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WOOD BIOMASS PRODUCTION WITH FAST GROWING TREES ON ARABLE LAND IN SLOVENIA: CURRENT STATE, PAST EXPERIENCE, AND FUTURE PROSPECTS

STANJE, IZKUŠNJE IN MOŽNOSTI PRIDOBIVANJA LESNE BIOMASE S HITRORASTOČIMI DREVESI NA ZUNAJ GOZDNIH POVRŠINAH V SLOVENIJI

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ABSTRACT UDC 630(497.4):604.4:662.6:579

Wood biomass production with fast growing trees on arable land in Slovenia: current state, past experience and future prospects

This paper presents a historical overview of plantation activities with fast growing trees in the last 60 years, the production potential of indigenous poplars (*Populus nigra* L., *Populus alba* L.) and willows (*Salix* spp.) in Slovenia based on their share relative to other tree species in the growing stock of lowland forests, and its comparison with intensive poplar production plantations on arable land. Data was obtained from the Forestry Information System of the Slovenia Forest Service, from grey and published literature, and through interviews. New possibilities for SRC plantations for energy wood biomass production in short rotation cycles are discussed.

Key words: Populus x spp., *Salix* x spp., biomass, plantation, short-rotation forestry, Slovenia

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Stanje, izkušnje in možnosti pridobivanja lesne biomase s hitrorastočimi drevesi na zunajgozdnih površinah v Sloveniji

V prispevku obravnavamo zgodovinski pregled zasajanja nasadov na zunajgozdnih površinah v Sloveniji s hitrorastočimi drevesnimi vrstami v 60-letnem obdobju. Podali smo oceno proizvodnih potencialov avtohtonih topolov (*Populus nigra* L., *Populus alba* L.) in vrb (*Salix* spp.) v naravnih sestojih glede na njihov delež v skupni lesni zalogi nižinskih gozdov. Rezultate smo nadalje primerjali z intenzivnimi topolovimi proizvodnimi nasadi. V analizo smo zajeli podatke Gozdarskega informacijskega sistema Zavoda za gozdove Slovenije za leto 2007, bibliografske podatke ter podatke, ki smo jih pridobili z intervjuji. Prispevek obravnava tudi nove možnosti SRC-nasadov za pridobivanje lesne biomase v energetske namene s kratkimi obhodnjami.

Ključne besede: *Populus* x spp., *Salix* x spp., biomasa, nasad, gozdarstvo s kratkimi obhodnjami, Slovenija

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1. INTRODUCTION

Slovenia is a forested country (more than 60 % of the land is covered in forests) and has traditionally used wood as a source of materials and energy. Among the various land use changes in Slovenia, the most relevant is the abandonment of agricultural activities (a process that has been taking place over the last 30 years). Abandoned agricultural areas usually undergo a process of spontaneous afforestation. The land categories of forestland and cropland represent important carbon dioxide sinks in Slovenia. With regard to forestland the net CO_2 removals in the analysed period 1998 – 2007 were between 10,942 Gg CO_2 and 11,374 Gg CO_2 (Piškur, M. & N. Krajnc 2007). For these calculations, new data from two successive national forest inventories were taken into consideration (source: National Inventory Report for Slovenia 2009).

According to the National Renewable Energy Action Plan (2010 – 2020) the share of energy from renewable sources in the final overall energy consumption for 2006 in Slovenia was 16.2 percent. Slovenia must achieve at least a 25-percent share in the balance of final energy by 2020. The most important renewable source of energy in the country is wood biomass, followed by hydroenergy, while in recent years development has been most dynamic in exploiting solar energy and biogas. Among renewable energy sources (RES), energy from wood biomass represents 5 %. Biomass is used mainly (95 %) for heat production in households. According to data from the Statistical Office the number of households using wood biomass has been increasing over the last five years. The main problem is that conventional systems use outdated technologies based on relatively low efficiency.

According to our data around 1,500,000 stock meters of wood logs are produced every year in Slovenia. This production is associated mainly with forest owners and their own consumption, or it is geared to local markets. Production of wood chips for energy production has been growing in the last eight years (subsidies for investments in wood chippers had a significant influence on this development). In recent years several studies on state-of-the-art production of wood chips have been conducted. In our database we have data on approximately 62 wood chippers all around Slovenia. Their production was estimated at more than 460,000 loose m^3 of wood chips. The production of pellets and briquettes is less significant, although constant from 2006 onwards. According to the pellet and briquette producers, their annual production amounts to about 60,000 t (Source: Slovenia - Country Market Statement 2011).

Although forests were and are the main source of round wood in Slovenia, many test and production plantations with fast growing tree species, especially poplars, were established between the years 1960 and 1980 in different site conditions arable land. Planting material derived from local basic source trees of black and balsam poplars selected in Slovenia and from tested poplar clones of imported origin. Expert supervision was provided by the Slovenian Forestry Institute, where the register of the basic material for vegetative propagation and production of planting material was also kept.

The first plantation with the function of landfill leachate phytoremediation and evapotranspiration with poplar clones was established in spring 1993 on 2.5 ha of the municipal landfill site in Ljubljana (Macarol 1993; G. Božič 1995; Griessler Bulc et.al. 1996) using the Ecolotree methodology (Licht 1993). The first energy plantations of willow were established in spring 2009 on 8 ha of land on two post-mining areas in Šoštanj (Krajnc & Piškur 2009) and Trbovlje (Malovrh 2009; Nagode 2009).

2. MATERIAL AND METHODS

The goal of the study was to determine broader prospects and possibilities for biomass production with fast growing trees in Slovenia according to the land potential, building on past experience and new trends. As a basis for an estimation of the present situation of poplar and willow stands in Slovenia, the data set of the Slovenia Forest Service was used. Besides the official data set, some other available sources were used. At the beginning, we made a review of available literature and we conducted some interviews. For some specific data, requests were sent to regional units of the Slovenia Forest Service. The main barrier to gathering data about the present state-of-the-art of poplar plantations was the lack of data sets and written literature. Information was obtained mainly from older foresters that were involved in the establishment of plantations before 1990.

An investigation of possibilities for biomass production with fast growing tree species in Slovenia was done by evaluating the production potential of autochthonous genetic resources of lowland and floodplain forest and

intensive poplar plantations established on non–forested land. Data was collected from the Forestry Information System of Slovenia Forest Service (Source: Slovenia Forest Service 2007), published data, literature and personal communications. All the data gathered were analysed and used for the preparation of the historical overview.

3. RESULTS AND DISCUSSION

3.1 Wood biomass yield of poplars and willows on currently forested land in Slovenia

Of the total area of Slovenia (2.025.469 ha), 1,185,169 ha were covered by forest in the year 2010 (Source: Slovenia Forest Service 2011). Forests are distributed in such a way that they predominate on as much as three quarters of the Slovenian territory. The majority of forests are dominated by beech, fir-beech and beech-oak with high timber production. Site conditions are favourable mainly for the development of high forest (Perko 2007). Slovenia is a mountainous country and more than a third of its territory lies above an elevation of 600 m.

Primarily indigenous poplars and willows in Slovenia are preserved in small locations along the main rivers and their tributaries on alluvial sites (G. Božič et.al. 1999). Forest areas covered with natural poplars have been declining since the 1960s, when soil reclamation started along with intensive establishment of test and production plantations of poplar clones and hybrids. Willow clones were used for testing purposes and were not planted in production plantations.

The analyses of the Forestry Information System of the Slovenia Forest Service (data for 2007) revealed that stands including poplars (*Populus nigra* L., *Populus alba* L.) and willows (*Salix* spp.) cover 22,549 hectares, which

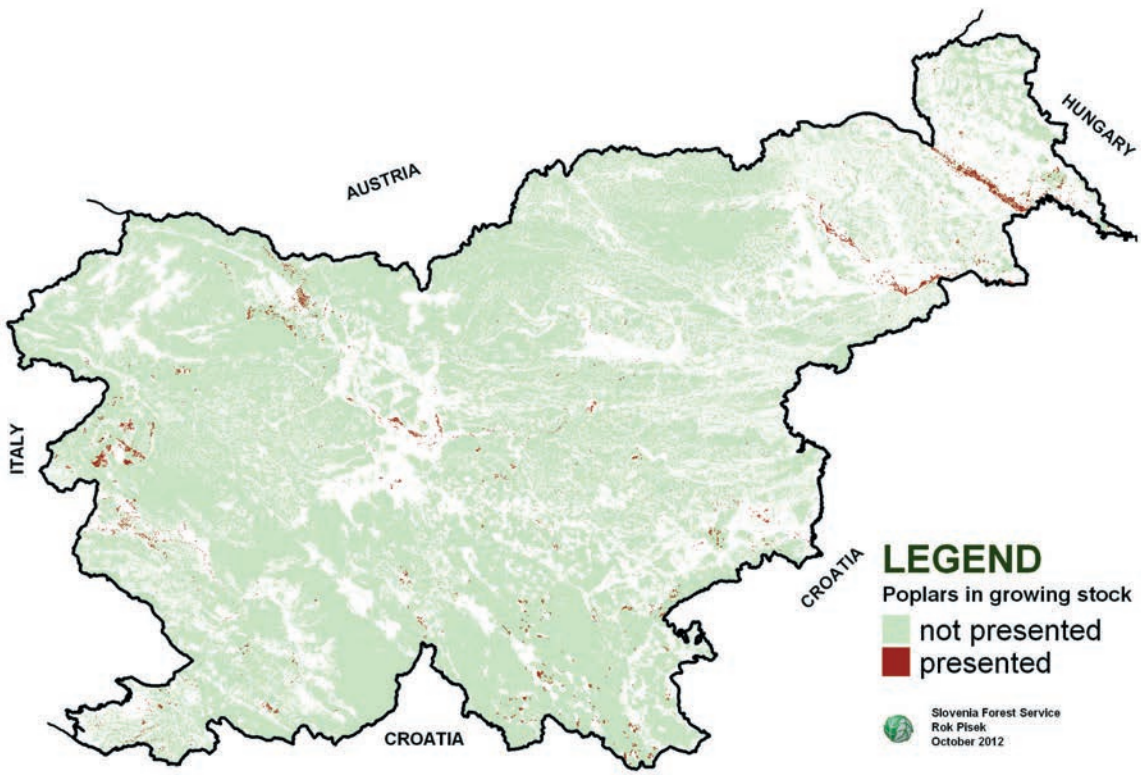

Figure 1: The current distribution of Populus nigra L. and Populus alba L. in Slovenia (PISEK 2012).
Slika 1: Razširjenost Populus nigra L. in Populus alba L. v Sloveniji (PISEK 2012).

represents 1.9 % of the total Slovenian forested area. Species of interest were found mainly in the following vegetation communities: *Salici–Populetum, Salicetum gr., Carici elatae–Alnetum glutinosae, Carici elongatae--Alnetum glutinosae, Carici brizoidi-Alnetum glutinosae, Alnetum glutinoso-incanae, Alnetum incanae, Carici remotae–Fraxinetum, Querco robori-Carpinetum* and *Querco robori-Ulmetum*. As poplars are concentrated in similar sites as willows along the main Slovenian rivers and their tributaries and are also sporadically present in lowlands of Slovenia, we can consider roughly this area (Figure 1) as the main natural distribution area of poplars and willows in Slovenia.

According to the survey of the Forestry Information System of the Slovenia Forest Service (data for 2007) it can be concluded that in the category of indigenous forest, the share of *Populus nigra*, *Populus alba* and *Salix* spp. relative to other tree species in the stand growing stock is 1.9 %, indicating that primarily poplars and willows are present in stands mainly as individual trees (solitaires) or in small groups. Stands where only willows are included in the growing stock cover 8,729 ha or 39 % of the natural distribution area of poplars and willows in Slovenia, and the share in the growing stock relative to other tree species is 5.9 %. Stands where both poplars and willow species are included in the growing stock cover 7,172 ha or 32 % of their natural distribution area, with a share of willow and poplar species in the growing stock of 16.7 %. Stands where only poplars are included in the growing stock cover 6,648 ha or 29 % of the natural distribution area of poplars and willows in Slovenia. The share of poplars in the growing stock versus other tree species is on average 1.5 %.

Poplar stands are managed mainly for production purposes (94 %); 74 % of willow stands are managed for production and 26 % for protection purposes, while in stands where poplars and willows are both included in the growing stock, the protective role is even more important than production (53 % vs. 47 %). As regards native poplars (*P. nigra* and *P. alba*) the average mean increment in indigenous forests is 0.6 m^3/ha/year and it is higher than for *Salix* species (Table 1).

Table 1: Characteristics of poplar and willow tree species in Slovenia presented by forest categories
Preglednica 1: Značilnosti topolov in vrb v Sloveniji s prikazom po gozdnih kategorijah

Poplars and Willows Forest categories (topoli in vrbe s prikazom po gozdnih kategorijah)		Year 2007 (Leto)						
				Purpose (Namen)				
		Area (ha) (površina)	% of presence versus other spp.(*) (% delež vrste glede na druge spp.(*))	Production (%) (pridobivanje)	Protection (%) (varstvo)	Average MAI m^3/ha/yr (povprečni letni prirastek)	Average Rotation Length (years) (povprečna dolžina obhodnje)	Annual Removals m^3 (letni posek)
Indigenous stands (naravni sestoji)	Poplars (topoli)	6648	1.5	94	6	0.6	-	6617
	Willows (vrbe)	8729	5.9	74	26	0.4	-	2378
	Mix P & W (zmes T & V)	7172	16.7	47	53			
	Total (skupaj)	22549	1.9					
Planted stands (nasadi)	Poplars (topoli)	542	100	100	0	14-18	20-25	5000
	Willows (vrbe)	0	0					
	Mix P & W (zmes T & V)	0	0					
	Total (skupaj)	542	100	100	0			
Overall total (skupaj)		23091						13995

Note: (*) Presence of poplars, willows or mix poplar & willows (Mix P & W) relative to other tree species in stand growing stock (Source: Forestry Information System of the Slovenia Forest Service 2007).
Opomba: (*) Zastopanost topolov, vrb ali zmesi topolov in vrb (T & V) glede na druge drevesne vrste v lesni zalogi sestoja. (vir: Gozdarski informacijski sistem Zavoda za gozdove Slovenije 2007).

In the category of planted forest characterised by fast growing poplar and willow tree species in Slovenia, only poplar plantations are included. The majority of trials and production plantations which were established in the years of intensive poplar production (1960 - 1980) were cut or are not in operational use any more. According to Bitenc (1998) and to data collected through personal communications, in Slovenia there still exist 452 ha of poplar production plantations for use in longer production periods (more than 20 years). All plantations are located on non-forest land and they are not included in the forest data base. The production of plantations established with selected poplar clones is highly productive in comparison with natural stands poplars and wil-

lows. In poplar plantations, the mean annual increment is evaluated at around 14- 18 m^3/ha/year. Annual removals (5000 m^3) in the planted forest category with poplars represent more than half (55.6 %) of all wood removals obtained annually from indigenous poplar and willow populations in Slovenia (Table 1). Production plantations can also have important potential for biomass production in Slovenia but more reliable data are needed for more detailed wood biomass potential estimation. Since Slovenia is a mountainous country, the possibilities for poplar plantations (5 m x 5 m, 400 plants/ha) are limited. In 1959 the area of such potential sites was estimated at 13,324 ha (Miklavžič & Žumer 1959). The most important potential areas are located along riverbanks and floodplain areas at an elevation up to 300 m, where we have to take into consideration the conservation of natural genetic resources of autochthonous tree species.

Until 2007 there were no plantations which were established for biomass production in short rotation coppice (SRC). In spring 2009, the first two commercial short rotation plantations with two selected willow clones were established on 8 ha of land on two post-mining areas in Šoštanj and Trbovlje. The primary aim of these plantations is the production of biomass power plants and recultivation of land directly or indirectly affected by mining activities. Potential areas for short rotation plantations (*Populus* spp., *Salix* spp., *Alnus* spp., *Fraxinus* spp., *Robinia pseudoaccacia* L.) on arable land are beside riverbanks and flooded areas, also agricultural land with low productivity and areas affected by heavy industry.

3.2 Historical overview of test and production plantations on arable land

Although the country's potential for the establishment of fast growing plantations is relatively small, long-term experience exists. The main aim of plantation establishment was the production of raw material mainly for pulp production. In consideration of natural conditions and economic goals, poplar was selected as the most suitable tree species for long and medium term non-forest plantations. Plantations were established on alluvial sites along main rivers in Slovenia (Drava, Krka, Mura, Sava, Savinja, Soča), where primarily autochthonous poplars and willow grew. Plantations were also introduced on temporary flooded agriculture land.

Table 2: Overview of plantations established outside of forest in Slovenian forestry districts from 1950 to 1998 (Bitenc 1998) and in the year 2010 (Horvat, Bratkovič, Köveš, Kovačič, Kozorog, Maljković, Marković, Petrič, personal communications)

Preglednica 2: Pregled zunajgozdnih nasadov s prikazom po gozdno gospodarskih območjih Slovenije od leta 1950 do 1998 (Bitenc 1998) in v letu 2010 (Horvat, Bratkovič, Köveš, Kovačič, Kozorog, Maljković, Marković, Petrič, osebna komunikacija)

Forest district (gozdno gospodarsko območje)	Area (ha) (površina)			
	Years (leta) 1950-1955	Years (leta) 1980-1984	Year (leto) 1998	Year (leto) 2010
Tolmin	48	148	30	5
Bled	-	10	-	-
Kranj	17	7	-	-
Ljubljana	130	162	135	64
Postojna	-	6	1	-
Novo mesto	52	-	-	-
Brežice	-	540	240	180
Celje	-	1	1	-
Slovenj Gradec	-	10	-	-
Maribor	632	686	6	3
Murska Sobota	50	329	220	200
Sežana	35	46	-	-
Total (skupaj)	964	1944	633	452

At the end of 1955, about 800 ha of sites which were occasionally flooded and 164 ha of other sites located in lowlands, along roads and in hilly areas were planted with poplars (Miklavžič 1957; Miklavžič & Žumer 1959). Planted areas were distributed almost all over the country regardless of the soil conditions. Planting material derived mainly from basic source trees selected in Slovenia. Clones of *P. alba*, *P. nigra*, *P. nigra* var. italica and *P.* × *canadensis* ('Green Robusta', 'Marilandica') were used. As no attention was paid to the choice of clones for a given habitat in consideration of their physiological requirements, many poplars were planted in unfavourable site conditions. The productivity of clones was low and plantations were mostly unsuccessful.

The fast development of the pulp and wood processing industry in the late 1960s and 1970s steadily increased the interest in the additional supply of wood from non-forest plantations. Prior to the establishment

of intensive poplar plantations, comprehensive studies were done. The main aim of these studies was to determine the compatibility of potential poplar plantation sites and of poplar clone sources of indigenous and foreign origin. The research programme of the Slovenian Forestry Institute with biological and production silvicultural studies of poplars was a permanent part of the research work up until 1995 (J. Božič 1967a, 1967b, 1973, 1979, 1983, 1990; J. Božič, Pavšar & Smolej 1974; Eleršek & J. Božič 1981; G. Božič 1993; G. Božič & Batič 1995). In the beginning, the technological aspect of establishment and tending measures in poplar plantations of different planting forms and intensity categories dominated the research. Later, studies on different poplar clones prevailed. In recent decades the phytoremediation potential of fast growing poplar and willow clones in different treatment of landfill wastewater conditions has also been investigated (G. Božič 1995; Zupančič Justin et al. 2010; Zupančič Justin, Jurše & Vrhovšek 2011; Jurše et.al. 2012), and short rotation coppice plantations on arable land have been promoted (Krajnc et.al. 2009; Medved et.al. 2011).

The first planting material for the establishment of poplar plantations derived from basic source trees of black and balsam poplars, selected in Slovenia. In forest nurseries, planting material derived from tested poplar clones of indigenous and imported origin. These were especially clones from Italy ('I-154', 'I-214', 'I-264', 'I-455', 'I-476', 'I-488', 'I-45/51') and other European countries: Austria, Belgium, Germany, France, the Netherlands, Serbia, and Switzerland. Approximately 150 clones were tested, from which about 1/3 were successfully accepted in production plantations. Expert oversight was provided by the Slovenian Forestry Institute, where a register of the basic material for vegetative propagation and production of planting material was also kept.

Along with poplar commercial plantations, clonal testing field plantations have been established with selected poplar trees from the sections *Aigeiros*, *Tacamahaca* and their hybrids, as well as with hybrids from the section *Leuce*. In total 14 test clonal plantations were established in the years 1965 to 1980, covering an area of 9.7 ha. In ten plantations (sections *Aigeiros* and *Tacamahaca*) 51 clones were planted: *P.* × *canadensis* (6), *P. deltoides* (41), and *P. trichocarpa* (4) clones. In plantations of the section *Leuce* 31 hybrid families were planted: *P. tremula* × *P. tremula* (9), *P. tremula* × *P. tremuloides* (7), *P. tremula* × *P. grandidentata* (3), *P. tremula* × *P. alba* (4), *P. alba* × *P. tremula* (1), *P. alba* × *P. grandidentata* (3), *P. alba* × *P. tremuloides* (1) and *P. alba* (3) families. In the years 1977–1981 also 5 clonal plantations with 36 clones of *Salix alba* were established covering an area of 2 ha. Test clonal plantations were established under supervision of the Poplar Research Institute from Novi Sad, Serbia in three different ecological regions in Slovenia: Vrbina near Brežice along the river Sava, the Ljubljana Marshes and in areas near Murska Sobota along the Mura River (Herpka 1982).

According to available data, in the period from 1980 to 1984 around 1,944 ha of arable land were planted with different selected clones of poplar (Bitenc 1998). In the transition period (after 1990) the economic situation changed. The wood processing and pulp industry faced a heavy decline due mainly to the loss of the Yugoslav market. This change in the market situation also influenced the development and establishment of new plantations. According to the data we gathered, the area of poplar plantations in 1998 decreased to 633 hectares. If we take into consideration an average 20-year rotation, it is clear that many plantations were cut down in this period, but only a small portion were re-established afterwards. This trend remained the same also in the following years, so that only 452 ha of poplar plantations remained in 2010. Data in Table 2 confirm that all poplar plantations in Slovenia are concentrated in three main areas. These areas are: Litija along the Sava River and areas in the Ljubljana Marshes (central Slovenia), Vrbina near Brežice along the Sava River (SE Slovenia) and along the Mura River, where much of the Slovenian agricultural industry is concentrated (NE Slovenia).

The main barrier for the development of new SRC plantations nowadays is very limited commercial activity and, along with this, a lack of tests in the local environment for the modern highly suitable poplar and willow clones for arable land, no nursery tradition for developing new clones, little information available for possible investors, and the low level of up to date research results.

In order to prevent the loss of individual clones, a national archive of poplar clones was established (1993) in the Slovenian Forestry Institute's nursery in Zadobrova (Ljubljana). The most bio-ecologically suitable and productive poplar clones for wood production are included in the living archive and maintained by the Slovenian Forestry Institute (Table 3). The genetic archive also serves as the source for collection of vegetative reproductive material for scientific purposes.

The area of poplar production plantations will be significantly reduced also in the future because the Forest Action Strategy is changing to more natural management of forest plantations (Source: Resolution on National Forest Programme 2007). New poplar plantations with a longer production period (20- 25 years) will be restricted to the most suitable sites and will be used mainly for the wood processing industry (production of wood pallets, wooden boxes and packaging) and for pulp production.

Table 3: Poplar clones maintained in the National Living Archive in Zadobrova (Ljubljana)
Preglednica 3: Topolovi kloni v nacionalnem živem arhivu Zadobrova (Ljubljana)

No (št.)	Clone label (Oznaka klona)	Species name (ime vrste)	Country of origin (država izvora)
1	S 1-3	*P. deltoides* Bart.	Serbia
2	S 1-5	*P. deltoides* Bart.	Serbia
3	S 6-1	*P. deltoides* Bart.	Serbia
4	S 6-7	*P. deltoides* Bart.	Serbia
5	S 6-20	*P. deltoides* Bart.	Serbia
6	S 6-36	*P. deltoides* Bart.	Serbia
7	S 11-8	*P. deltoides* Bart.	Serbia
8	709	*P. deltoides* Bart.	Serbia
9	457	*P. deltoides* Bart.	Germany
10	I-69 / 55 (sin. Lux)	*P. deltoides* Bart.	Italy
11	PN-6	*Populus nigra* L.	Slovenia
12	cl. 45 / 51	*P.* × *canadensis* Moench	Italy
13	cl. I – 214	*P.* × *canadensis* Moench	Italy
14	BL Constanzo	*P.* × *canadensis* Moench	Italy
15	Gattoni	*P.* × *canadensis* Moench	Italy
16	Triplo	*P.* × *canadensis* Moench	Italy
17	Eco 28	*P.* × *canadensis* Moench	Italy
18	Marilandica	*P.* × *canadensis* Moench	Slovenia
19	Regenerata	*P.* × *canadensis* Moench	Slovenia
20	Green Robusta	*P.* × *canadensis* Moench	Slovenia
21	Panonnia (syn. M1)	*P.* × *canadensis* Moench	Hungary
22	Dorskamp	*P.* × *canadensis* Moench	Netherlands
23	Robusta	*P.* × *canadensis* Moench	France
24	Blanc du Poitou	*P.* × *canadensis* Moench	France
25	Heidemij	*P.* × *canadensis* Moench	Netherlands
26	Fritzi Pauley	*P.* × *canadensis* Moench	USA, France
27	Serotina	*P.* × *canadensis* Moench	France
28	Rochester	*P.* × *canadensis* Moench	USA
29	I - 044/67	*P. trichocarpa* Torr. et Gray	Italy
30	cl. 45/54 (syn. Muhle Larsen)	*P. trichocarpa* Torr. et Gray	Germany
31	Androscoggin	*P. maximowiczii* Henry × *P. trichocarpa* Torr. et Gray	Germany
32	Koreana	*P. koreana* × *P. trichocarpa* Torr. et Gray	Germany
33	cl. Max 1	*P. nigra* L. × *P. maximowiczii* Henry	Germany
34	cl. Max 2	*P. nigra* L. × *P. maximowiczii* Henry	Germany
35	cl. Max 3	*P. nigra* L. × *P. maximowiczii* Henry	Germany
36	cl. Max 4	*P. nigra* L. × *P. maximowiczii* Henry	Germany
37	cl. Max 5	*P. nigra* L. × *P. maximowiczii* Henry	Germany
38	Matrix	*P. maximowiczii* Henry × *P. trichocarpa* Torr. et Gray	Germany
39	Oxford	*P. maximowiczii Henry* × *P. berolinensis* Dippel	no information

3.3 Possibilities of SRC plantations in Slovenia

Wood biomass is the most important renewable source of energy in Slovenia. According to decisions and plans formulated in the framework of Slovenia's energy policy, the use of wood for energy production is expected to increase over the next 10 years. Forests are the primary source of wood for energy production, but the amount of available wood is limited. Other important sources of energy wood are wood wastes and wood residues from wood industry, but in general these sources are already allocated to energy production or wood particle board production. The only additional sources of wood biomass that we can consider for SRC are plantations on arable land. Despite the financial aid introduced by the Rural Development Programme and other EU initiatives, the market for solid biomass produced on arable lands from short rotation energy crops is not developing well in Slovenia. SRC harvested on a 3-4 year cycle is the most common across Europe and was introduced in new SRC willow plantations established in 2009 in Slovenia; however, a growing interest in coppice with a lower planting density and rotation cycles up to 5-6 years can be observed. In the coming years an extensive plantation programme using new poplar hybrids suitable for ex-arable land is expected to be launched by private initiative. The main potential locations suitable for short rotation poplar coppice are at Vrbina near Brežice in the south-eastern part of Slovenia and along the Mura River in the north-eastern part of Slovenia, where pop-

lar production is popular, farmers are already familiar with the species, and nurseries still maintain poplar planting material (G. Božič & Marković 2011).

One of the main barriers hindering the development of this market is, from a supply chain point of view, the low availability to farmers of clear and transparent information on which to choose among the various possible investments - the ones that turn out to be more suitable depending on the different cultivation opportunities and final energy use. New and up-to-date research results are needed to support the further development of SRC plantations in Slovenia. The most important questions at this point are: setting up priority areas and plantation programmes based on the most appropriate tree species for the local environment, estimation of costs along the production chain, description of possible production chains, the payback period for investments, annual average gain per hectare, and setting up a policy to promote or suppress SRC establishment (depending on area and present land use). Important issues that should be addressed in the future are competition with food production on agricultural land and assessments of all (positive and negative) socio-economic and environmental aspects of SRC plantations on arable land.

New SRC plantations established in spring 2009 represent the first steps along this new path of solid biomass production on arable land. Around 8 ha of land were planted with two different varieties of *Salix* spp.: Inger / (*S. triandra* × *S. viminalis*) and Tordis / (*S. schwerinii* × *S. viminalis*) × *S. viminalis*. Planting was performed in April 2009 with plant spacing 3 m x 0.40 m (double rows). The planting phase was done by accurate soil preparation. During the first year, weeding and harrowing (30 cm) were performed in order to control weeds. We prepared forms to monitor energy consumption (use of fossil fuels for machinery) and time spent for the first year of operation. Data will be analysed and published when the first cycle is finished. The anticipated rotation period is 3 years, followed by cutting in the first year. The expected yield is from 9 to 12 $t_{d.m}$/ha/year. Statistical samples were applied at two plots to estimate mortality of both clones and to analyse growth in the first year (diameter and height were measured). Preliminary results shows that the annual yield on this test plantation is lower (only 1.41 $t_{d.m}$ /ha/year), while mortality reached nearly 13% (Čebul 2011). Samples of wood were also taken to analyse the heavy metal content in plants growing on post-mining areas. It is important to stress that these plantations were established as a private initiative on post-mining areas that could cover the demand for wood biomass in the close neighbourhood of the two largest thermal power plants in Slovenia (for co–firing with coal). The main drivers for the establishment of these plantations were: availability of land, the green electricity market and trading with CO_2 emissions. We think that those drivers will be very important also in the future. A new driver for landowners in the future will also be the question of additional income from arable land and regional support for the establishment and the management of fast rotation forestry crops, diversification of agricultural activity and increased demand for wood biomass within close range from district heating plants or power plants.

4. CONCLUSIONS

The demand for wood in Slovenia is developing rapidly, especially in the form of wood biomass for energy. The main sources are forests and the wood processing industry (wastes from production). Resources are limited. New potential sources are SRC plantations with fast growing trees, especially selected willow and poplar clones. High biomass production in very short rotations in different site conditions on arable land is a new challenge and will represent an important part of research activities also in future because only tested clones in the local site conditions will provide adequate protection against fungal infection and disease while also having superior growth.

Although the economic significance of forests is of major importance in Slovenia, there is no national strategy or action plan on the promotion of plantations on non-forest land. Combinations of long and short rotation plantations are one of the newer options for securing a wood biomass supply; this will have no negative effects on forests and the wood processing industry but competition for food production should be taken into account.

The existing selected material, which was reproduced in Slovenian nurseries, needs to be supplemented and replaced by new highly suitable clones selected for short rotation forestry on arable land which perform better than the present ones in terms of survival, production, wood quality and resistance to leaf and bark diseases. Besides reproduction of standard material, it is also necessary to continue with the introduction of modern poplar and willow clones and introduce into mass reproduction the selections that have yielded the best results in Slovenian field experimental tests.

In 2009, the first two test plantations with fast growing willow and poplar clones were established in Slovenia in post-mining areas to test the new possibilities to cover the demand for wood biomass in the larger thermal power stations in Slovenia (for co–firing with coal). Development of the technological production chain is a challenge also for international projects and cooperation with neighbouring countries.

The main weaknesses for the further development of SRC plantations in Slovenia is the country's topography (more than a third of its territory lies above an elevation of 600 m), the availability of technologies for planting, maintaining and cutting, and a lack of experience with new developed poplar and willow clones. In the near future we are planning to devote more effort to obtaining detailed information about potential areas and performing case studies for use of appropriate plant material in different site conditions, as well as evaluating costs, energy consumption, and energy and CO_2 balances.

5. POVZETEK

Namen naše raziskave je oceniti potencialne možnosti za pridelavo lesne biomase v nasadnih oblikah na zunajgozdnih površinah z uporabo izbranih drevesnih vrst hitrorastočih listavcev, predvsem topolov in vrb. Primerjali smo proizvodni potencial topolov in vrb v lesni zalogi naravnih sestojev s proizvodnimi nasadi. V analizo smo zajeli podatke Gozdarskega informacijskega sistema Zavoda za gozdove Slovenije za leto 2007, bibliografske podatke ter podatke, ki smo jih pridobili z intervjuji odgovornih oseb na območnih enotah Zavoda za gozdove Slovenije. Pogovarjali smo se tudi s skrbniki zunajgozdnih lesnih nasadov v Sloveniji. Prispevek obravnava donos lesne biomase topolov in vrb na gozdni površini v Sloveniji, podaja zgodovinski pregled testnih in proizvodnih nasadov na zunajgozdnih zemljiščih in nove možnosti za osnovanje SRC nasadov s kratkimi obhodnjami v Sloveniji.

Rezultati raziskave nakazujejo, da se v Sloveniji sestoji z zastopanostjo topolov (*Populus nigra* L., *Populus alba* L.) in vrb (*Salix* ssp.) v lesni zalogi razprostirajo na površini 22.549 ha, to je na 1,9 % celotne površine gozdov v Sloveniji (slika 1). Omenjene drevesne vrste se pojavljajo večinoma v vegetacijskih združbah: *Salici–Populetum, Salicetum gr., Carici elatae–Alnetum glutinosae, Carici elongatae-Alnetum glutinosae, Carici brizoidi-Alnetum glutinosae, Alnetum glutinoso-incanae, Alnetum incanae, Carici remotae–Fraxinetum, Querco robori--Carpinetum* in *Querco robori-Ulmetum*. Topoli in vrbe se pojavljajo na poplavnih območjih večjih rek in njihovih pritokov. V lesni zalogi sestojev je njihov delež v primerjavi z drugimi drevesnimi vrstami v povprečju 1,9 %, kar pomeni, da topoli in vrbe v teh sestojih rastejo predvsem kot posamezna drevesa (soliterji) ali pa v manjših skupinah. Sestoji, v katerih se v skupni lesni zalogi pojavljajo le vrbe brez topolov, zajemajo površino 8.729 ha ali 39 % območja skupne razširjenosti belih in črnih topolov ter vrb v Sloveniji. V primerjavi z drugimi vrstami dreves v skupni lesni zalogi sestojev je delež vrb v povprečju 5,9 %. Sestoji, kjer se v lesni zalogi skupaj pojavljajo črni in beli topol ter vrbe, se razprostirajo na 7.172 hektarjev ali na 32 % območja skupne naravne razširjenosti belih in črnih topolov ter vrb v Sloveniji. Delež lesne zaloge topolov in vrb v skupni lesni zalogi teh sestojev je v povprečju 16,7 %. Sestoji, v katerih se v skupni lesni zalogi pojavljajo le topoli brez vrb, zajemajo 6.648 hektarjev ali 29 % naravnega območja razširjenosti topolov in vrb v Sloveniji. V primerjavi z drugimi drevesnimi vrstami je delež topolov v lesni zalogi sestoja v povprečju 1,5 %. V sestojih, kjer so v lesni zalogi zastopani topoli, večinoma gospodarijo v proizvodne namene (94 %), v sestojih z zastopanostjo vrb pa je ta odstotek nižji (74 %), medtem ko je pri 26 % sestojev njihova vloga varovalna. V sestojih, kjer so vključeni tako topoli kot vrbe, pa je varovalna vloga pomembnejša od proizvodne (53 % v primerjavi s 47 %). Povprečni letni prirastek črnega in belega topola je 0,6 m^3/ha/leto in je višji od povprečnega letnega prirastka pri vrbah. Zunajgozdni proizvodni nasadi, zasajeni s selekcioniranimi topolovimi kloni, imajo povprečni letni prirastek od 14 do 18 m^3/ha /leto. Letni posek (5.000 m^3) v proizvodnih zunajgozdnih lesnih nasadih pokriva več kot polovico (55,6 %) skupnega letnega poseka črnega in belega topola ter vrb v naravnih sestojih (preglednica 1).

Gojenje topolov za pridelovanje topolovine je pomemben dodatni vir lesa na površinah zunaj gozda. V Sloveniji poteka v večjem obsegu že od leta 1955 dalje. Pri testiranju novo pridobljenih klonov iz skupine križancev topolov in vrb sta v preteklosti sodelovala Gozdarski inštitut Slovenije in Inštitut za topole v Novem Sadu. V letih od 1980 do 1984 je bilo s topolom zasajenih 1.944 ha zunajgozdnih zemljišč. Po letu 1990 so se gospodarske razmere spremenile in temu ustrezno se je spremenil tudi trend vlaganja v dopolnilno lesno proizvodnjo. Po številnih podatkih je bilo v letu 1998 v Sloveniji le še okoli 633 ha topolovih nasadov. Glede na sečno zrelost (okoli 20 let) so bili kasneje številni topolo-

vi nasadi posekani, žal pa je bil le manjši del le-teh tudi ponovno obnovljen. Zaradi tega se je površina topolovih nasadov iz leta v leto manjšala, v letu 2010 se je znižala na 452 ha. Iz preglednice 2 lahko ugotovimo, da so danes večje površine, zasajene z različnimi topolovimi kloni, trenutno ohranjene le še na treh lokacijah, in sicer v Vrbini ob reki Savi pri Brežicah, ob reki Muri in na Ljubljanskem barju. Površina proizvodnih topolovih nasadov se bo zmanjševala tudi v prihodnje. Tudi nasadi na zasebnih kmetijskih površinah bodo postopoma izsekani, a zaradi predvidenih visokih stroškov za obnovo najverjetneje ne bodo več obnovljeni.

Pridelovanje lesa zunaj gozda (npr. sanacija ekološko spornih zemljišč, stabilizacija talnega profila, proizvodnja lesne biomase) je v razvitem svetu pomemben, dodaten vir lesa, zlasti ob napovedani vse večji porabi, ki je gozdna proizvodnja v celoti ne bo mogla več pokrivati. Za osnovanje vitalnih nasadov pa potrebujemo kvalitetne sadike z izraženo sposobnostjo prilagoditve na specifično spremenjene razmere okolja. V Sloveniji je testirani topolov klonski material izjemno bogastvo. Da bi zmanjšali nevarnost izgube posameznih topolovih klonov, ki se odlikujejo z biološko odpornostjo in velikimi prirastki, smo v drevesnici Gozdarskega inštituta Slovenije Zadobrova (Ljubljana) že leta 1993 osnovali živi arhiv topolovih klonov na nacionalnem nivoju, ki ga stalno negujemo in dopolnjujemo (preglednica 3).

Povpraševanje po lesu v Sloveniji hitro narašča, še posebej je zanimiva lesna biomasa za pridobivanje energije v obliki toplote, hlajenja in elektrike. Lesno biomaso zastopajo predvsem les iz gozdov, lesni odpadki iz predelovalne industrije ter odpadni proizvodi iz lesa. Viri so omejeni. Med alternativnimi rešitvami, kako doseči ravnotežje med naraščajočimi potrebami in dejanskim možnostmi, je pomembna tudi proizvodnja lesne biomase s hitrorastočimi listavci v zunajgozdnih nasadih s krajšimi (3 - 6 let) in daljšimi obhodnjami (20 let). Biološki material selekcioniranih topolovih klonov, ki ga gojijo v slovenskih drevesnicah, je treba dopolniti ali nadomestiti z bolj primernimi kloni za nasadne oblike s krajšimi obhodnjami (večja sposobnost preživetja, večja odpornost proti bolezni in škodljivce, hitrejša rast). Poleg razmnoževanja standardnega materiala, testiranega v Sloveniji, je prav tako treba nadaljevati s testiranjem sodobnih klonov topolov in vrb ter jih v primeru dobrih rezultatov vključiti v množično proizvodnjo. Z zunajgozdnimi lesnimi nasadi lahko zagotavljamo dodaten vir lesne biomase za uporabo v energetske namene in s tem posredno tudi pripomoremo k ohranitvi naravnega gozda.

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