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PLANTATION FORESTS AS REGIONAL STRENGTH FOR DEVELOPMENT OF RURAL BIOECONOMY

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Abstract. The establishment of plantation forests in areas not viable for agriculture can make a significant contribution to the economy. The yield from 1 ha of plantation forest depends on the management purpose - obtaining of round wood (pulpwood, sawnlog, veneer log, tare), bioenergy and extraction of tree foliage (broadleaved and coniferous). In Latvia, based on 2019 data, plantation forests achieve 2760 ha of Scots pine, 7855 ha of Norway spruce, 7431 ha of Birch, 2123 ha of Grey alder, 1274 ha of Black alder and *Populus spp.* and 618 ha of *Salix spp.*

Estimated and projected gains are calculated both as round wood over 20 to 50 years: pine - 410-to 994 thou. m^3; spruce, - 335 to 2.906 thou. m^3, birch - 1.040 -2.452 thou. m^3. Accordingly, it is possible to obtain gross income from the whole plantation forest area in Latvia: pine-12.42-63.8 mln. EUR; spruce - 40.1 -192.3 mln. EUR; for birch - 32.2 -202.7 mln. Eur. Additionally to that, 18.6 -21.6 t ha^{-1} and 24.0 -37.0 t ha^{-1} of processed foliage can be obtained from 1 ha of pine and spruce forest plantations (40-50 years old). *Alnus incana sp*. (5-20 years), yielding 19.65-122.65 thou. Solid m^3 and *Salix spp*. (3-5 years), yielding 58.71-84.97 thou. solid m^3, are used for energy production, furthermore *Alnus spp*. wood can be used than valuable raw material for plywood production. At the same time, it is possible to capture 106-1477 thou. tonnes of CO_2 equivalent. Systematic investigations of chemical composition of above mentioned Latvian plantation trees, wood and bark, have shown that incorporation of extraction treatment in existing processing schemes will allow to manufacture high value added monomeric and oligomeric products which are of great demand for substitution of synthetic ones in different economy sectors (agriculture, including means for plant protection, food industry, polymer production, pharmacy etc.). Creation of small and medium-sized enterprises in rural region in close proximity to plantations opens the opportunity for the appearance of new working places, including organization of new nurseries, plantation services, private businesses for processing of various lignocellulosic waste into new special products / semi-products / feedstock for green industrial materials and chemicals, at the same time diminishing the logistics expenses.

Key words: plantation forest, coniferous, deciduous species, productivity, biomass diversity, biomass extraction, socio-economic impact, net income, CO_2.
JEL code: R11

Introduction

The Sustainable Development Goals, the Paris Climate Agreement, the European Forest Process, as well as EU goals and policies, set new requirements for European forests. These include helping to mitigate climate change, provide goods and services, create jobs and act as a source of fuel and raw materials. The development of an innovative, sustainable bioeconomy is a key strategy and forestry is expected to play a major role in providing the raw materials and services needed in Europe. There is new evidence that sustainable management of plantations, especially as part of the landscape-scale mosaic, has great potential in the context of new European policy priorities. Scientific evidence on how best to achieve these goals while achieving multifunctionality and maximizing synergies between ecosystem services is key to the success of future forestry programs (Freer-Smith et al. 2015; Baunhus et al., 2011; Paguette and Messier, 2010; Payn et al., 2015, Botto et al., 2016).

Plantation forests can be defined as "forest or other wooded land with native or introduced tree species created by planting or sowing" (FAO, 2006). The importance of forest plantations is reflected in the "Forestry Principles" adopted by the United Nations Conference on Environment and Development (UNCED) in Brazil in 1992 and reiterates the importance of heavily managed forest plantations. Principle 6d states: "The importance of cultivated forests as a sustainable and environmentally friendly source of renewable energy and as industrial raw materials should be recognized, enhanced and promoted. Their contribution to maintaining ecological processes, relieving pressure on primary / natural forests and ensuring regional employment and development must be recognized and improved. (Keenan et al., 2015; Freer-Smith et al., 2019).

Plantation forest functions and services are diverse. For example, the FAO distinguishes between 'productive' and 'protective' plantations (Penna, 2010). Production plantations are mainly focused on the production of industrial wood, fuel wood and other wood products (animal fodder, beekeeping, essential oil, bark, cork, latex, food), while protected plantations are designed to provide conservation, recreation, carbon sequestration, water quality control, erosion control, and degradation of degraded lands, which also includes improving landscapes and landscaping (Freer-Smith et al., 2019; Savill et al, 2009).

Plantation forestry is also shifting from large-scale monoculture to smaller-scale or medium-sized areas where local households and communities are owners or co-owners and are employed in plantation forest management (Freer-Smith et al. 2019). The forest areas planted in the former agricultural lands in Latvia are not large. A total of 48,547 ha of forest stands planted on agricultural land for 20 years (1999-2018), of which 21,231 h were declared as plantation forest. The data show that if forest stands were mostly planted at the beginning of the period (1999), only from 2015 plantation forest dominates over planted forest stands on former agriculture areas. State Forest Service data show that the most often planted tree species is spruce – 36 %, birch – 35 %, common pine – 13 % of the total planted amount (Latvian Forest Sector in facts & figures 2020, https://www.zm.gov.lv/public/ck/files/ZM/mezhi/skaitlifakti_ENG20.pdf). Meanwhile, according to the Forest Monitoring and LVMI Silava research data, in the period 1993-2013 - about 233 thousand. ha of uncultivated agricultural land is naturally afforested (Lazdins, 2011). According to Rural Support Service Republic of Latvia data, as of 1 October 2019, untreated agricultural land in Latvia still constituted 256 179.66 ha (http://www.lad.gov.lv/lv/atbalsta-veidi/noderigi /lauksaimnieciba-izmantojamas-zemes-apsekosana-1/).

Based on MEA (2005) and scientists, ecosystem services and services are grouped here in four main categories: Production functions; Regulatory functions; Recreational functions; Ecosystem services; Ecological assessment (https://www.millenniumassessment.org/en/index.html; de Groot et al., 2002).

On 20 December 2012, the National Development Plan of Latvia 2014-2020 was adopted, which requires the rational use of land (Latvian National Development Plan, 2012). The Latvian State Land Service (SLS) is developing guidelines for land use policy in Latvia. This document defines its objectives, directions and ways of achieving these objectives (http://www.varam.gov.lv /in_site/tools/download.php?file=files/text/Sab_lidzdaliba/sab_apsp//VARAM_Zemes_politikas_plan s_211116.pdf). The document states, that "measures and incentives should be developed for the afforestation, ecological and landscaping of non-farm lands, contributing to the preservation of traditional rural landscapes", as well as forestry, tourism etc. Currently, the National Development Plan of Latvia for 2021-2027 is being updated, where one of the priority measures is to raise the standard of living and quality of population by increasing employment and income" (https://www.pkc.gov.lv/en/aktualit%C4%81tes/expert-groups-have-initiated-national-development-plan-2021-2027-year-detailed).

Research on plantation forest and tree planting possibilities in unmanaged agricultural lands in Latvia is still ongoing (Daugaviete et al., 2017). Scientists are studying optimal growing conditions for different tree plantations (Pinus spp., Picea spp., Betula spp., *Populus spp., Alnus spp*., Salix spp.), methods for plantation establishment and subsequent productive management (Lazdina & Daugaviete, 2010; Daugaviete et al., 2017).

Long-term studies show that the selection of suitable soil for planting forest, short rotation plantations of relevant tree species (*Pinus spp., Picea spp., Birch spp., Populus spp., Alnus spp., Salix spp.*) significant benefits in the short term- both economically and ecologically (Lazdins, 2011; Daugaviete, et al., 2017).

Current paper reflects results of potential incomes from production function.

Research objective is to identify and evaluate the value and benefits of short-rotation plantations and plantation forests on different soil types *for Latvian rural development* and possibility to obtain high value-added products by integration of extraction as an intermediate additional unit into production of final fuel wood.

Materials and methods

Plantation productivity - yield, output (pulpwood, sawdust, veneer log, tare log, woodchip, etc.) was calculated both by plantation survey and pronation of plantation stock up to management target output (Lazdiņa & Daugaviete, 2010; Daugaviete et al., 2017).

Estimation of income from establishment, management and production of short-rotation tree plantations and plantation forests to assess potential economic benefits. Data from the Central Statistical Bureau database (www.csp.gov.lv) have been used. Carbon content in wood is assumed to be 50% on average according to good practice guidelines for the calculation of CO_2 capture and GHG emissions in land use, land use change and forestry (Liepins, 2020). The conversion of carbon (C) storage to CO2 has been made by multiplying C tonnes by 44 and dividing the result by 12 (Lazdins, 2012, Liepins, 2020).

Qualitative and quantitative liquid chromatography alongside with complex of physical-chemical and wet chemistry methods were used as tools which allowed to evaluate potential of the Latvian plantation trees (in particular, deciduous trees as black & grey alder, willow) as a source of high value added biologically active compounds (Telysheva et al. 2018, Lauberte et al. 2017, Janceva et al. 2017, Ponomarenko et al. 2014, Lauberts et al. 2018).

Research results and discussion

1. Productivity and potential economic income

Forecasting the sustainable development of plantation forests and their benefits for the Latvian economy, the survey of the first 20 years, current research results and current norms for forest taxation in the Republic of Latvia have been taken into account (Daugaviete et al., 2017).

Studies show that the growth rate of the most common tree species planted on agricultural land in young plantations corresponds to the Ia site index parameters, therefore in future forecasts Ia site index data were taken in pine, spruce, birch, black alder and grey alder stands (Daugavietis et al. 2013; Donis, 2014). Forecasts show that the management of plantations of the most common tree species in Latvia (pine, spruce, birch, grey alder, black alder) can result in a significant increase in wood yielding significant current assets for the economy (Table 1).

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Table 1

Potential wood stock from plantation forests, m^3

Tree species	Area of plantations, ha	Growing stock, m^3.ha^{-1} / thou. m^3 (m^3 * area^{-1})			
		During 20 years	During 30 years	During 40 years	During 50 years
Pine	2760	150/410	240/662	310/856	360/994
Spruce	7855	170/1335	250/1964	300/2356	370/2906
Birch	7431	140/1040	200/1486	250/1858	330/2452
Grey alder	2123	150/319	240/509	-	-
Black alder	1274	170/217	240/306	300/382	330/420

Estimated revenue is calculated by taking into account the distribution of extracted wood according to the wood and assortments (Lipins & Liepa, 2007) as well as the average (2016-2018) prices of timber (https://www.csb.gov.lv/lv/statistika/statistikas-temas/lauksaimnieciba /mezsaimnieciba/meklet-tema/2616-apalo-kokmaterialu-videjas-iepirkuma-cenas; http://latkoks.lv/?page_id=2927).

Table 2

Estimated gross revenue from plantation forests (NPV), mln. EUR

Tree species	Estimated revenue, Eur.ha^{-1} / Total revenue EUR mln. EUR			
	During 20 years*	During 30 years**	During 40 years***	During 50 years****
Pine	4500/12.42	7488/20.7	19401/53.5	23102/63.8
Spruce	5100/40.1	10143/79.7	19489/153.1	24487/192.3
Birch	4340/32.2	7650/56.8	11500/85.5	27281/202.7
Grey alder	3975/8.4	7291/15.5	-	-
Black alder	4505/5.7	7180/9.1	10466/13.3	12198/15.5

Explanation:* Pine, Norway spruce, Birch, Grey alder, Black alder- 50 % pulpwood, 50 %-fire wood; ** Pine – 65 % pulpwood , 35 %- firewood; Norway spruce- 42 % pulpwood, 42 % roundwood, 16 %- firewood; Birch – 35 % pulpwood, 35 %-roundwood, 30 %- firewood; Grey alder- 30 % pulpwood, 37 % roundwood, 33 % firewood; Black alder- 30 % pulpwood, 37 %-roundwood, 33 % - firewood; *** Pine- 85 % sawntimber, 20 % pulpwood, 5 % firewood; Norway spruce – 85% sawntimber; 20% pulpwood, 5% firewood; Birch – 72% veener log; 17 %-pulpwood; 11 % firewood; Black alder- 71 % sawn timber; 20 % pulpwood; 9 % - firewood; * Pine – 86 % sawnwood, 14 % pulpwood, 10 %- firewood; Norway spruce-90 % sawntimber, 5 % -pulpwood, 5%- firewood; Birch- 70 % veener log, 20 %-sawn timber, 10 %- firewood; Black alder – 62 % sawntimber, 30 % pulpwood, 8 % firewood***

As Table 2 shows, plantation forestry is a significant source of income and employment. Expected income for the first 20 years of management (in the form of felling stock) is for spruce plantations, followed by pine, black alder and birch plantations. In later years, 30-40-year-old plantations can be marked as the most productive spruce and birch plantations, because it is possible to obtain both high quality logs and plywood for the production of plywood. Table 2 also estimates the income for 50-year-old plantations, but it is likely that only pines will grow until the age of 50, as yield and income growth is only 8 % compared to 40-year-old pine plantations. Birch plantations show the highest revenue growth in calculations, but this is achieved with the cost of Class A plywood blocks, as the difference in price per m^3 of Class A and Class B plywood shows a 60% increase.

2. Short rotation plantations and tree plantations to provide renewable resources

The contribution that can be gained from short-rotation plantations and tree agriculture practice management (Law on Agriculture and Rural Development, in force since 16 October 2014) is essential for the provision of renewable energy. The most promising tree species: osier, willow (Salix spp.), Grey alder (*Alnus spp*.), Poplar (*Populus spp*.), Hybrid aspen (*Populus hybrids*).

The management of grey alder stands for the production of woody biomass occupies an important place in Latvia. Analysis of the growth of grey alder stands shows that grey alder is suitable for the production of woody biomass in short rotation plantations (Daugaviete et al. 2017). Studies have shown that in 5-20-year-old white alder forest stands it is possible to obtain an average of 47-286 solid m^3 ha^{-1}.

Between 1999 and 2018, 2123 ha of grey alder afforested or formerly naturally afforested agricultural land were declared as plantations. Currently, willow plantation management is expanding in Latvia as well (Lazdins, 2011; Lazdiņa&Daugaviete, 2010;https://www.zemeunvalsts.lv/karkli-resursi-plantacija-iespejas). 618 ha of willow plantations are officially registered in Latvia. When calculating the resources and income of willow and grey alder plantations, it must be concluded that it is necessary to increase the area of willow as well as to manage grey alder in forest areas as potential biomass producers (Table 3).

Table 3

Short rotation plantation resource and revenue forecasts, m^3, thou. EUR

	Willow plantation rotation 3-5 years	**Grey alder plantations (5-20 years)**
Area to be developed, ha	618	2123
Obtained biomass t ha^{-1}	28.50-41.25	14.82-92.43
Potential biomass yield, thou. t plantation $area^{-1}$	17.61-25.49	31.46-196.23
Potentially obtained thou., solid m^3 plantation $area^{-1}$	58.71-84.97	19.65-122.65
Revenue, EUR ha^{-1}	906 -1310	470 – 1174
*** Revenue, thou. EUR $area^{-1}$**	560 -810	998 -2492

***** *http://www.balticforest.lv/cenas , http://www.latvianwood.lv***

3. Production of non-wood products

One of the benefits of plantation forests is the use of non-wood products. The big impact in this field in Latvia was made by manufacture of valuable products by extraction of biologically active compounds from the foliage of coniferous trees and working out and manufacture on its basis of new valuable products (Daugavietis, 2013; Polis & Spalvis, 2013). Studies on the amount of conifer green foliage show that 100 ± 20 kg of spruce foliage and 80 ± 10 kg of pine foliage can be obtained per m^3 of wood (Daugavietis, 2013; Daugaviete & Korica, 2013; Polis&Spalvis, 2013), the processing of which into valuable ecological products (www.biolat.lv) can make a significant contribution to the economy (Table 4).

Besides the foliage, unique composition of bark biomass allows to obtain numerous value-added products (individual compounds and mixtures of synergetic activity) that allows to consider tree bark as the classic object for biorefinery. The yield of bark varies from 2-4 % up to 10-12 % and more from the total tree biomass (depending on tree species and age) that makes the bark very promising resource for technological processing.

The lack of knowledge about composition, properties of biomass to be extracted and extract-oriented efficiency of green solvents to be used according to current safety requirements as well as necessity to improve existing extraction devices efficiency underpin modern investigations all over the world. In our case, the microwave assisted extractor of original design allowed to obtain promising results for the mentioned purposes at the decreased consumption of energy, solvents and duration of process. After full extraction cycle bark residues could be used for bio-pellets production with improved calorific properties (Arshanitsa et al. 2016, Janceva et al. 2017).

Currently, on the basis of investigations of the Latvian deciduous plantation tree bark, different products for industry, agriculture and human health are developed. Among them, there are effective antioxidants, food supplements, cosmetic creams, including sun protection means, adhesives for wood particle boards, hydroxyl-rich polymer building blocks for polymers synthesis and polyurethane composite materials for thermoinsulation, fuel pellets, which all meet the requirements of EU standards (Telysheva et al. 2018, Arshanitsa et al. 2010, Andersone et al. 2018). Even more species are suitable for obtaining of specific compound groups, and individual compounds, in particularly Salix for salicin and proanthocyanidins and alder bark for diarylheptanoids and proanthocyanidins.

On the basis of oregonin-rich extract from alder, the food-supplement "Orvital" was produced as a commercial product (three cosmetic creams were produced and sold through pharmacies (registered in the Latvian food and veterinary service).

For realization of opportunities that are opened at the processing of bark in the context of biorefinery, cooperative net of SME engaged in processing is necessary. Whereas plantations could be considered as bioeconomy key points: drivers, primary feedstock suppliers, and in some case consumers (of the means necessary for plant healthening).

Studies on the amount of conifer green foliage show that 100 ± 20 kg of spruce foliage and 80 ± 10 kg of pine foliage can be obtained per m^3 of yield (Daugavietis, 2013; Daugaviete & Korica, 2013; Polis&Spalvis, 2013), the processing of which into valuable ecological products (www.biolat.lv) can make a significant contribution to the economy (Table 4).

Table 4

Estimated revenue from coniferous green foliage use in plantation forests

	Tree species	
	Pine	**Spruce**
Area to be developed, ha	2760	7855
Harvested stocks (40-50-year.) m^3 ha^{-1}	310-360	300-370
Green biomass obtained from 1 m^3 timber, kg	50-60	80-100
Green biomass obtained from 1 ha, t	18.6 – 21.6	24.0-37.0
Revenue from 1 t of processed lingon products, EUR	2000	910
Estimated income from 1 ha plantation, thou. EUR ha^{-1}	37.2 -43.2	21.8-33.7
Estimated income from plantation area, mln. EUR	102.7 -119.2	171.2- 264.7

4. Greenhouse effect mitigation options

During the climate change period, the amount of carbon dioxide captured by plantation forests is an important contribution, thus reducing the greenhouse effect in the atmosphere (https://lzj.lv/en/sildumnicas-effekts; Lazdins, 2012; Liepins, 2020). In sustainably managed forests, carbon accumulation never stops, as new trees replace felled trees. In the felled tree, carbon is still attached - as a "storage" of carbon. Young stands attract CO_2 very strongly and use it for growth (Lazdins, 2012; Jansons, 2017; Daugaviete et al., 2008; Liepins, 2020).

In the forests managed by LVM (Latvian State Forests), every year the forests attracts 4.1 million. tons of carbon or 15 mln. tons of CO_2 eq., but the total storage in living biomass or in all forests managed by LSF (Latvian State Forests) is 123 mln. tons of carbon or 450 mln. tons of CO_2 eq. (The conversion factor for emissions from carbon to carbon dioxide is 3.67) (Lazdins, 2012)

LSFRI Silava scientist J. Liepins (2020) has carried out extensive literature analysis, evaluating the results of 31 scientific studies from around the world on changes in carbon content between different regions, conifers and deciduous groups and concluded that regardless of climatic region the carbon content of conifers (50.8 ± 0.7) %) is significantly higher in wood than in deciduous trees (47.7 ± 0.3 %). When evaluating the data, it is recommended that, since there is still no conclusive data on the wood carbon content to be used in the hemiboreal forest zone, mean values for coniferous and deciduous trees are most stable, 50.8 ± 0.6 % and 48.8 ± 0.6 %, respectively, Thomas & A.R. Martin (2012) recommends moderate and boreal band.

Table 5

Estimated amount of carbon sequestered in plantation forests, thou, t CO_2 equivalent

Tree species	Area of plantations, ha	CO_2 t/ha^{-1}, t * area^{-1}			
		During 20 years	During 30 years	During 40 years	During 50 years
Pine	2760	76/210	122/337	157/435	183/505
Spruce	7855	86/675	127/998	152/1193	188/1477
Birch	7431	68/505	98/728	122/906	161/1196
Grey alder	2123	73/155	117/248	-	-
Black alder	1274	83/106	117/149	146/186	161/205

According to the data of Table 5, the relatively small amount of plantation forests in Latvia is capable of attracting a relatively large amount of CO_2 and varies from 106 thou. CO_2 equivalent up to 1.48 mln. CO_2 equivalent.

Conclusions, proposals, recommendations

1) The establishment of plantation forests in areas, which are not viable for agriculture can make a significant economic contribution to the economy. The yield from 1 ha of plantation forest depends on the management purpose - extraction of roundwood (pulpwood, sawlog, veneer log, tare) or biomass (energy wood).
2) The yield of pine plantations during the forest management period of 20-50 years at the forecasted volume (150-360 m^3 ha^{-1}) amounts to 4.5 (20 years) to 23.1 (50 years) thou. EUR ha^{-1} or at the existing plantation area (2760 ha) - 12.42 -63.8 mln. EUR.
3) The yield from spruce plantations in the forest management period 20-50 years at the forecasted volume (170-370 m^{3}ha^{-1}) amounts to 5.1 (20 years) to 24.5 (50 years) thou. EURha^{-1} or at the existing plantation area (7855 ha) - 40.1 -192.3 mln. EUR.
4) The yield from birch plantations during the forest management period 20-50 years at the forecasted volume (140-340 m^3 ha^{-1}) amounts to 4.3 (20 years) to 27.3 (50 years) thou. EUR ha^{-1} or at the existing plantation area (7431 ha) - 32.2 -202.7 mln. EUR.
5) Benefit from Grey alder short-rotation plantations for energy wood production with 5-20 year circulation is 14.82-92.43 t ha^{-1}, potential yield biomass at existing plantation area (2123 ha) is 19.65-122.65 thou. solidm^3 or 998 -2,492 thou. EUR, respectively.
6) The yield from short-rotation plantations of willow (Salix spp.) for energy wood production with 3-5 year circulation is 28.5-41.25 t ha^{-1}, the potential biomass at existing plantation area (618 ha) is 58.71-84.97 thou. m^3 or in cash 560 - 810 thou. EUR, respectively.
7) Results of hardwood bark obtained from fast growing trees showed good prospects for integration of extraction cluster into existing streams of fast growing hardwood tree biomass biorefinery.

8) From 1 ha of pine and spruce plantation forest (40-50 years old) it is possible to obtain 18.6-21.6 t ha^{-1} and 24.0 -37.0 t ha^{-1} of green foliage respectively; from 1 t foliage processing it is possible to obtain production for 2000 $EURt^{-1}$ and 910 EUR t^{-1}, gross income reaches 37.2 -43.2 thou. EUR ha^{-1} and 21.8 -33.7 thou. EUR ha^{-1}, gross income 102.7 to 119.2 mln. EUR and 171.2-264.7 mln. EUR. of the whole plantation area, respectively.
9) The projected amount of carbon leakage in existing plantation forests is calculated from 106 thou. t CO_2 equivalent up to 1.477 thou. t CO_2 equivalent with a 20-50 year plantation cycle.

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