B	*Calcaric Luvisol*	1375	62	22
407/LP19	SB	B	*Calcaric Luvisol*	1650	30	55
404/LP16	SB	B	*Dystric Planosol*	1375	19	73
403/LP15	SB	B	*Eroded Calcaric Luvisol*	1050	92	11
Mean ± S.E. (*n* = 5):				1315 ± 106	46 ± 14 c	40.9 ± 11.1 b

[a] Experimental area identification number according to Noltfox online database (http://noltfox.metla.fi)

Korjus and Padari (Korjus and Padari 1994, Korjus 1999). The distribution of timber into assortments was calculated with the following models and input parameters: 1) the model of diameter classes (Padari et al. 2009); 2) the height curve (Prodan 1965, Padari et al. 2009); 3) the taper curve equation (The Standard of Forest Inventory… 1988, Ozoliņš 2002); 4) the bark equation (Padari et al. 2009). The minimal top diameter under the bark of the log was estimated as 28 cm for birch veneer logs, 18 cm for aspen and birch logs, 7 cm for aspen pulpwood, 6 cm for birch pulpwood and 5 cm for firewood. The volume of the top was added to the volume of branches. The volumes of branches were estimated roughly as a specific percentage of the volume of the stem – 12% in aspen and 8% in silver birch (Krigul 1971). The calculated volumes of assortments were corrected according to the percentage of damages and defects (Padari et al. 2009). 50% of the damaged wood of all assortments of the merchantable wood was classified as fuel wood. The rest of the damaged wood was classified as pulpwood. After that, the effect of crook was taken into account – 10% of aspen and 25% of birch stems were classified either as pulpwood or fuelwood (instead of logs).

Based on the literature we expected the rotation period of hybrid aspen to be 20–30 years (Tullus et al. 2012). The legitimate felling age of silver birch in Estonia is 60–70 years (Metsa majandamise eeskiri 2010). Thus we analysed the economics of hybrid aspen plantations both during one rotation period, as well as including the second rotation period. The second generation arises vegetatively from root suckers and does not include any establishment cost. Heavy thinning of the second generation hybrid aspen stand is needed 2–4 years after the clear-cut (Rytter 2006). Besides that the management and development of the second generation is assumed to resemble the first (planted) generation (Table 3). The simulation period was longer than the expected maturity ages of the studied plantations in order to ensure that the determined financial maturity age would fall within the simulated stand growth period.

Table 3. Timing of management activities in plantations growing on sites with excellent (A) and good-moderate (B) fertility during one rotation period for birch and two rotation periods (R1, R2) for aspen. The timing of thinnings is based on the growth model prediction up to 60 years

Action	Scenario / year			
	Aspen A_{R1}	Aspen A_{R2}	Aspen B_{R1}	Aspen B_{R2}
Establishment, 1300 trees ha^{-1}	0	0 (vegetative regeneration)	0	0 (vegetative regeneration)
Tending in the first year	1	-	1	-
Tending in the second year	2	-	2	-
Intensive thinning of the regenerating root sucker stand	-	3	-	3
1. thinning	16	16	19	19
2. thinning	26	26	26	26
3. thinning	33	33	34	34
4. thinning	42	42	44	44
5. thinning	54	54	57	57
	Birch A		Birch B	
Establishment, 2500 trees ha^{-1}	0		0	
Tending in the first year	1		1	
Tending in the second year	2		2	
Pruning 0-2 m, 200 trees ha^{-1}	10		10	
Pruning 2-4 m, 200 trees ha^{-1}	15		15	
1. thinning	14		17	
2. thinning	19		23	
3. thinning	26		31	
4. thinning	35		51	
5. thinning	51		-	

Economic analysis

There is multitude of methodologies for conducting economic analysis of different plantation systems, among which different profitability analysis and valuation methods are most common. Götze et al. (2008) divide investment appraisal methods into the following subgroups: static, discounted cash flow, and advanced. From the given division the most commonly used methods for plantation system economic analysis have been net present value (NPV) and internal rate of return (IRR) (e.g. Gaffney 1957, Rose et al. 1988, Guo et al. 2006, Ying et al. 2010), or their modifications. The NPV concept has been widely used, but it is not suitable for the comparison of projects that demand a different amount of initial investment. For the current analysis, IRR methodology will be applied, expressed as (Götze et al. 2008):

$$\sum_{t=0}^{T}(CIF_t - COF_t)\times(1+IRR)^{-t} = 0, \quad (1)$$

where *CIF* is cash inflow; *COF* cash outflow. The IRR methodology has some deficiencies, of which the most important is the assumption of a reinvestment rate equaling IRR (e.g. Kierulff 2008). Still, in the current study this is not problematic, as it is possible to reinvest cash inflows with IRR to the same projects, as land for creating plantations is not constrained (i.e. it is possible to reinvest in similar projects). Also the research objective of the current paper does not demand the usage of more complicated methodologies than IRR. The results will be outlined for two cases, where for the first land price is omitted from calculations and for the second it will be included in the calculations. This helps to open the context of plantation profitability for wider audience, as land prices can vary a lot through countries. Also, the omission of land price allows present practical implications for investors who already own land. Results obtained with IRR application can also be compared with returns from other investment possibilities (e.g. shares, bonds or deposits). Another common tool for analyzing the economics of plantations is land expectation value (LEV) method (see e.g. Gong 1998), which as IRR allows to understand whether the plantation management can be profitable at all. LEV concept was already applied by Faustmann (1849) and the basics of it have not changed, although the method has been developed to account for larger number of variables and criteria. LEV is composed of the summed discounted cash flows that plantation project creates, this way outlining the maximum price that could be paid for the plantation land. Unlike IRR, the LEV method also allows to calculate the results which are easily comparable with current land prices. LEV method will be applied with different discount rate values in order to outline their impact on the result.

The establishment and processing costs and timber prices (Table 4) that were used as input data for IRR calculations were based on mean values from big forest enterprises in Estonia in 2010 (the State Forest Management Centre: http://www.rmk.ee/en and timber market overview by the foundation Private Forest Centre: http://www.eramets.ee/). Land price is the arithmetic average of the median agricultural land sales prices from 2006-2010 in Estonia, collected from Estonian Land Board (http://www.maaamet.ee) price statistics database. As a simplification, in the IRR calculation where land purchase is considered, the sale of land with the same price is accounted in the last period of analysis. As it is difficult to forecast the precise changes in future prices of land, timber and processing, price changes have been not accounted in the current analysis.

Altogether six different management scenarios were composed: 1) hybrid aspen plantations growing on excellent sites during one rotation period (referred to as Aspen A_{R1}), 2) hybrid aspen plantations growing on good to moderate sites during one rotation period (Aspen B_{R1}), 3) hybrid aspen plantations growing on excellent sites during two rotation periods (Aspen A_{R2}), 4) hybrid aspen plantations growing on good to moderate sites during two rotation periods (Aspen B_{R2}), 5) silver birch plantations growing on excellent sites (Birch A), 6) silver birch plantations growing on good-moderate sites (Birch B). For LEV calculations two period solution is excluded from analysis, as it uses perpetual approach.

Table 4. Establishment and processing costs and road-side timber prices (net values, i.e. VAT (GST) excluded)

Expense items	Unit	EUR per unit
Land	ha	797.05
Silver birch seedling	each	0.15
Hybrid aspen clonal plant	each	0.61
Plant protector	each	0.21
Planting with protector	each	0.08
Weed control with herbicide	ha	42.61
Site preparation	ha	53.26
Tending	ha	79.89
Pruning of 200 trees	ha	117.17
Clear felling	m^3	8.64
Thinning	m^3	15.19
Chopping (energy wood)	m^3	5.40
Revenue sources		
Aspen log	m^3	27.93
Aspen pulpwood	m^3	25.56
Birch plywood	m^3	63.91
Birch log	m^3	44.55
Birch pulpwood	m^3	31.01
Energy wood*	m^3	26.36

* The price of one m^3 chopped wood was multiplied by 2.5 to estimate the price of one m^3 solid energy wood biomass

The first possible harvesting year for both tree species is year 13 and analysis was run up to year 60 in one-rotation scenarios. For two-rotation scenarios (Aspen A_{R2} snd Aspen B_{R2}) in total 48 * 48 analyses were run, as it is possible to make both the first and the second cut on random year from 13 to 60. For each scenario the potential financial maturity age was then determined as the year of harvest when IRR has maximum value.

Results

Profitability of the analysed scenarios was directly dependent on the prices of wood assortment obtained from harvest. Based on the IRR analysis, the financial maturity ages (harvest years providing the highest IRR) were estimated for all scenarios (Table 5). In the case of hybrid aspen the highest share of revenues at financial maturity age was from logs (Aspen A_{R1} 49% and Aspen B_{R1} 52%), followed by pulpwood and energywood. For silver birch the predominant revenue source was pulpwood (Birch A 49% and Birch B 46%), followed by logwood, and minor shares were from plywood and energywood. However the share of plywood surpasses other assortments after 50-60 years and becomes the dominant revenue source.

The share of aspen timber assortments by sales revenues was almost equal to the share of each assortment by timber volume (Fig. 1). In the case of silver birch cheaper assortments (energy wood and pulpwood) constituted higher share by volume than by revenues and more expensive assortments (logs and veneer logs) exhibited the opposite trend (Fig. 1).

Based on IRR analyses, the hybrid aspen one-rotation scenario on excellent sites had slightly better results than silver birch, but in the case of good-moderate fertility sites the results were the opposite (Table 5). Such a trend was observed for both cases, where land is included or excluded from the analysis. The hybrid aspen two-rotations scenario on excellent fertility sites produced better results than all other viewed scenarios and in the case of moderate fertility the two-rotations scenario outran all one-rotation scenarios for good-moderate fertility sites (Table 5). It can

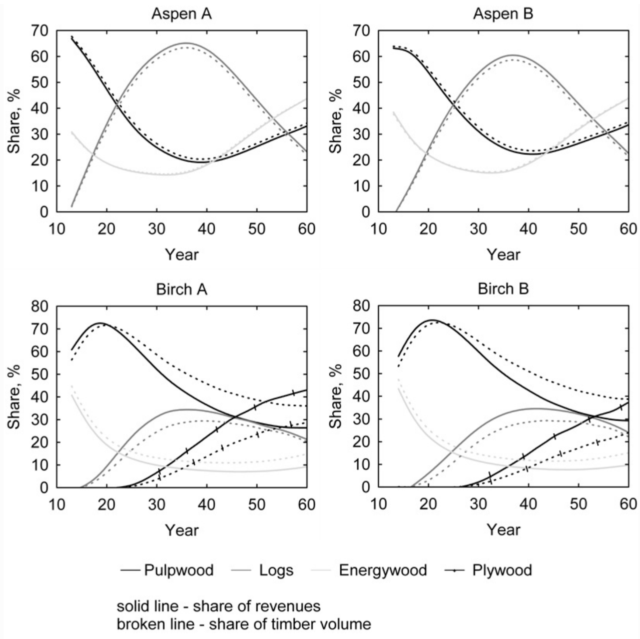

Figure 1. The share of assortments by sales revenue and by volume in hybrid aspen and silver birch plantations during the simulated growth period

be summed, that the plantation projects are profitable for both cases, with and without land cost, and outrun profitability of several instruments like deposit accounts and government bonds.

IRR development of the analysed scenarios indicated that after gaining its maximum value, the profitability of hybrid aspen one-rotation scenarios starts to decline and drops lower than that of silver birch values (Fig. 2). IRR of birch scenarios and two-rotations aspen scenarios remained more stable enabling the potential harvest year to be varied without considerable loss in profitability.

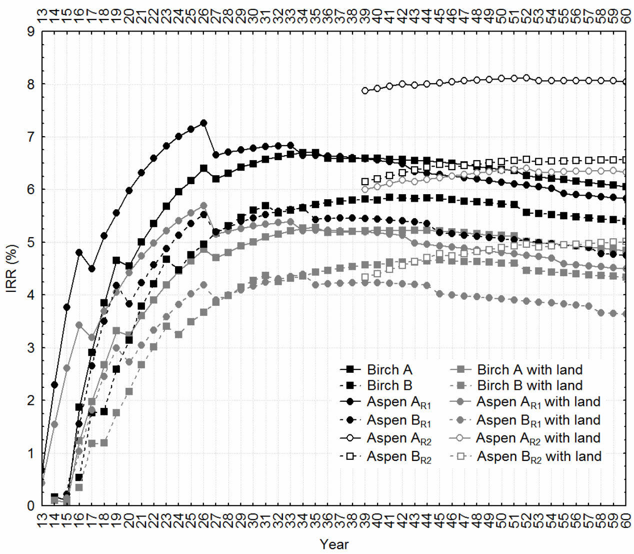

Figure 2. IRR dynamics of silver birch and hybrid aspen plantations

LEVs (Table 6) indicate that in case of 1% discount rate the land had high value, especially in comparison to agricultural land price in Estonia during recent years. In case of 3% discount rate LEV values did not differ substantially from the current land prices, except

Table 5. Management scenarios providing the maximum internal rate of return (IRR). Y – year since stand establishment, E-R – expenses-revenues (EUR ha^{-1}), M – removed volume (m^3 ha^{-1}) of pulpwood and logs + energywood (tops, branches and low-quality timber).

Management activity	Y	E-R	M	Y	E-R	M
Scenario:	*Birch A (IRR = 6.7%)*			*Birch A with land (IRR = 5.3%)*		
Establishment	0	-1201	-	0	-1998	-
Tending	1; 2	-160	-	1; 2	-160	-
Pruning	10; 15	-234	-	10; 15	-234	-
Thinning	14; 19; 26	2416	128+39	14; 19; 26	2416	128+39
Harvest	34	7334	237+33	35	8619	252+34
Scenario:	*Birch B (IRR = 5.8%)*			*Birch B with land (IRR = 4.7%)*		
Establishment	0	-1201	-	0	-1998	
Tending	1; 2	-160	-	1; 2	-160	-
Pruning	10; 15	-234	-	10; 15	-234	-
Thinning	17; 23; 31	2666	140+37	17; 23; 31	2666	140+37
Harvest	41	7949	248+33	45	10695	295+38
Scenario:	*Aspen A_{R1} (IRR = 7.3%)*			*Aspen A_{R1} with land (IRR = 5.7%)*		
Establishment	0	-1266	-	0	-2063	-
Tending	1; 2	-160	-	1; 2	-160	-
Thinning	16	691	63+17	16	691	63+17
Harvest	26	7336	371+67	26	8133	371+67
Scenario:	*Aspen A_{R2} (IRR = 8.1%)*			*Aspen A_{R2} with land (IRR = 6.4%)*		
Establishment	0	-1266	-	0	-2063	-
Tending	1; 2	-160	-	1; 2	-160	-
Thinning	16; 29; 42	2282	126+104	16; 29; 42	2282	126+104
Harvest	26; 52	14672	742+134	26; 52	15469	742+134
Scenario:	*Aspen B_{R1} (IRR = 5.7%)*			*Aspen B_{R1} with land (IRR = 4.4%)*		
Establishment	0	-1266	-	0	-2063	-
Tending	1; 2	-160	-	1; 2	-160	-
Thinning	19; 26	1851	141+34	19; 26	1851	141+34
Harvest	34	5779	281+51	34	6576	281+51
Scenario:	*Aspen B_{R2} (IRR = 6.6%)*			*Aspen B_{R2} with land (IRR = 5.0%)*		
Establishment	0	-1266	-	0	-2063	-
Tending	1; 2	-160	-	1; 2	-160	-
Thinning	19; 26; 29; 45	2039	114+79	19; 26; 29; 45; 52	3160	198+96
Harvest	26; 52	9314	458+96	26; 60	11233	510+99

for aspen at excellent site scenario, which showed two times higher LEV. In case of 5% discount rate LEVs were still positive, but very small, thus the establishment of plantation would not be reasonable and there could be more profitable usages for such land. The highest LEV values were always estimated for excellent site aspen plantations, followed by birch plantations in excellent sites. The ranking of scenarios for good-moderate sites depended on the discount rate, for small discount rate (1%) the LEV for birch being better than for aspen.

Table 6. Results from the land expectation value (LEV) analysis (in EUR ha^{-1}) for three discount rates (r) and respective rotation periods (in brackets)

Scenario	LEV (r = 1%)	LEV (r = 3%)	LEV (r = 5%)
Birch A	14481 (44 years)	1448 (34 years)	199 (26 years)
Birch B	12562 (51 years)	990 (31 years)	79 (31 years)
Aspen A_{R1}	16355 (26 years)	2086 (26 years)	378 (26 years)
Aspen B_{R1}	10351 (34 years)	1000 (26 years)	72 (26 years)

Discussion and conclusions

In the current paper we analysed the economics of silver birch and hybrid aspen, which are both regarded as promising hardwoods in Northern Europe (Hynynen et al. 2010, Tullus et al. 2012), but which have seldom been compared from the economic aspect. The study relied on Estonian prices, which generally reflect the timber market of the nearby region - Fennoscandia and other Baltic states. In addition, there is a clear convergence and trend of deepening integration also in the European wood market as a whole (Hänninen et al. 2007).

The profitability of all compared hybrid aspen and silver birch management scenarios was in the range of 5.7-8.1% (Table 5) without land cost and 4.4-6.4% with land cost respectively. Commonly the IRR of forestry investments in this region varies from 2-4% (Brukas and Weber 2009), seldom over 7% (Kaimre 2002). In Sweden an IRR of 10% (without land cost) was reported for hybrid aspen plantations (Rytter et al. 2011), which is roughly comparable with the best scenario from our study. Thus short-rotation forestry with fast-growing hardwoods could be a profitable alternative to traditional high forestry with long rotation periods in the Northern temperate climate of the hemiboreal forest zone. At the same time the profitability of plantation forestry systems could be much higher in southerly regions, e.g. an IRR of 13-23% has been reported for eucalyptus plantations in South America (Cubbage et al. 2007).

Our results (Fig. 2, Tables 5 and 6) indicated that the most profitable scenario would be a hybrid aspen plantation during two rotation periods on an excellent fertility site (Aspen A_{R2}) and, in the case where the land-owner decides to manage the plantation during only one rotation period, hybrid aspen on an excellent fertility site (Aspen A_{R1}) will also produce the highest profitability. Profitability of silver birch plantations was about 1% lower; thus there was no considerable difference between the two hardwoods from this perspective. However, maximum IRR was reached 7-8 years earlier in hybrid aspen plantations (Table 5). During a longer period involving several rotations, hybrid aspens should thus have an advantage over birch due to successful vegetative regeneration via root suckers (Rytter 2006). To establish a new silver birch generation the preferred method is usually planting if the production of high-quality timber is the goal (Hynynen et al. 2010). At the same time silver birch regenerates naturally abundantly by seed; thus the leaving of seed trees could be an economically reasonable option for birch regeneration after the clear-cut of the first planted generation. Alternatively plantations can be split into smaller fields and harvested not at once, but stepwise so that the remaining fields are a source of seeds for harvested areas.

As the estimated IRR values are relatively similar (Table 5), changes in the prices of wood assortments can result in remarkable shifts in revenue sources, but also in the ranking of scenarios measured according to IRR. However, we did not perform sensitivity analyses or robustness tests here, as the main emphasis was on the comparison of the two hardwoods. As expected, pulpwood constituted the highest share of the timber yield in birch plantations at the financial maturity stage (Fig. 1). Somewhat surprisingly the share of logs exceeded the share of pulpwood in hybrid aspen plantations that were aimed at pulpwood production when established over a decade ago. This means that landowners should consider the possibility to produce aspen logs from short-rotation hybrid aspen plantations and apply necessary measures (pruning of the best trees) during the rotation. The demand and price of logs and plywood is predicted to remain constant or to increase slightly in the region (Leskinen and Kangas 2001). In the case of pulpwood the share of tropical hardwoods is probably going to rise, and thus a decrease in Nordic pulpwood prices is expected (Leskinen and Kangas 2001). There is a clear trend for the rise in demand and price of energy wood. This is supported by the energy policy of European Union, which obligates Member States to raise the share of energy from renewable sources to 20% by 2020 (DIRECTIVE 2009/28/EC). Currently energy wood prices have already reached almost the same level as pulpwood prices. For example Di Fulvio et al. (2011)

found that it is more profitable to sell all timber from the commercial thinning of a birch stand as energy wood even if some of it meets pulpwood dimensions. Our analysis regarding the distribution of timber into assortments was based on minimum dimensions and current prices, which both increase in the following order: energy wood d” pulpwood < logs < plywood (Table 4). Obviously the share of assortments would be different if the prices change. Theoretically the land owner could sell the whole timber as energy wood at the established financial maturity ages. Thus aspen and birch plantations offer flexible marketing opportunities for land owners.

As expected, the rotation periods based on the predicted financial maturity are rather short (Table 5). For hybrid aspen this is in accordance with previous estimations in Northern Europe (Tullus et al. 2012), but for birches the traditional rotation period is over 50 years. This is grounded on both the expectation for higher outcome of the most valuable assortment – plywood - as well as on environmental considerations. Solely from the economic point of view the rise in the share of more expensive assortments at an older age (Fig. 1) was not accompanied by a rise in profitability, as the investment period becomes too long. At the same time the IRR of scenario Birch A would change by only -0.5% if the harvest takes place at the age of 60 years instead of the financial maturity age of 34 years. Thus land owners could delay with the harvest of birch in the expectation of a more favourable market situation. Such a ”buffer” is shorter for hybrid aspen because the aspen growth function considered the spread of trunk rot, which reduces the merchantable timber volume when aspen stands become older. Thus a delay in the harvest of aspen plantation could result in a faster decline in profitability.

Earlier studies have shown that the growth rate of hybrid aspen and silver birch is considerably faster on fertile soils (Tullus et al. 2007, 2010, Kund et al. 2010). Thus we did not analyse the profitability of plantations growing on less fertile sites. The difference in IRR between excellent and good-moderate fertility sites was -0.9% in birch plantations and -1.5% to -1.6% in hybrid aspen plantations (Table 5). On one hand this distinction is not great but on the other hand it agrees with previous studies showing the high sensitivity of hybrid aspen to site conditions and the more stable growth of silver birch at various sites. Thus the risk of losing in profitability with unsuccessful site selection is lower when establishing a birch plantation. It must also be considered that hybrid aspen is a half-exotic species, and the potential negative impact on the environment with large-scale establishment of hybrid aspen plantations is higher than in the case of planting endemic silver birch. A major threat for both hardwoods is moose browsing, the occurrence of which has been found to be four times higher in aspen dominated stands than in birch dominated stands (Jalkanen 2001). Thus it is recommended to fence hardwood plantations.

Land expectation values for birch and hybrid aspen plantation systems have rarely been reported in Northern Europe. For silver birch plantations on abandoned agricultural lands Niskanen (1999) reported LEVs of 1064-1104 EUR/ha (interest rate = 3%), which is comparable to our results (Table 6). Similarly to IRR results, LEV analysis showed slightly higher value of hybrid aspen compared to silver birch, especially on more fertile sites.

The current study relied on optimal management of already existing plantations. Further studies should clarify the impact of different plantation densities and thinning regimes on economics of plantation forests in the region.

Conclusions

- Establishment of forest plantations with fast-growing hardwoods on abandoned agricultural lands could be a profitable alternative forestry practice in hemiboreal conditions.
- Both hybrid aspen and silver birch are promising hardwoods for establishing forest plantations in the region and there is no clear reason to prefer one over the other.
- On the basis of maximum expected IRR the potential harvest time would be 26-34 years in hybrid aspen and 34-45 years in silver birch plantations which are considerably shorter rotation periods than practiced in traditional aspen and birch forests in Northern Europe.
- Hybrid aspen enables slightly higher profitability within a shorter time than silver birch, and its new generations arise vegetatively without further establishment costs. At the same time its growth is more dependent on site fertility, it is more threatened by moose browsing, and being half-exotic, its potential negative impact on the environment could be higher than in the case of endemic silver birch.
- Silver birch offers more versatile assortments and an opportunity to delay with harvest without considerable loss in profitability.
- Land expectation values of both species remain positive with discount rates in the range of 1-5%, but for the 5% discount rate the value is very small.

Acknowledgements

The study was supported by the Estonian Science Foundation (grant No 7298), the ministry of Education and Research (project No SF0180037s08) and the EFINORD project "Short-rotation forestry on former agricultural land". The authors would also like to thank Olavi Andres and Edvard Eelsalu for their help in field work and Ilmar Part for language revision.

References

Beuker, E. 2000. Aspen Breeding in Finland, New Challenges. *Baltic Forestry* 6 (2): 81-84.

Brukas, V. and Weber, N. 2009. Forest management after the economic transition-at the crossroads between German and Scandinavian traditions. *Forest Policy and Economics* 11: 586-592.

Cubbage, F., MacDonagh, P., Júnior, J.S., Rubilar, R., Donoso, P., Ferreira, A., et al. 2007. Timber investment returns for selected plantations and native forests in South America and the Southern United States. *New Forests* 33: 237-255.

Daugaviete, M., Krūmiņa, M., Kāposts, V. and Lazdiņš, A. 2003. Farmland Afforestation: the Plantations of Birch *Betula pendula* Roth. on Different Soils. *Baltic Forestry* 9 (1): 9-21.

Di Fulvio, F., Kroon, A., Bergström, D. and Nordfjell, T. 2011. Comparison of energy-wood and pulpwood thinning systems in young birch stands. *Scandinavian Journal of Forest Research* 26 (4): 339-349.

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

FAOSTAT. 2011. © FAO Statistics Division 2011. Retrieved December 26, 2011, from http://faostat.fao.org/

Faustmann, M. 1995. On the determination of the value which forest land and immature stands possess for forestry. Allgemeine Forst- und Jagd-Zeitung vol.15, 1849. Reprint in *Journal of Forest Economics* 1 (1): 7-44.

Gaffney, M.M. 1957. Concepts of financial maturity of timber and other assets (A.E. Information Series No. 62). Department of Agricultural Economics, North Carolina State College, 105 pp.

Gong, P. 1998. Determining the optimal planting density and land expectation value – A numerical evaluation of decision model. *Forest Science* 44 (3): 356-364.

Götze, U., Northcott, D. and Schuster, P. 2008. Investment appraisal. Methods and models. Heidelberg, Springer, 391 pp.

Guo, Z., Zhang, Y., Deegen, P. and Uibrig, H. 2006. Economic analyses of rubber and tea plantations and rubber-tea intercropping in Hainan, China. *Agroforestry Systems* 66: 117-127.

Hänninen, R., Toppinen, A. and Toivonen, R. 2007. Transmission of price changes in sawnwood and sawlog markets of the new and old EU member countries. *European Journal of Forest Research* 126 (1): 111-120.

Heräjärvi, H. and Junkkonen, R. 2006. Wood Density and Growth Rate of European and Hybrid Aspen in Southern Finland. *Baltic Forestry* 22 (1): 2-8.

Hynynen, J., Ahtikoski, A. and Eskelinen, T. 2004. Viljelyhaavikon tuotos ja kasvatuksen kannattavuus [Yield and profitability of aspen plantation]. *Metsätieteen aikakauskirja* 1: 113-116, (in Finnish).

Hynynen, J., Niemistö, P., Viherä-Aarnio, A., Brunner, A., Hein, S. and Velling, P. 2010. Silviculture of birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) in northern Europe. *Forestry* 83 (1): 103-119.

Jalkanen, A. 2001. The probability of moose damage at the stand level in southern Finland. *Silva Fennica* 35 (2): 159-168.

Johansson, T. 1999. Biomass equations for determining fractions of pendula and pubescent birches growing on abandoned farmland and some practical implications. *Biomass and Bioenergy* 16: 223-238.

Johansson, T. 2007. Biomass production and allometric above and below-ground relations for young birch stands planted at four spacings on abandoned farmland. *Forestry* 80: 41-52.

Kaimre, P. 2002. Metsanduse ökonoomika [Forest Economics]. Tartu Ülikooli Kirjastuse trükikoda, Tartu, 95 pp, (in Estonian).

Karlsson, A., Albrektson, A and Sonesson, J. 1997. Site index and productivity of artificially regenerated *Betula pendula* and *Betula pubescens* stands on former farmland in southern and central Sweden. *Scandinavian Journal of Forest Research* 12: 256-63.

Kasesalu, A. 1965. Kasepuidu füüsikalis-mehaanilistest omadustustest erinevates kasvukohatüüpides [Physical-mechanical properties of birch timber in different site types]. *Forestry Studies / Metsanduslikud Uurimused* 4: 149-157, (in Estonian).

Kierulff, H. 2008. MIRR. A better measure. *Business Horizons* 51: 321-329.

Kiviste, A. and Kiviste, K. 2006. Difference equations of stand height, diameter, and volume depending on stand age and sitefactors for Estonian state forest. In: Second International Conference on Forest Measurements and Quantitative Methods and Management & The 2004 Southern Mensurationists Meeting; Proceedings of the conference held on 15-18 June 2004, Hot Springs, Arkansas USA. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA, 30602, p. 284-296.

Kiviste, A. and Kiviste, K. 2009. Algebraic difference equations for stand height, diameter, and volume depending on stand age and site factors for Estonian state forests. *Mathematical and Computational Forestry & Natural-Resource Sciences* 1 (2): 67-77.

Korjus, H. 1999. Hooldusraiete mudelitest [About thinning models]. EPMÜ Metsandusteaduskonna toimetised nr. 32. Pidev metsakorraldus. Tartu, p. 44-49, (in Estonian).

Korjus, H. and Padari, A. 1994. Hõreduse piir Soome ja Rootsi hooldusraiete normatiivides [Stand sparsity limits in the Finnish and Swedish thinning models]. EPMÜ Teadustööde kogumik nr. 173. Tartu, p. 35-49, (in Estonian)

Krigul, T. 1971. Metsataksaatori teatmik [Reference book for forest measurer]. Eesti Põllumajanduse Akadeemia. Tartu, 151 pp, (in Estonian).

Kund, M., Vares, A., Sims, A., Tullus, H. and Uri, V. 2010. Early growth and development of silver birch (*Betula pendula* Roth.) plantations on abandoned agricultural land. *European Journal of Forest Research* 129 (4): 679-688.

Leskinen, P. and Kangas, J. 2001. Modelling future timber price development by using expert judgments and time series analysis. *Silva Fennica* 35 (1): 93-102.

Liepins, K. 2007. First-year Height Growth of Silver Birch in Farmland Depending on Container Stock Morphological Traits. *Baltic Forestry* 13: 54-60.

Metsa majandamise eeskiri [Forest Management Guidelines]. 2010. Retrieved December 26, 2011, from https://www.riigiteataja.ee/akt/13299966, (in Estonian).

Niskanen, A. 1999. The financial and economic profitability of field afforestation in Finland. *Silva Fennica* 33 (2): 145-157.

Ozolinš, R. 2002. Forest stand assortment structure analysis using mathematical modelling. *Forestry Studies / Metsanduslikud uurimused* 37: 33-42.

Padari, A. and Muiste, P. 2003. Analysis of Maturity Ages of Estonian Forests. *Baltic Forestry* 9 (2): 16-19.

Padari, A., Muiste, P., Mitt, R. and Pärn, L. 2009. Estimation of Estonian Wood Fuel Resources. *Baltic Forestry* 15 (1): 77-85.

Peterson, U. and Aunap, R. 1998. Changes in agricultural land use in Estonia in the 1990s detected with multitemporal Landsat MSS imagery. *Landscape and Urban Planning* 41: 193-201.

Prodan, M. 1965. Holzmesslehre. Frankfurt am Main, Germany: J. D. Sauerländer's Verlag, 644 pp.

Rose, D. W., Blinn, C. R. and Brand, G. J. A. 1988. Guide to Forestry Investment Analysis. Research Paper NC-284. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, 23 pp.

Repola, J. 2006. Models for vertical wood density of Scots pine, Norway spruce and birch stems, and their application to determine average wood density. *Silva Fennica* 40 (4): 673-685.

Rytter, L. 2006. A management regime for hybrid aspen stands combining conventional forestry techniques with early biomass harvests to exploit their rapid early growth. *Forest Ecology and Management* 236: 422-426.

Rytter, L. and Stener L.-G. 2005. Productivity and thinning effects in hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) stands in southern Sweden. *Forestry* 78 (3): 285-295.

Rytter, L., Johansson, T., Karačić, A. and Weih, M. 2011. Investigation for a Swedish research program on the genus Populus (Skogforsk, Arbetsrapport No. 733). Uppsala, (in Swedish with English summary).

Soo, T., Tullus, A., Tullus, H. and Roosaluste, E. 2009. Floristic diversity responses in young hybrid aspen plantations to land-use history and site preparation treatments. *Forest Ecology and Management* 257: 858-867.

The Standard of Forest Inventory of Latvian SSR. 1988. Riga,175 pp. (In Russian).

Tullus, A. 2010. Tree growth and the factors affecting it in young hybrid aspen plantations. PhD thesis, Estonian University of Life Sciences, 2010.

Tullus, A., Tullus, H., Vares, A. and Kanal, A. 2007. Early growth of hybrid aspen (*Populus x wettsteinii* Hämet-Ahti) plantations on former agricultural lands in Estonia. *Forest Ecology and Management* 245: 118-129.

Tullus, A., Kanal, A., Soo, T. and Tullus, H. 2010. The impact of available water content in previous agricultural soils on tree growth and nutritional status in young hybrid aspen plantations in Estonia. *Plant and Soil* 333: 129-145.

Tullus, A., Rytter, L., Tullus, T., Weih, M. and Tullus, H. 2012. Short-rotation forestry with hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) in Northern Europe. *Scandinavian Journal of Forest Research* 27: 10-29.

Vakkari, P. 2009. EUFORGEN Technical Guidelines for genetic conservation and use of silver birch (*Betula pendula*). Bioversity International, Rome, Italy. 6 pp.

Vares, A., Uri, V., Tullus, H. and Kanal, A. 2003. Height Growth of Four Fast-Growing Deciduous Tree Species on Former Agricultural Lands in Estonia. *Baltic Forestry* 9 (1): 2-8.

Weih, M. 2004. Intensive short rotation forestry in boreal climates: present and future perspectives. *Canadian Journal of Forest Research* 34: 1369-1378.

Ying, Z., Irland, L., Zhou, X., Song, Y., Wen, Y., Liu, J., et al. 2010. Plantation development: Economic analysis of forest management in Fujian Province, China. *Forest Policy and Economics* 12: 223-230.

Yu, Q., Tigerstedt, P. M. A. and Haapanen, M. 2001. Growth and phenology of hybrid aspen clones (*Populus tremula* L. × *Populus tremuloides* Michx.). *Silva Fennica* 35 (1): 15-25.

Received 03July 2012
Accepted 30 November 2012

ЭКОНОМИЧЕСКИЕ АСПЕКТЫ ВЫРАЩИВАНИЯ ГИБРИДНОЙ ОСИНЫ (*POPULUS TREMULA* L. *Ч P. TREMULOIDES* MICHX.) И БЕЛОЙ БЕРЕЗЫ (*BETULA PENDULA* ROTH.) НА ЗАБРОШЕННЫХ СЕЛЬСКОХОЗЯЙСТВЕННЫХ УГОДЬЯХ ЭСТОНИИ

А. Туллус, О. Лукасон, А. Варес, А. Падари, Р. Луттер, Т. Туллус, К. Каролес и Х. Туллус

Резюме

Проведен анализ экономических аспектов выращивания гибридной осины и березы бородавчатой, являющихся быстрорастущими видами лиственных пород и рекомендованы для создания лесонасаждений на заброшенных сельскохозяйственных угодьях в странах Северной Европы. При лесопользовании с одним оборотом рубки внутренняя норма доходности (ВНД) для насаждений осины составляла 4,4–7,3%, а для насаждений березы – 4,7–6,7%. Наибольший показатель ВНД (8,1%) прогнозируется для сценария посадки гибридной осины в идеальных условиях с двумя оборотами рубки (26 + 26 лет). Более высокие значения ВНД наблюдались в местах посадки с идеальными условиями, причем ВНД осины в большей мере зависит от условий местообитания. При включении в анализ стоимости земли показатель ВНД снижается на 1,1–1,7% по сравнению со случаями, в которых стоимость земли в анализе не учитывалась. Возраст финансовой спелости осины, соответствующий максимальному прогнозируемому показателю ВНД и при сценарии с одним оборотом рубки составлял 26 лет и 34 года соответственно в наиболее пригодных и средних по качеству условиях местопроизрастания. При этом возраст спелости не зависит от того, включалась ли в проводимый анализ стоимость земли. Возраст спелости при различных сценариях выращивания березы находился в пределах от 34 до 45 лет. Ожидаемая стоимость земли (ОСЗ) оставалась положительная при дисконтировании 1–5%. При дисконтировании 3% ОСЗ для всех сценариев является примерно сопоставимой с текущей средней ценой сельскохозяйственных угодий. Делается вывод, что выращивание обеих изученных видов может являться прибыльной инвестицией в условиях Северной Европы, и для повышения прибыльности следует использовать более короткие обороты рубки, чем это традиционно принято в данном регионе.

Ключевые слова: заброшенные сельскохозяйственные угодья, лесонасаждения, лиственные деревья, экономика лесного хозяйства, гибридная осина, внутренняя норма доходности, ожидаемая стоимость земли, лесопосадки, лесное хозяйство с коротким оборотом рубки, береза бородавчатая.