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Full Length Research Paper

Energy plantations of dendroflora species on open-pit coal mines overburden deposits

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In order to define the models of energy plantations of the short rotation on deposols of open-pit coal mines, The Serbian Ministry of Science and Technological Development supported the researches aimed at the determination of the post-exploitation areas suitable for the short rotation plantations in the Kolubara basin. Besides the research of ecological conditions of the post-exploitation areas, research of the development and productivity of biomass in the forest cultures established during the biological recultivation, the comparative experiment was set with the number of fast-growing species, in order to determine the technology of the soil preparation, feeding, density of sowing, measures of protection, effects of phytoremediation, the selection of the mechanical devices, the analysis of the economic parameters, etc. The aim of the research is the increase of the participation of energy from biomass and partial replacement of the fossil fuels, in accordance with the Kyoto Protocol, Davos Forum and other international agreements. This paper presents some results which are part of the project.

Key words: Biomass, short rotation plantations, deposols, Kolubara lignite basin.

INTRODUCTION

The industrial, general-economic, as well as civilization developments of the human community are inconceivable without the energy sources. The non-renewable fossil energy sources such as coal, oil and natural gas, which account for 2/3 of the known world reserves of the primary energy sources, are still the most important. The coal accounts for 46% of the reserves.

Since Serbia is relatively poor in the reserves of quality and high-calorie brown coals and since they are exploited by the deep mines, they do not cause major disturbances to the landscapes and nature ecosystems in these areas. However, Serbia is rich in low-calorie lignite which is mainly used for the production of the electricity in thermal plants. The increasing need for electricity and the limited hydro-energy potential as the most important, eco-friendly, renewable potential, results to the further increase of the lignite production in open-pit mines . It implies the disruption of orography, destruction of the ecosystems and further endangering of the environment by the pollutants of the current and future thermal plant (Drazic et al., 2007).

Short rotation forestry (SRF) in Europe has a long tradition and originally aimed at providing a supply of fuel, fodder and convenience wood, usually by means of coppice systems. The main genera involved are: *Populus, Salix, Eucalyptus, Robinia, Betula, Alnus, Castanea* and *Quercus*. Eucalypt is confined to the Mediterranean parts of Europe, whereas willow and birch mainly are found in the northern parts. SRF systems are employed in forestry and agriculture and have integrated functions in agroforestry, shelterbelt- and environmental applications such as vegetation filter systems. Modern SRF has developed towards an industry which needs large volumes and a continuous supply. Consequently the focus is on species with a high initial growth rate and breeding programmes are directed towards resistance or tolerance against pathogens. With the actual range of final products in mind (biomass for energy purposes, paper pulp, particle board, veneer, construction wood) a

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wide range of growing systems has been developed, ranging from densely planted willow coppice ($2x10^4$ stools ha^{-1} and harvested each 2 to 4 years) to widely spaced single stem poplars (100 stems ha^{-1} and harvested after 25 years). Major developments of European SRF during this century are envisaged in the fields of specialised high quality products and in the field of bioremediation. The increasing amounts of sewage sludge, slurry and other organic waste products from the society form an excellent resource for biomass production by means of SRF (Verwijst, 2004; Verwijst and Nordh, 2004).

The experiences from East Germany where the area of more than 1,000 km^2 was consumed by strip mining and open pits are very significant and similar as in Serbia. With the transformation process from a planned economy to market economy in East Germany most of the mines had to close down. The lignite or brown-coal mining had destroyed the landscape. By removing the over-burden the micro-organisms, vegetation, and animals, were lost. Particularly in the 1970's and 1980's, mining was carried out so intensively, that the reclamation did not keep up with the area devastated by mining. The political leaders had other priorities and so the state-run mining companies did not receive the funds for remediation and reclamation. The remediation was particularly difficult as the overburden consists of sand and gravel and hardly any topsoil. In the dumping areas a new covering soil need to be established and the interrupted nutritional chains have to be build up again to bring back plants and animals. In addition the residual pits are forming dangers to man and nature that appear from the physical properties of the pit slopes.

The funds are provided for safety-measures in the disused open-cast mines restoration of the waterbalance, and rehabilitation and land reclamation. In early spring of 1999, the program is well established as Europe's largest environmental program. Area of waste-land and dump-areas to be reclaimed (without water-areas) 65.370 ha accomplished in early 1999: reclamation of forest on 27.280 ha, reclamation of agricultural land on 11.590 ha, natural revegetation and controlled succession on 5.760 ha (total reclaimed area 44.630 ha). New ecosystems are established in order to bring the post-mining landscape on the path leading towards a sustainable development and achieve as well the desired future land use – with many new lakes with water of bathing quality and you will also see thousands of acres of young forests and new agricultural land and areas protected for wildlife (Bismarck, 2000).

The researches conducted at the disposal sites of the open-pit mines in Germany showed that growth increment ranges from 5.3 to 19.6 tonnes of the dry matter/ha in four years old plantations grown even under the unfavourable soil conditions. The biomass produced in this way is characterized by the low concentration of heavy metals, high calorie value, favourable properties of ash – high concentration of macronutrients. The use of ash for amelioration can compensate for the loss of nutrients owning to the collection of biomass.

Partial substitution of fossil fuels, especially coal as the non-renewable resource which significantly pollutes the environment, by the renewable resource – biomass has many, mainly ecological advantage (Drazic et al., 2005).

The underway researches are aimed at the determination of the potential post-exploitation areas favourable for the establishment of the plantations of the short rotation in Kolubara basin, environmental conditions of the post-exploitation areas with the selection of the locations suitable for the plantations of the short rotation, the researches on the dynamics, development and productivity of biomass in the current forest cultures of the different species of deciduous and coniferous trees established on deposols during the process of biological recultivation.

MATERIAL AND METHODS

The environmental conditions of the post-exploitation areas were determined as follows: climate and microclimate conditions, physical, chemical and microbial characteristics of deposols at disposal sites of barren soil, content of heavy metals and other pollutants in substrat. The comparative researches of the development of the present dendroflora at disposal sites of the open-pit mines in the forest cultures established during the biological recultivation of Kolubara-Tamnava coal basin were also conducted.

The aim of these researches is the determination of the productivity of planted tree species. Since these plantations were not established for the specific purpose and do not have the character of the plantations of the short rotation, the obtained results of the diameter, height and volume growth increment are only the approximate indicators. These values are significantly lower than the potential values of the studied species in the plantations of the short rotation established for the specific purpose, because of the lack of the suitable technical preparations of soil (deposols), as well as lack of the agro-ameliorative measures, watering, the supplementary feeding, etc.

To investigate the possibilities of biomass production at the disposal sites of barren soil (deposols) the comparative experiment was set with number of fast-growing plant species. Trees were planted in order to determine the optimal method and technology of the soil preparation (deposols), initial supplementary feeding by fertilizers and other growth stimulants, planting density and technology by each species, protective measures in the plantations of the short rotation from the harmful insects and phytopathogens, effects of phytoremediation, selection of the suitable mechanical devices in all the phases of work.

The experimental plot in Baroshevac was established at the waste disposal site of barren soil (deposol) within Kolubara basin between 2006 and 2007. On the experimental plot the following parameters were monitored: the degree of the survival of the planted plants, dynamics of the height and diameter growth increase, effects of the applied care measures, fertilization and effects of phytoremediation.

The aim of the research is also the increase of the participation of energy from biomass and partial replacement of the fossil fuels, in accordance with the Kyoto Protocol, the conclusions made of Davos Forum and other international agreements.

Table 1. Summary of the activities done in the aim of biological recultivation.

Type of recultivation	Exploitation fields			Total	
	"A"+"B"	"D"	"Tamnava-Istok"	ha	%
Forest recultivation - forests	301	510	60	971	74.8
Agricultural recultivation- plowed /cultivated fields	40	235	23	298	23.0
Orchards	6	11	-	17	1.3
Nurseries	-	12	-	12	0.9
Total agricultural recultivation	46	258	23	327	25.2
Total biological recultivation	347	768	83	1.298	100.0

Table 2. Survey of the areas according to the tree species.

Tree species	Total	
	ha	%
Pure Austrian and Scotch pine cultures	262.00	27.7
Pure common larch cultures	33.00	3.4
Pure Douglas fir cultures	13.00	1.3
Pure Eastern-white pine cultures	21.00	2.1
Pure oak cultures	23.00	2.3
Pure maple cultures	29.00	3.0
Pure black locust cultures	82.00	8.4
Mixed cultures of the other deciduous trees	78.00	7.9
Mixed cultures of conifer trees	109.00	11.1
Mixed deciduous cultures	93.00	9.6
Mixed conifer and deciduous cultures	228.00	23.2
Total	971.00	100.0

RESULTS

Present forest cultures in Kolubara basin

The biological recultivation was conducted on more than 1,000 ha of Kolubara basin (Drazic and Veselinovic, 2006). Recultivated areas of the exploitation fields and types of recultivation are shown in Table 1.

From the presented survey it can be seen that forest account for 74.8% of the recultivated area, cultivated and plowed fields for 23%, orchards for 1.3%, and nurseries which are classified as the agricultural recultivation for 0.9%, that is agricultural recultivation account for 25.2%.

Depending on the micro environmental conditions and types of deposols, the great number of conifer and deciduous trees were used for afforestation (Table 2).

The possibility of biomass production in the plantations of short rotation at disposal sites of barren soil (deposols) of Kolubara basin

The following trees were planted: 1008 common larch seedlings, 978 Douglas fir seedlings, 651 poplar seedlings and 1449 willow seedlings (Figures 1 and 2).

Tables 3, 4, 5 and 6 present the results of analysed soil (deposol) properties. The seedlings were watered regularly, depending on the meteorological conditions. In the spring one year after the planting the initial supplementary feeding was conducted by 30 g of NPK mineral fertilizer per a seedling, in order to provide the best possible thriving and start growth, however, in the second year the supplementary feeding was performed by the waste sludge, which is obtained in the process of coal procession. The percentage of the survival of seedlings in first two years after the planting is shown in Table 7.

Thriving of deciduous and coniferous species have differed in first two years after planting. Poplar has shown the best results with thriving of almost 100% in both years. Common larch had better thriving in first year whereas Douglas fir and especially willow have shown much better results in second year after poor start in first year after planting. Thriving of coniferous and deciduous species in the relation to the number of the planted seedlings were not significantly different (79.6: 80.6%) two years after planting.

The average values of the elements of growth (Table 8) in seedlings "*in situ*"– length of the above-ground part of the seedlings with the main sprout and diameter of root collar (presented in Figures 3 and 4, respectively) show

Figure 1. Italian poplar clone (*Populus x euramericana* I-214), the first year after the planting on the experimental plot.

Figure 2. Vital seedlings of common larch (*Larix europaea* L.), willow (*Salix* sp.), poplar *Populus* x *euramericana* I-214) and Douglas fir (*Pseudotsuga menziesii* Mirbel. Franco.).

that the broadleaf species had significantly better height increment.

Poplar (267.1 cm) had the better height increment in the comparison with willow (255.9 cm). In the group of

Table 3. Chemical properties of deposol.

Sample	Marked as	pH		Absorption complex					$CaCO_3$	Total		C/N	Available	
		H_2O	KCl	T	S	T-S	V	Y1		Humus	N		P_2O_5	K_2O
				ekv,mmol/100 g			%	cm^3	%	%	%		mg/100 g	
64/08	Willow 1	5.5	4.4	23.03	16.99	6.03	73.80	9.28	-	1.33	0.27	2.85	2.5	17.3
65/08	Willow 2	5.7	4.3	17.06	12.64	4.42	74.07	6.81	-	0.55	0.11	2.84	16.0	16.3
66/08	Willow 3	5.4	4.5	19.05	13.82	5.23	72.56	8.04	-	1.58	0.15	6.15	5.9	17.1
67/08	Common larch 1	6.1	4.9	17.44	14.22	3.22	81.55	4.95	-	1.07	0.12	5.13	< 1	14.3
68/08	Common larch 2	6.2	4.8	21.81	17.39	4.42	79.72	6.81	-	1.16	0.26	2.62	< 1	13.2
69/08	Common larch 3	6.1	4.7	19.43	15.41	4.02	79.30	6.19	-	0.94	0.12	4.62	< 1	10.8
70/08	Douglas fir 1	6.4	4.9	18.61	16.20	2.41	87.04	3.71	-	0.48	0.18	1.54	< 1	10.5
71/08	Douglas fir 2	6.2	4.6	16.64	13.82	2.82	83.08	4.33	-	0.42	0.11	2.15	< 1	7.7
72/08	Douglas fir 3	6.4	4.5	19.02	15.80	3.22	83.09	4.95	-	0.44	0.11	2.24	< 1	7.1
73/08	Poplar 1	5.7	4.2	14.74	12.35	2.39	83.79	3.68	-	0.23	0.14	0.97	< 1	5.9
74/08	Poplar 2	5.7	4.3	17.51	13.53	3.98	77.26	6.13	-	0.46	0.09	3.14	< 1	8.1
75/08	Poplar 3	6.0	4.2	22.22	17.45	4.78	78.50	7.35	-	0.70	0.12	3.31	1.0	9.9

Table 4. Physical properties of deposol.

Sample	Marked as	Coarse sand	Fine sand	Dust	Clay	Total sand	Total clay	Texture class
		%	%	%	%	%	%	
64/08	Willow 1	0.8	50.4	19.5	29.3	51.2	48.8	Sandy clay loam
65/08	Willow 2	0.5	61.7	15.0	22.8	62.2	37.8	Sandy loam
66/08	Willow 3	0.8	60.1	15.8	23.3	60.9	39.1	Sandy loam
67/08	Common larch 1	0.7	57.3	6.8	35.2	58.0	42.0	Sandy loam
68/08	Common larch 2	1.0	47.5	21.1	30.4	48.5	51.5	Sandy clay loam
69/08	Common larch 3	0.8	56.8	15.1	27.3	57.6	42.4	Sandy loam
70/08	Douglas fir 1	0.6	57.5	13.5	28.4	58.1	41.9	Sandy loam
71/08	Douglas fir 2	0.5	66.9	11.7	20.9	67.4	32.6	Sandy loam
72/08	Douglas fir 3	0.5	54.8	17.7	27	55.3	44.7	Sandy loam
73/08	Poplar 1	0.4	69.3	12.2	18.1	69.7	30.3	Sandy loam
74/08	Poplar 2	0.6	60.9	14.6	23.9	61.5	38.5	Sandy loam
75/08	Poplar 3	0.6	50	20.3	29.1	50.6	49.4	Sandy clay loam

the conifer species there were no significant differences between common larch (37.9 m) and Douglas fir (41.8 m), although Douglas fir had a little better value.

In regard of the diameter increment, the deciduous seedlings also had the better increment. Poplar has shown the best results with diameter increment of 17.5 mm in first year after planting and 24.3 mm in second year. In the group of the coniferous species, common larch had the better increment (5.2 mm in first year after planting and 8.7 mm in second year) than Douglas fir (4.8 mm in first year after planting and 7.9 mm in second year). It is important to emphasize that height and diameter increment of the deciduous species was greater as early as in the first year of the growth than the diameter increment of the coniferous species from the second year of growth.

Laboratory analysis of the seedlings

Along with the analysis of the plants „*in situ*“, some seedlings were taken from the substrat and used for the analysis of the total height and volume increase and dry mass (Table 9). The differences between the species are clearly visible in Figures 5 to 8.

As it can be seen from the survey of the Table 9 and Figures 3 to 8, the average values of the height and diameter increase are somewhat different of the seedlings "*in situ"* from seedlings which are extracted and analysed in the laboratory conditions, along with the measurement of the elements of growth and measuring of mass. This difference is the result of the size of the sample which is much greater in the first instance.

The fresh mass, particularly of the trees or leaves

Table 5. Content of the easily- soluble metals.

Sample	Marked as	B	Cd	Co	Cu	Fe	Mn	Mo	Ni	Pb	Zn
		ppm (mg/kg)									
1/08	Sludge	1.62	0.00	0.64	1.83	213.20	21.88	0.07	3.99	1.74	2.86
64/08	Willow 1	0.00	0.02	0.54	1.35	53.04	37.26	0.00	3.89	2.22	0.75
65/08	Willow 2	0.00	0.01	0.26	0.89	52.61	15.24	0.00	3.89	1.85	0.43
66/08	Willow 3	0.00	0.02	0.36	1.00	66.62	17.91	0.00	4.58	2.02	0.67
67/08	Common larch 1	0.00	0.01	0.25	1.03	27.67	19.43	0.00	2.67	1.54	0.50
68/08	Common larch 2	0.00	0.00	0.45	1.16	42.00	31.53	0.00	2.65	2.15	0.63
69/08	Common larch 3	0.00	0.02	1.25	0.95	30.69	58.83	0.00	4.15	0.52	0.64
70/08	Douglas fir 1	0.00	0.01	0.28	1.10	19.37	16.68	0.00	1.92	1.55	0.43
71/08	Douglas fir 2	0.00	0.00	0.11	0.84	12.47	8.14	0.00	1.78	0.92	0.35
72/08	Douglas fir 3	0.00	0.00	0.20	0.87	17.68	15.46	0.00	1.59	1.19	0.34
73/08	Poplar 1	0.00	0.00	0.09	0.91	9.93	9.40	0.00	2.66	0.93	0.33
74/08	Poplar 2	0.00	0.00	0.36	1.04	16.38	26.97	0.00	3.74	1.37	0.31
75/08	Poplar 3	0.00	0.01	0.33	1.04	25.04	21.50	0.00	3.40	1.77	0.37

Table 6. The number of the physiological groups of the soil microorganisms.

Sample	MPA	Erzbi's agar	Synthetic agar		Chapek's agar	
	Ammonificators	Oligonitrophils	Actinomycetes	Fungi	Actinomycetes	Fungi
Common larch 1	21	26	29	23	8	10
Common larch 2	75	33	-	28	-	25
Douglas fir 1	58	19	8	38	7	27
Douglas fir 2	57	9	-	7	-	8
Poplar 1	52	50	6	26	12	52
Poplar 2	22	13	-	19	-	6
Willow	47	8	-	26	-	27

1,000 pieces /1 g of dry soil.

Table 7. Thriving of the seedlings.

Species	Number of planted seedlings	First year (2007)		Second year (2008)		In relation to number of planted seedlings (%)
		Number of seedlings	%	Number of seedlings	%	
Larix decidua	1.009	913	90.5	780	85.4	77.3
Pseudotsuga menziesii	978	847	86.6	801	94.6	81.9
Populus sp.	651	648	99.5	641	98.9	98.5
Salix sp.	1.449	973	67.1	909	93.4	62.7

greatly differs between deciduous and coniferous species, as well as between some species. The total mass of the above-ground part with the twigs and leaves of the poplar seedlings was eight times greater than the total mass of the common larch, nine times greater than the total mass of the willow, and eighteen times greater than the total mass of the Douglas fir seedlings.

In the deciduous species the mass of the stem was 2 to 7 times greater than the mass of the leaves, whereas in the coniferous species the ratio is the opposite, that is, the leaf mass is 3 to 4 greater than the mass of the stem. This ratio is similar in the regard of the dry mass.

The mass of the root of the poplars was also the greatest – it was eleven times greater than the mass of the common larch, thirteen times greater than the mass of the willow, and even fifteen times greater root mass in

Table 8. The average values of the elements of growth in seedlings „*in situ*“.

Species	Statistical elements	Diameter (mm) 2007	Diameter(mm) 2008	Height (cm) 2007	Height (cm) 2008
Larix decidua	Sample	913	780	913	780
	Min	2.0	4.0	5.0	9.5
	Max	12.0	22.5	70.0	99.5
	Average	5.2	8.7	35.0	37.9
Pseudotsuga menziesii	Sample	847	801	847	801
	Min	1.5	3.0	3.0	8.0
	Max	14.5	22.0	64.0	106.0
	Average	4.8	7.9	31.3	41.8
Populus sp.	Sample	648	641	648	641
	Min	10.0	12.5	40.0	120.0
	Max	29.5	57.0	315.0	461.0
	Average	17.5	24.3	217.6	267.1
Salix sp.	Sample		973		973
	Min		5.0		40.0
	Max		34.0		460.0
	Average		14.1		255.9

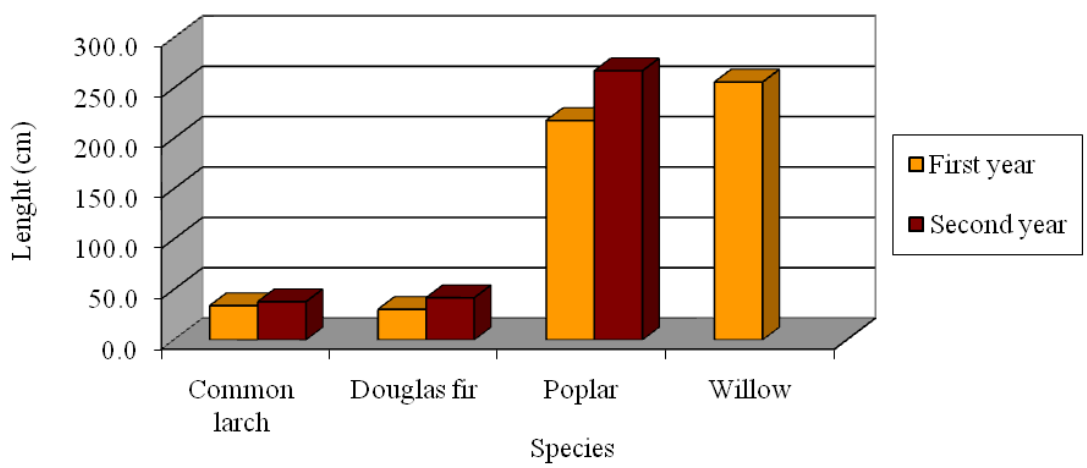

Figure 3. The length of the above -ground part of the seedlings with the main sprout (m) – "*in situ*".

the comparison with the Douglas fir.

DISCUSSION

In order to alleviate the harmful effects of the development of open-pit mines, thermal power stations and other sections in the coal processing, mining activities should be followed obligatory by the biological recultivation of the degraded disposal sites in order to re-establish the vegetation ecosystems on the deposols - deposited barren soil.

Forest ecosystems are the greatest absorbers of carbon dioxide and other pollutants released in huge quantities from the thermal power plants and the most efficient filters of the solid particles from air (Drazic et al., 2005). Because of that biological recultivation, afforestation should be favoured particularly in areas with low percentage of the forest cover and where there are no forest ecosystems between the mines or thermal power plants and great urban areas.

There are significant unused areas of disposal sites of barren soil currently in Serbia and new areas are being created every day. These degraded areas are mainly

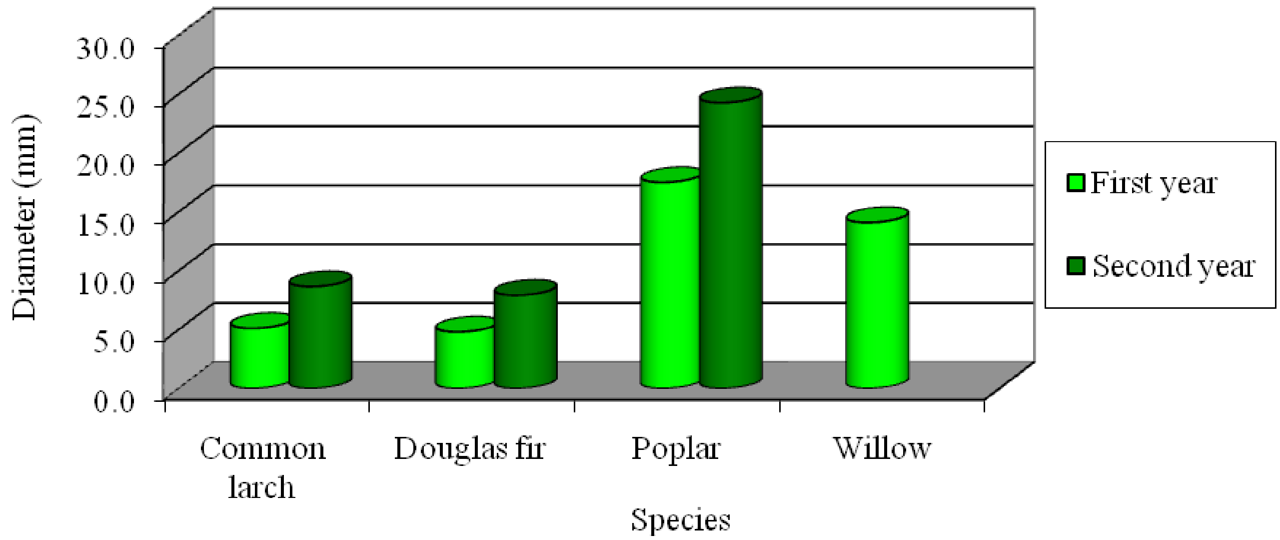

Figure 4. Diameter of the root collar of the seedlings (mm) - "*in situ*".

Table 9. The average values of the length of the above-ground part, length and diameter of the root collar, mass of the above-ground part, mass and volume of root, as well as of dry mass of the above-ground part of the extracted seedlings.

Analysed parameter		Species			
		Larix decidua	***Pseudotsuga menziesii***	***Populus* sp.**	***Salix* sp.**
Length of the above-ground part with the main sprout (cm)		60.0	55.0	351.0	276.0
Length of the above-ground part without the main sprout (cm)				326.0	
Length of the main sprout(cm)				24.0	
Length of the root (cm)		32.0	21.0	54.0	43.0
Diameter of the root collar (mm)		9.9	13.8	34.8	15.9
Mass of the above-ground part (g)	Stem	36.3	19.6	860.3	150.0
	Twigs			189.2	
	Leaves			485.3	20.7
	Leaves with twigs	144.0	62.8		
	Total	180.3	82.5	1534.8	170.7
Dry mass of the above-ground part (g)	Stem	11.8	6.5	447.7	80.7
	Twigs			86.7	
	Leaves			176.7	8.2
	Leaves with twigs	68.3	23.5	711.0	88.9
	Total	80.1	30.0		
Mass of the root (g)		46.7	35.2	523.0	41.7
Dry mass of the root (g)		13.9	9.4	246.3	22.2
Volume of the root (ml)		36.7	25.0	444.3	60.0

situated within the open-pit mines of lignite (Kolubara-Tamnava basin, Kostolac basin, etc.), open-pit mines of non-ferrous metals, exploitation of clay, stones and other raw materials. It is estimated that about 1000 km^2 will be degraded by the open-pit exploitation of mineral and other raw materials in Serbia. Among other things, in these areas the biological recultivation will be a necessity in order to re-establish natural balance by the restauration of the forests and other ecosystems.

Based on the comparative researches, which were

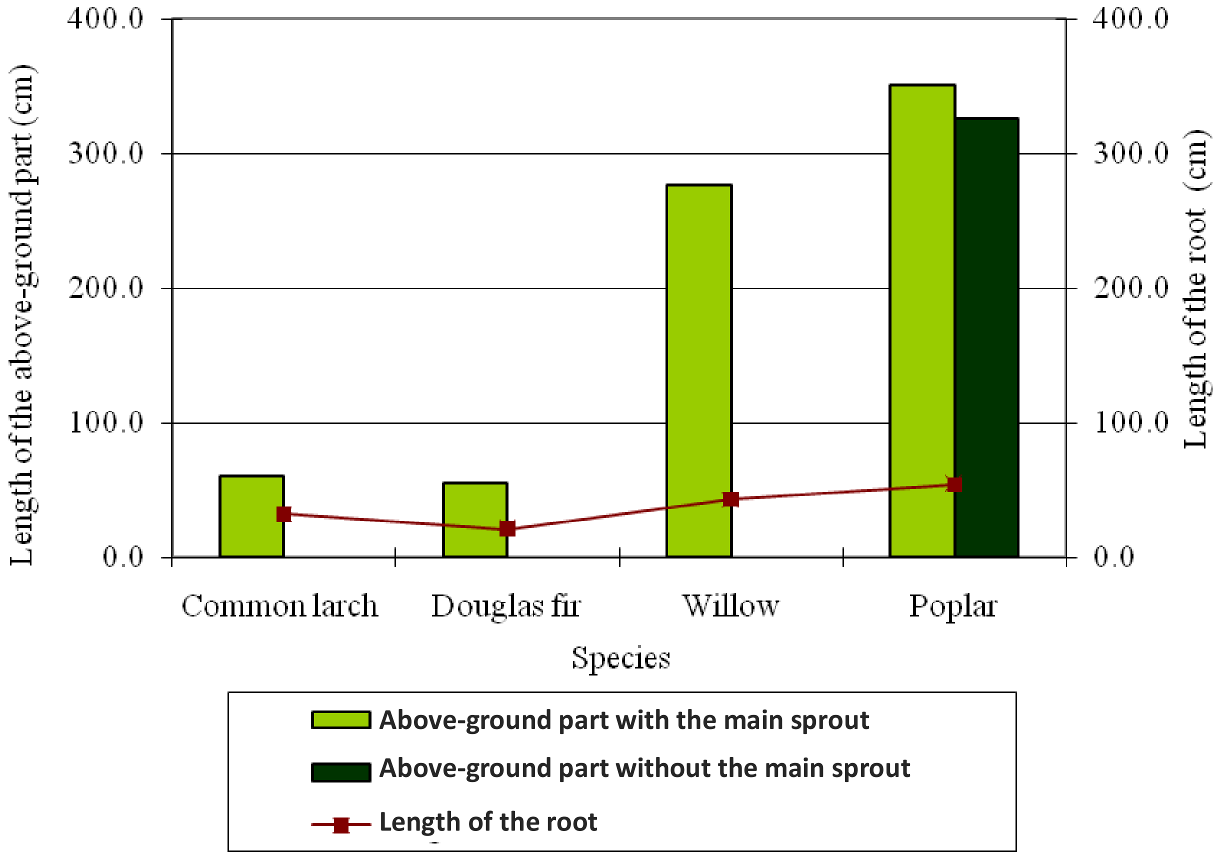

Figure 5. Length of the above-ground part with and without the main sprout and root – extracted seedlings.

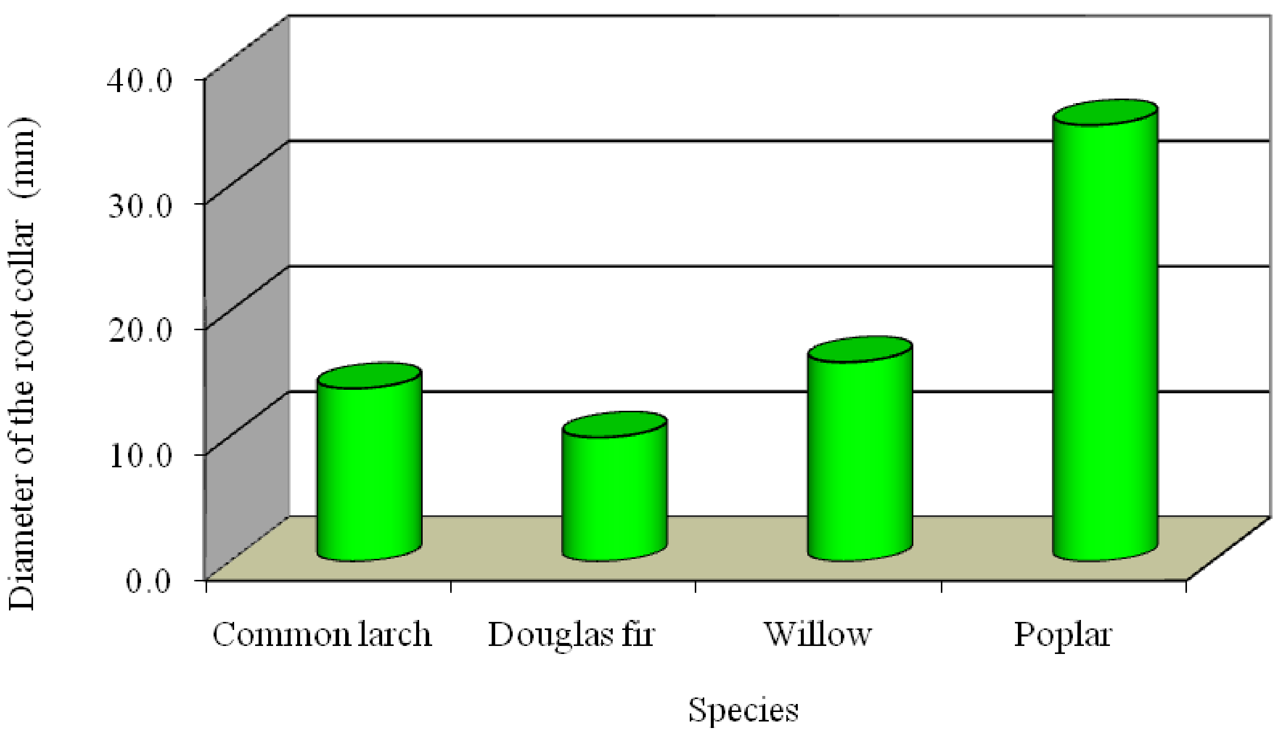

Figure 6. Diameter of the root collar – extracted seedlings.

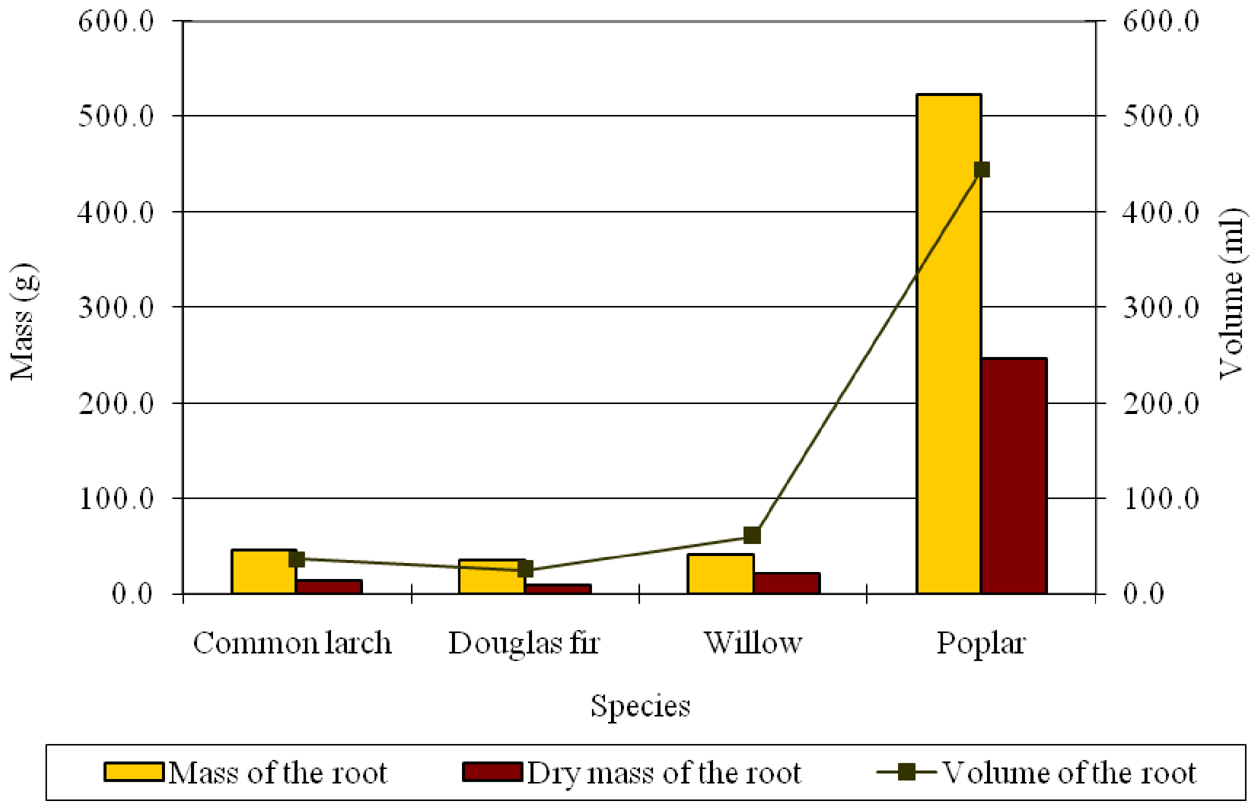

Figure 7. Mass and dry mass of the above-ground part and the root

conducted on the present dendroflora at the disposal sites of the open-pit mines in the forest cultures established during the biological recultivation of the Kolubara coal basin and areas in which the further establishment of this type of plantations is planned, by the preliminary estimations, the production of biomass can be expected as shown in Table 10.

Some recultivated areas can be used for the establishment of the energy plantations of the fast-growing species of dendroflora or perennial herbaceous plants. According to the results of the previous analysis of growth in the plantations of short rotation, it can be concluded that in regards to the height and volume increment and mass of the seedlings in the second year of growth there is a significant difference between the deciduous and coniferous species, as well as between some species within the same group. The growth of the deciduous species, particularly of poplar, was better, since the growth of the Douglas fir was the lowest. The data on height and volume increment and mass of the extracted willow seedlings, as well as on the increment of seedling willow "*in situ*" were obtained after only one year of growth. Also, one should bear in mind that these are the preliminary results, i.e. the initial phase of the research and that the real results of the increment can be obtained only in a few years, that is, at the end of the rotation for each analysed species.

In Kolubara lignite basin the successful biological recultivation was conducted in the area of about 1,300 ha. The forest cultures of the different species of the coniferous and deciduous trees account for 75% of it. These species are very vital, and show the good results of the growth and development, despite the unfavourable site conditions.

Researches have shown that the potential of expected production of air dry biomass in Kolubara basin is very significant and it is estimated to be about 200,000 tones per year, that is, over 1,200,000 tones in six year rotation period.

The aforementioned facts, as well as the experience of the other countries, primarily of Germany, pointed to the possibility of the establishment of the fast-growing plantations of the woody species at the disposal sites of the barren soil (deposols) of the open-pit coal mines.

The experimental plots with a few species of dendroflora established on the deposol of Kolubara basin, even though two to three-year old, point to the fact that the establishment of the energy plantations for the specific purpose, in which the significant quantity of the biomass will be provided, is a feasible project. Thereby, the production of dendrobiomass for the energy needs will be unified in the zone of the influence of the open-pit mines of the lignite coal, with the capacity of the coal procession and thermal power plants, which is important

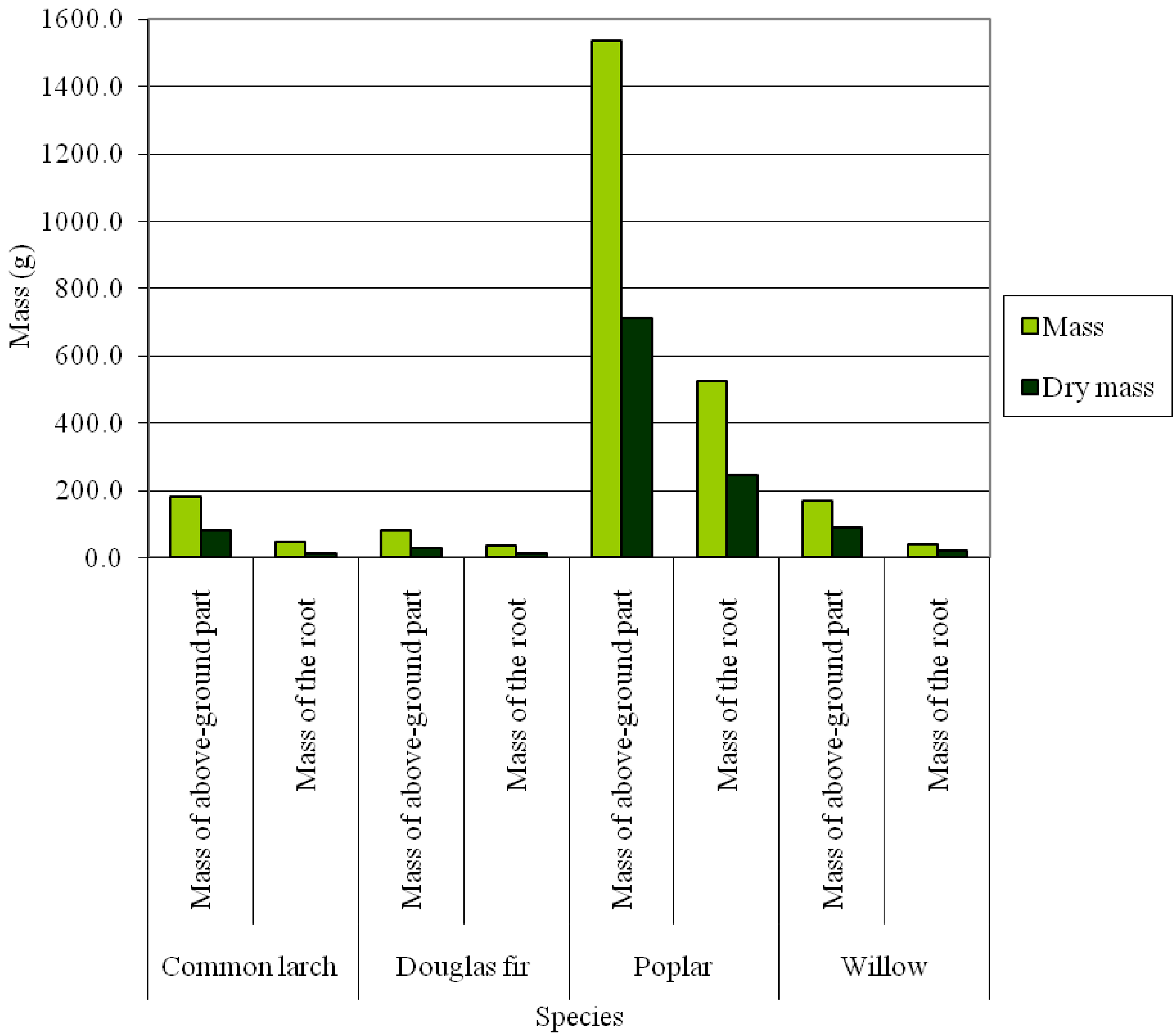

Figure 8. Parameters of the root growth.

Table 10. The expected production of airily dry biomass in Kolubara basin.

Tree species	Number of trees per ha	Planned area (ha)	The expected production of airily dry biomass (t)			
			Annual growth increscent		In six years	
			Per1 ha	Total	Per1 ha	Total for 6.000 ha
Common larch	10.460	1.080	31.2	33.696	187.2	202.176
European alder	8.340	1.200	27.2	32.640	163.2	195.840
Birch	8.340	840	21.5	18.060	129.0	108.360
Black locust	8.340	660	22.4	14.784	134.4	88.704
Common elm	8.340	600	25.6	15.360	153.6	92.160
EA of poplars	7.000	900	46.8	42.120	280.8	252.720
Selected willows	8.000	720	38.0	27.360	228.0	164.160
Total		6.000	Average 30.67	184.020	184.02	1.104.120

both from the economic and ecological point of view.

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