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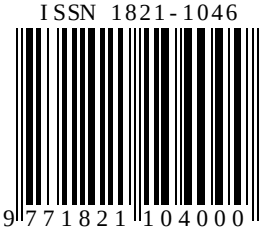

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TOM 63-64

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SUSTAINABLE FORESTRY **ODRŽIVO ŠUMARSTVO**
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Original scientific paper

DEPENDENCE OF DOUGLAS-FIR MEAN DIAMETER ON GEOGRAPHIC ORIGIN OF CANADIAN PROVENANCES IN SEEDLING NURSERY CONDITIONS

Vladan POPOVIĆ[1], Vera LAVADINOVIĆ[1]

Abstract: *Seed and seedling tests, performed with the aim of acquiring knowledge of the genetic potential of selected provenances, are generally one of the first trials in a complex system of comparative examinations to be conducted upon introduction of alien tree species. This paper presents the results of the investigation of the dependence of the mean diameter of 14 Canadian origin Douglas-Fir provenances, originating from 49°10' to 51°35' latitude, 115°20 ' to 120°10' longitude and the altitude of 488 to 1,070m, on the geographic origin.*
Understanding the variability of a seedling mean diameter is of the major importance for acquiring knowledge of genetic potential of selected provenances, which is one of the key parameters for introduction of Douglas-fir into relevant forest sites in Serbia.

Key words: Douglas-fir, provenance, seedlings, mean diameter

ЗАВИСНОСТ СРЕДЊЕГ ПРЕЧНИКА ОД ГЕОГРАФСКОГ ПОРЕКЛА ДУГЛАЗИЈЕ КАНАДСКЕ ПРОВЕНИЈЕНЦИЈЕ

Извод: *Тестови са семеном и садницама, у којима се упознаје генетски потенцијал селекционисаних провенијенција, по правилу су међу првим огледима у сложеном систему компаративних испитивања која се спроводе при интродукцији страних врста дрвећа. У овом раду су приказани резултати испитивања зависности средњег пречника од географског порекла 14 провенијенције дуглазије пореклом из Канаде, које потичу: од 49°10` до 51°35` географске ширине , од 115°20` до 120°10` географске дужине и са надморске висине од 488 до 1070 м.*

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Translation: Dejan Arsenovski

Познавање променљивости испитиваних параметара средњег пречника саднице од значаја је за упознавање генетског потенцијала селекционисаних провенијенција, као једног од битних параметара за интродукцију дуглазије на одговарајућа станишта у Србији.

Кључне речи: дуглазија, провенијенција, саднице, средња висина

1. INTRODUCTION

The primary reason for establishment of provenance test is to determine the economic justification for introduction and to assess the risk arising from a transfer of seeds from their natural, autochthonous zones of origin. Introduction must involve only those species that attain maximum production qualities and economic effectiveness in their natural areal. Upon the transfer of seeds into forest sites with new ecological conditions, the genetic potential of species is tested by means of provenance trials. Another important reason for establishment of provenance trials is avoiding risk and damage from introduction of non-productive and non-adaptive provenances. Several years-long trials of introduced seed, begin by a laboratory analysis of germination, measurement of tray plants, survival percentage of seedling nursery plants, establishment of a field trial and a years-long measurement of plant taxation elements until fruit bearing and collection of F2 generation seeds.

Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) has a broad areal in North America, from west Oregon, across the Washington state, to British Columbia. Autochthonous forests of this type are one of the most productive forests in the world, which is a reason for a considerable interest that exist for establishment of this culture beyond the limits of its natural areal. (J. Bradley, St. Clair i R. Sniezko, 1999). Owing to its extensive adaptability, ecological variability and a potential value, Douglas- fir is one of the most investigated and, at the same time, most important allochthonous conifer species in Europe (John, 1988; Linhart, 1990; Kleinshmit, Bestien, 1992; Schober, 1963). According to the available data, cultures of this species have been established in 26 European countries, on the surface area of 200,000ha (Schober R.). The process of Douglas-fir introduction to Europe was initiated in 1850, when first cultures were established. The success and productivity of the first established cultures differed, largely due to the unknown origin of the seeds used for production of seedlings for their establishment. Based on the studies conducted in North America, as well as potential tests of this species in Europe, a detailed knowledge of the genetic potential of Douglas-fir provenances was acquired. The obtained results from the comparative tests had an impact on regionalisation and more proper selection of the seed sources in North America, which contributed to stability and overall quality of Douglas-fir cultures in forest sites outside its natural areal. The introduction of Douglas-fir in the region of South East Balkans began towards the end of 19th and at the beginning of 20th century. Initially, it was planted as a park-decorative species, and later as a species in forest cultures. (Vrcelj- Kitić, D., 1982). Two Douglas-fir provenance trials were established in Serbia in 1982, with the seed from the known North America seed sources, ranging from New Mexico to British Columbia. Trial facilities were

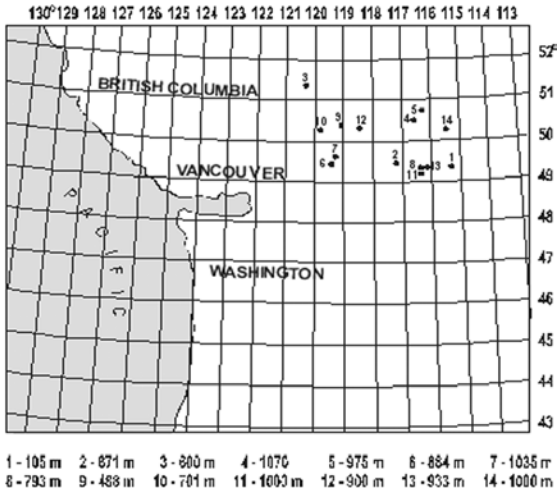
created in Juhor near Jagodina and Tanda near Bor from the seedlings produced in the seedling nursery of the Institute of Forestry in Belgrade.

The results of the research conducted in the experimental facilities in Serbia, (Lavadinović, V., et al. 1995, 1996a, 1996b, 1996c,1997, 1999, 2001) proved that provenances from the higher latitudes of North America are characterised by genetic potential that makes them suitable for establishing their cultures in Serbia. The above-stated results directed the further research towards Douglas-fir provenances from Canada, of the latitude ranging from 49°10' to 51°35', longitude from 115°20' to 120°10' and altitude from 488 to 1070 m.

2. MATERIAL AND WORK METHOD

The paper presents the results of the seedling mean diameter measurement and their discrepancies, depending on geographic characteristics of the seed origin, in a plant juvenile development phase at the seedling nursery in Sremčica. The seed of 14 Douglas-fir provenances, originating from its natural areal in Canada and obtained through a forest seed centre 'Canadian Forest Service' from British Columbia, was used for production of seedlings for establishment of the trial. The sowing of seed was conducted in May 1999, while the trial was established in April 2002, at the seedling nursery in Sremčica. The planting was conducted in rows, one provenance in one row. The distance between the rows was 2m, while the distance between seedlings in a row was 1m. Picture 1 presents the spatial layout of provenance origins, while their geographic characteristics and original codes are presented in table 1.

In summer 2010, breast diameters of all trial trees were measured by a caliper, with the accuracy of 0.1mm. The obtained data were processed by a computer programme STATGRAPHICS Plus. Statistical justification of differences between breast diameter arithmetic means was established by the LSD test, with the probability of 95%. The impact of provenances' geographic origin on seedling breast diameter is determined by the Pierce linear correlation coefficient.



Picture 1. *Spatial layout chart of investigated provenances*

Table 1. *Geographic characteristics of tested provenances*

Provenance		Location			Altitude
No.	Code		latitude	longitude	(m)
1.	03333	Cranbrook	49°25'	115°20'	1050
2.	00848	Inonoaklin	49°50'	118°10'	671
3.	30667	Mann Creek	51°35'	120°10'	600
4.	05227	Gavia Lake	50°56'	116°35'	1070
5.	05226	Nine Bay	50°58'	115°32'	975
6.	03356	Trout Cr	49°40'	119°52'	884
7.	03360	Michell Cr	49°54'	119°37'	1035
8.	01198	Salmo	49°15'	117°30'	793
9.	30460	Mara Lk	50°48'	119°00'	488
10.	00278	Monte Crk	50°37'	119°52'	701
11.	03383	Sheep Creek	49°10'	117°15'	1000
12.	30461	Cooke Creek	50°38'	118°49'	900
13.	03389	Benton Creek	49°12'	117°25'	933
14.	05092	Sun Creek	50°08'	115°52'	1000

3. RESULTS AND DISCUSSION

A comparative analysis of the attained mean diameters of Douglas-fir seedlings from 14 Canadian provenances was published for the purpose of establishing inter-provenance variability and its dependence on geographic characteristics of the seed origin.

Table 2. *Breast diameter of tested Douglas-fir provenances*

Provenance		Diameter
No.	Code	(mm)
1.	03333	13
2.	00848	28
3.	30667	20
4.	05227	10
5.	05226	7
6.	03356	6
7.	03360	8
8.	01198	7
9.	30460	22
10.	00278	11
11.	03383	15
12.	30461	14
13.	03389	21
14.	05092	10

The largest breast diameter of 28 mm was attained by the trees of the second provenance (00848), followed by the ninth 22 mm (30460), the thirteenth 21mm (03389), while the smallest diameter of 6 mm was attained by the trees of the sixth provenance (03356), the fifth 7mm (05226) and the eighth, also 7 mm (0119), as can be seen in table 2.

The obtained statistical data point out to the existence of genetic variability in selected Douglas-fir provenances, understanding of which is essential for the further success of introduction work.

Table 3. *Summary statistics*

Provenance	Average	Standard deviation	Coeff. of variation	Range
1	13,0	9,46044	72,7726%	31,0
2	28,4688	12,59	44,2238%	56,0
3	20,0641	9,41585	46,9288%	41,0
4	10,3793	5,12984	49,4237%	25,0
5	6,66667	4,19921	62,9881%	15,0
6	6,0	3,09121	51,5201%	9,0
7	7,82353	3,63043	46,404%	14,0
8	7,31818	4,04011	55,2065%	14,0
9	21,7015	10,8698	50,0877%	45,0
10	10,6667	7,42582	69,6171%	37,0
11	14,5952	7,47372	51,2066%	37,0
12	13,8298	6,83126	49,3952%	25,0
13	20,5082	10,366	50,5457%	46,0
14	10,4588	5,73534	54,8373%	31,0
Total	15,8236	10,6947	67,5866%	61,0

Table 4. *Variance analysis*

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	27268,8	13	2097,6	29,26	0,0000
Within groups	43301,0	604	71,6903		
Total (Corr.)	70569,8	617			

The results of the variance analysis (table 4) indicate the existence of statistically significant discrepancies at the level $p<0.05$, between breast diameters of 14 Douglas-fir provenance trees.

Table 5. *LSD test*

Provenances	Mean	Homogeneous Groups
6	6,0	X
5	6,66667	XX
8	7,31818	XXX
7	7,82353	XXX
4	10,3793	XXXX
14	10,4588	XX
10	10,6667	XXXX
1	13,0	XXX
12	13,8298	XX
11	14,5952	X
3	20,0641	X
13	20,5082	X
9	21,7015	X
2	28,4688	X

By means of the LSD test, statistically significant differences between mean breast diameters of Douglas-fir provenances were determined at the reliability level $p<0.05$. The provenances were grouped in 4 homogenous groups, which confirmed the variability of mean breast diameters of 14 Douglas-fir provenances. The provenances 2, 9, 13 and 3 belong to a homogenous group with the largest breast diameter, whereas the provenances 6, 5, 8 and 7 belong to a group with the smallest breast diameters.

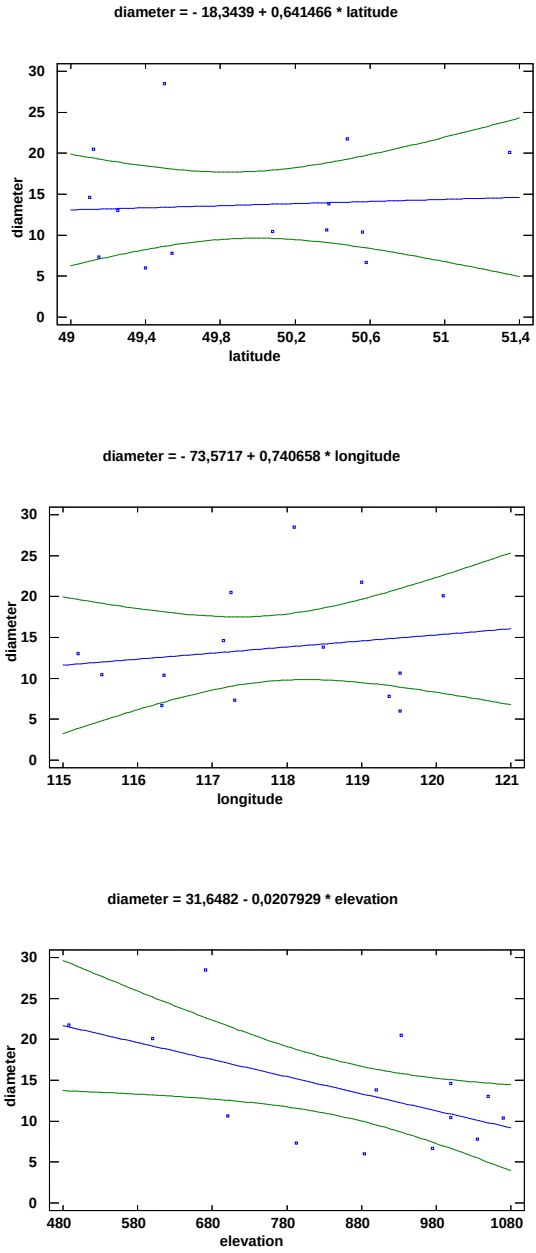
The impact of provenances' geographic origin on a Douglas-fir seedling diameter was examined by means of the Pierce linear correlation coefficient.

Table 6. *Geographic location and breast diameter correlation matrix of 14 Douglas-fir provenances, marked correlations are significant for p<0.05*

	Latitude	Longitude	Altitude	Breast diameter
Latitude	1,00	0,2897	-0,3803	0,0681
Longitude		1,00	-0,6337*	0,1756
Altitude			1,00	-0,5715*
Breast diameter				1,00

On the basis of the Pierce coefficient values (table 6), it could be concluded that there is a positive correlation between longitude and diameter, but that correlation is not statistically significant. There is a negative correlation between altitude and diameter, and that correlation is statistically significant. A similar correlation was also established in the tests involving seeds of the same provenances (Lavadinović, V., et al. 2004.)

Based on the obtained results, it can be concluded that the diameter size is increasing from east provenances to the west. The diameter size is decreasing with the increase of altitude and that is the most pronounced impact (graph 1).



Graph 1. *Latitude, longitude and altitude impact on breast diameter*

4. CONCLUSION

In the juvenile development phase in seedling nursery conditions, the plants exhibit variability of growth characteristics. In order to draw more certain

conclusions with respect to which provenance exhibits better adaptability, it is necessary to monitor the development of older trees.

In this phase of juvenile plant development, the provenances 2, 9, 13 and 3 stood out as the best according to the attained mean breast diameters, while the provenances 6, 5, 8 and 7 were ranked the worst. However, it is too early to propose those data as the underlying basis for the establishment of Douglas-fir cultures. The conducted research presents the basis for selection of a relevant Douglas-fir Canadian provenance for establishment of plantations in Serbia. In order to conduct a more proper selection of provenances, it is necessary to continue to monitor the plant development and then, by consolidating several research results, recommend provenances that are most suitable for establishment of Douglas-fir cultures in Serbia.

Acknowledgement

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CHANGES IN THE GROUND FLORA COMPOSITION OF ARTIFICIALLY ESTABLISHED EASTERN WHITE PINE, DOUGLAS-FIR AND LARCH STANDS AT THE SITE OF HUNAGRIAN OAK AND TURKEY OAK WITH HORNBEAM

Snežana STAJIĆ[1], Vlado ČOKEŠA[1], Zoran MILETIĆ[1], Ljubinko RAKONJAC[1]

Abstract: *The paper presents the results of phytocoenological investigations conducted in a mixed coppice Hungarian Oak and Turkey Oak with hornbeam forest (Carpino betuli-Quercetum farnetto-cerris) and artificially established eastern white pine, Douglas-fir and larch stands in the area of Bogovađa. The terrains of Bogovađa forests are situated in the area of a climatologically conditioned Hungarian Oak and Turkey Oak forest (Quercetum farnetto-cerris). It is the most common phytocenosis in this forest complex. It has been established that the floristic composition of artificially established coniferous stands, set up at the site of Hungarian Oak and Turkey Oak with hornbeam (Carpino betuli-Quercetum farnetto-cerris), is significantly less diverse in comparison to natural stands. The reduction of floristic composition diversity is to some extent the result of morphological properties of introduced coniferous species. In the course of their development, those cultures were exposed to various anthropogenic impact, and responded differently to microhabitat conditions, which was largely reflected in their floristic composition.*

Key terms: Hungarian Oak and Turkey Oak forest, floristic composition, conifers, Bogovađa.

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Translation: Dejan Arsenovski

PROMENE SASTAVA PRIZEMNE FLORE U VEŠTAČKI PODIGNUTIM SASTOJINAMA BOROVCA, DUGLAZIJE I ARIŠA NA STANIŠTU SLADUNA I CERA SA GRABOM

Izvod: *U radu su prikazani rezultati fitocenoloških istraživanja u mešovitoj izdanačkoj šumi sladuna i cera sa grabom (Carpino betuli-Quercetum farnetto-cerris) i veštački podignutim sastojinama borovca, duglazije i ariša na području Bogovađe. Tereni bogovađskih šuma nalaze se u području gde je šuma hrastova sladuna i cera (Quercetum farnetto-cerris) klimatogeno uslovljena. To je najrasprostranjenija fitocenoza u ovom šumskom kompleksu. Utvrđeno je da je u veštački podignutim sastojinama četinara, koje su osnovane na staništu sladuna i cera sa grabom (Carpino betuli-Quercetum farnetto-cerris) floristički sastav osiromašen u odnosu na prirodne sastojine. Smanjenje brojnosti florističkog sastava posledica je delom morfoloških osobina unešenih vrsta četinara. Tokom razvoja navedene kulture nalazile su se pod različitim antropogenim uticajem, i različito su reagovale na mikrostanišne uslove, što se takođe u znatnoj meri odrazilo i na njihov floristički sastav.*

Ključne reči: Šuma sladuna i cera, floristički sastav, četinari, Bogovađa.

1. INTRODUCTION

A Hungarian Oak and Turkey Oak forest is one of the first described forest associations in Serbia, present in the nearly entire region and in consequence a frequent subject to examination (Gajić, M. 1959, Glišić, M. 1977, Jovanović, B. 1954, 1986, Jovanović, B. & Dunjic, R. 1951, Vukićević, E. 1966, Tomić, Z. 2000, et al). The terrains of Bogovađa forests are situated in the area of a climatologically conditioned Hungarian Oak and Turkey Oak forest, which is the most represented phytocenosis in this forest complex.

In the course of afforestation and reclamation of degraded forests conducted in previous decades, insufficient attention was paid to complex properties of vegetation-forest ecosystems, which resulted in plantation of coniferous mono-cultures. Pines, white and black, and, to a lesser extent, spruce, were the species most commonly used for forest reclamation in the process of the introduction of conifers into beech and oak forests in Serbia. An increased use of other coniferous species in small areas, without a prior verification of their suitability for specific forest sites, began since 1970s and involved the following species: eastern white pine (*Pinus strobus* L), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), larch (*Larix decidua* Mill.), white fir (*Abies concolor* Lindl. et Gord.) and other species.

The forests of Bogovađa, the subject of the investigation, had been owned by the Bogovađa monastery until 1945, and, hence, are relatively well-preserved. The highest percentage of coppice forests in this complex were established during WWI, which means that their age is approximately 90-100 years. An intensive work on substitution of the existing coppice forest by introduction of fast-growing coniferous trees, primarily domestic pine species, eastern white pine, Douglas-fir and larch, was initiated in this area in 1964.

2. FOREST FACILITY AND WORK METHOD

The forest complex'Bogovađa' is located in the upper upstream part of the Colubara basin, at an approximately 4km straight line distance from the confluence of the river Ljig into the river Kolubara, in the south direction. The total surface area of this management unit, operated by Forest Administration Valjevo, is 379.61ha. The complex stretches over a strip of land of the altitude ranging from 130 to 235m; the terrain is quite conical, intercepted by depressions and valleys of numerous watercourses. The research of site conditions and the state of the stand was performed by means of series of trials, conducted in natural stands of Hungarian Oak and Turkey Oak with Hornbeam (section 10,17,18), and artificially established stands of eastern white pine (*Pinus strobus* L.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and larch (*Larix decidua* Mill.). Collection and processing of data were performed according to standard work procedures. For the purpose of the investigation of the floristic composition, phytocoenological records were collected by means of the Brown-Blanquet method, with a view to establishing a phytocoenological position of the investigated stands. Creation of pedological profiles and soil sampling were performed in all trial areas, with the aim of determining a pedological position.

3. RESEARCH RESULTS AND DISCUSSION

The parent substrate of the Bogovađa complex soil is composed of marl and claystone (bedded and laminated), conglomerates and sandstones (bedded and thick-bedded) and reef limestone, a complex of lake sediments of Older Neogene and Oligocene, contorted and strongly cracked (Antić, M., Marković, D. 1971). Based on detailed studies, it has been established that the soil in all investigated stands is pseudogleyed luvisol (loess soil with elements of pseudogley).

The investigated stands are located at the altitude of 207-212m, at different slope expositions and mild elevations of 3-8°. The canopy ranges in the interval from 0.7 to 0.9. The basic data on the investigated stands are presented in table 1 (Stajić, S., Rakonjac, Lj. 2006).

Table 1. *Basic characteristics of investigated stands*

Tree species	Age	Taxation elements			
		N(num/ha)	G (m^2/ha)	V(m^3/ha)	Iv(m^3/ha)
Hungarian Oak and Turkey Oak	100	455	32,85	392,84	5,3
Hungarian Oak and Turkey Oak	90	763	32,76	375,39	7,2
Eastern white pine	40	775	36,63	354,42	11,5
Douglas-fir	40	656	32,25	282,75	9,1
Larch	40	625	25,41	271,61	7,9

3.1 Floristic composition

According to the studies conducted by Glišić, M. (1968), the climatologically conditioned Hungarian Oak and Turkey Oak forest *(Quercetum farnetto-cerris Rudski)* is represented in two variants on the terrains of the

Bogovađa forest complex: a Hungarian Oak and Turkey Oak with butcher's broom forest (*Rusco-Quercetum farnetto-cerris* Jov.1951.) and a Hungarian Oak and Turkey Oak with hornbeam forest *Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979.

Based on their floristic composition, it has been established that the investigated natural stands phytocoenologically belong to a Hungarian Oak and Turkey Oak with hornbeam variant *Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979, whereas the artificially established stands, aged 40, were also established at the site of this forest. Phytocoenological table consists of 13 records (table 2).

Table 2. *Phytocoenological table*

Association	*Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979												
Record number	1	2	3	4	5	6	7	8	9	10	11	12	13
Management unit	Bogovađa												
Department (section)	18a	18a	10a	10a	18	18	17	17	17	17	18c	17c	17f
Size p.p. (m^2)	600	600	600	600	600	600	600	600	600	600	1600	1600	1600
Altitude (m)	212	211	210	210	207	211	210	210	210	210	211	207-211	210
Exposition	N-NE	N-NE	S-SW	S-SW	N	N	N-NW	N-NW	N-NW	N-NW	N	N-NE	N-NW
Elevation in ^{0}	7	5-7	3	-	3	7	4	6	4	7	3	3	8
Geological substratum	*marl and claystone*												
Soil	*pseudogleyed luvisol*												
I STOREY													
Canopy	0.8	0.8	0.7	0.7	0.8-0.9	0.8	0.8-0.9	0.8-0.9	0.8	0.8	0.8-0.9	0.8-0.9	0.8
Height-mean (m)	29	28	26	26	25	23	24	27	25	25	21	24	21
Diameter-mean(cm)	35	34	27	27	26	27	27	27	26	26	24	25	23
Distance (m)	2 -5	2 -5	2 -5	2 -5	2–5	3–5	2–5	2–5	2–5	2–5	3	2-4	2-4
Quercus cerris	3.3	3.3	2.1	2.2	3.3	3.3	3.3	3.3	2.2	2.2			
Quercus farnetto	2.2	2.2	3.3	3.3	2.2	2.2	2.2	3.3	3.3	3.3			
Carpinus betulus	2.2	2.2	2.2	1.2	1.1	2.2	1.1	1.1	2.2	2.1		+.1	1.1
Tilia argentea	+.1		+.1	+.1	1.1	+.1		1.1	1.1	+.1	1.1	1.1	1.1
Tilia grandifolia			+.1			+.1	+.1		+.1		+.1	+.1	+.1
Fraxinus ornus			+.1	1.1									
Quercus petraea	+	+											
Prunus avium													+
Pinus strobus											4.4		
Pseudotsuga menziesii												4.4	
Larix europeae													4.4
II STOREY													
Canopy	0.5	0.5	0.5	0.5	0.3	0.3	0.4	0.4	0.4	0.4	0.2	0.1	0.6
Carpinus betulus	1.1	2.1	2.2	2.3	2.1	1.1	2.1	1.1	2.1	1.1		1.1	3.3
Tilia argentea	1.1	1.1	1.1	+.1	2.1	1.1	1.1	1.1	1.1	1.1	1.1	+.1	+.1
Crataegus monogyna	1.1	1.1	1.1	+.1	+.1	1.1	1.1	1.1	1.1	1.1			2.1
Acer campestre	1.1	1.1	+.1	+.1	+.1	1.1	+.1	+.1	+.1	1.1			
Fraxinus ornus	1.1	1.1	1.2	1.1	1.1	+.1	1.1	1.1	1.2	2.2	+.1		1.1
Acer tataricum	1.1	1.2	2.1	1.1	+.1	+.1	+.1						
Lonicera caprifolium	4.4	3.3	2.2	3.3		2.2			3.2	2.2			
Rubus hirtus	2.2	2.2	2.2	1.2			2.2	2.1					
Pyrus pyraster	+.1	+.1			+.1	1.1		+.1					
Rosa arvensis	+.1	1.1	2.1	1.1								+.1	
Cornus mas	+.1	1.1	+.1	1.1									
Quercus cerris									1.1	+.1			

Sorbus domestica	+.1	1.1											
Sorbus torminalis				+.1									
Prunus avium										+.1			
III STOREY													
Cover	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.0	0.5	0.5	0.3
Quercus cerris	1.1	1.1	1.1	1.1	1.1	1.1	1.1	2.1	+.1	1.1			
Quercus frainetto	1.1	1.1	2.1	1.1	1.1	1.1	1.1	1.1	+.1	+.1		+.1	
Carpinus betulus	+.1	1.1	2.2	3.2	+.1	1.1	+.1	1.1	1.2	2.2	+.1	+.1	+.1
Rubus hirtus	2.2	1.2	1.2	+.2	1.2	2.2	1.2	+.2	2.2	2.2		1.1	1.2
Lonicera caprifolium	3.3	2.2	2.2	4.3	1.1	2.2	1.1	2.1	3.3	2.3			
Hedera helix	1.1	1.1	1.2	1.1	+.1	1.1	+.1	1.1	1.1	+.1	+.1	+.1	1.1
Ruscus aculeatus	3.3	3.2	1.2	2.2	1.2	+.2	1.2	2.2	2.2	2.1	1.2	1.1	+.1
Glechoma hirsuta	2.1	1.1	1.1		2.2	2.1	2.2	1.2	2.2	2.2	1.2	2.3	1.2
Veronica chamaedrys	+.1	1.1	+.1	1.2	+.1	+.1		+.1		+.1	+.1		
Helleborus odorus	+.1	+.1			+.1	+.1	+.1	+.1	+.1		+.1	+.1	+.1
Ligustrum vulgare	1.2	+.2			1.2	1.2		1.2	1.2	+.2			
Galium silvaticum			1.1	+.1	+.3	1..3		+.3	2.2	2.1			1.1
Euphorbia amygdaloides	+.1		1.2	+.1	+.1		+.1		+.1		+.1	+.1	+.1
Acer tataricum	1.1	1.2				+.1		+.1	+.1	+.1			+.1
Polygonatum multiflorum	+.1	+				+.1	+.1	+.1			+.1		
Viola silvestris		1.2			+.1	+.1	1.1	+.1			+.1	1.1	
Rosa arvense	+.1	1.1	+.1	1.1					+.1				
Cardamine bulbifera	+.1				+.1	+.1	+.1				+.1	+.1	+.1
Mycelis muralis	+.1				+.1		+.1	+.1			+.2		
Tamus comunis	+.1	+	1.1	+.1									+.1
Fraxinus ornus		+							3.2	2.2		+.1	+.1
Melica uniflora	+.1		+.1	+.2									
Prunus avium					+.1	+.1		1.1					
Galium cruciata	+.2		+.2	+.2							+.1	+.2	
Fragaria vesca	+.1		+.1	1.1									
Ruscus hypoglossum									1.1	+.1	+.1		+.1
Primula vulgaris	+.1					+.1							
Calamintha officinalis	+.1	1.1											
Veronica pseudochamedrys			+.1	1.1							+.1		
Stelaria holostea									1.1	+.1			
Crataegus monogyna			+.1	1.1									
Poa nemoralis			1.2	+.2									
Tilia argentea			1.2	1.1									
Carex pilosa						+.1	1.1						
Nefrodium filix mas					+.1			+.1					
Chamaecytisus hirsutus		+.1		+.1									
Dactuylis glomerata			+.1							+.1			
Asarum europeum	1.1	+									1.2	+.1	+.1
Asperula odorata	+.2										+.2	+.3	+.2
Glechoma hederaceae	1.1												
Hepatica nobilis	+												
Geranium robertianum	+.1												
Sorbus domestica	+.1												
Viola tricolor	+.1												
Polygonatum odoratum										+.1		+.1	
Galium aparine											+.1	+.2	
Sorbus torminalis											+.1		
Clematis vitalba											+.1		

Hornbeam, as a differential species, in addition to Hungarian Oak and Turkey Oak, also appears in the tree storey of the investigated Hungarian Oak and Turkey Oak natural stands. According to Tomić, Z. (2004), a Hungarian Oak and Turkey Oak with hornbeam forest - *Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979. is a specific ecological variant of a Hungarian Oak and Turkey Oak forest of a more mesophilic character, which is generally present at the contact point of zonal forest with sessile oak-hornbeam communities. Other species occurring in this storey are small-leaved linden, large-leaved linden, flowering ash and sessile oak. In addition to edificator species, the shrub storey is composed of linden, hornbeam, field maple, common hawthorn, Tatar maple, honeysuckle and blackberry, and, somewhat less frequently, of dog rose, wild pear, European cornel and service tree. The ground flora cover ranges between 0.9 to1.0. In the ground flora layer, in addition to young growth of main edificator species - Hungarian Oak and Turkey Oak, the species characterised by the most permanent presence are the following: *Ruscus aculeatus, Carpinus betulus, Lonicera caprifolium, Hedera helix, Glechoma hirsuta, Helleborus odorus, Ligustrum vulgare, Veronica chamaedrys, Acer tataricum, Polygonatum multiflorum, Rosa arvense, Tammus communis.* The following species are characterised by a slightly less permanent presence: *Euphorbia amygdaloides, Galium cruciata, Melica uniflora, Fragaria vesca, Viola silvestris, Calamintha officinalis, Primula vulgaris, Cytisus hirsutus, Ruscus hipoglossum, Asperula odorata, Glechoma hederaceae, Hepatica nobilis, Sorbus domestica, Viola tricolor* and other.

In the tree storey of the artificially established eastern white pine stand, in addition to the above-mentioned species, the presence of large-leaved linden and silver linden was observed. The shrub storey is poorly developed, and along with silver linden (*Tilia argentea*), flowering ash (*Fraxinus ornus*) occurs individually. The ground layer has a cover of 0.5. In the areas in which the stand is interrupted due to snowbreak and windbreak, the ground layer is abundant, as a result of an increased light inflow. The following species are observed in those areas: *Glechoma hirsuta, Carpinus betulus, Hedera helix, Ruscus aculeatus, Helleborus* odorus, *Mycelis muralis, Euphorbia amygdaloides, Polygonatum multiflorum, Viola silvestris, Cardamine bulbifera, Galium cruciata, Ruscus hypoglossum, Veronica pseudochamedrys, Galium aparine, Sorbus torminalis, Clematis vitalba.*

In the tree storey of the artificially established Douglas-fir stand, in addition to Douglas-fir, hornbeam (*Carpinus betulus)*, silver linden (*Tilia argentea)*and large-leaved linden (*Tilia grandifolia*) occur individually. The shrub storey is poorly developed and, as in the case of eastern white pine, *Tilia argentea* and *Pyrus pyrastero* are individually present. The ground layer has a cover of 0.5. Among present species, *Glechoma hirsuta* is slightly more represented, whereas other species constitute 5-10%. The species observed in this layer are the following: *Carpinus betulus, Rubus hirtus, Hedera helix, Ruscus aculeatus, Helleborus odorus, Euphorbia amygdaloides, Viola silvestris, Cardamine bulbifera, Fraxinus ornus, Galium cruciata, Asarum europeum, Asperula odorata, Polygonatum odoratum, Galium aparine*.

In the tree layer of the artificially established larch stand (*Larix decidua* Mill.), naturally mixed linden (*Tilia argentea i Tilia grandifolia)*is also present, in addition to larch. The shrub layer is far more represented in comparison to previous

two stands, and it is composed of hornbeam, linden, common hawthorn and flowering ash. Thinning of this stand was not performed in due time, whereas the late thinning was not of adequate intensity, which resulted in presence of a large number of larch trees with reduced crowns and a high slimness coefficient. Such condition of the investigated larch stand led to a snowbreak, which inflicted a severe damage, and resulted in opening of the canopy and the presence of a large number of accessory species in the shrub storey. The ground story consists of *Carpinus betulus, Rubus hirtus, Glechoma hirsuta Hedera helix, Ruscus aculeatus, Helleborus odorus, Galium silvaticum, Euphorbia amygdaloides, Acer tataricum, Cardamine bulbifera, Tamus communis, Fraxinus ornus, Ruscus hypoglossum, Asarum europeum, Asperula odorata*.

The depletion of floristic composition of artificially established conifer stands occurred to some extent as a result of morphological properties of introduced species, in this instance, eastern white pine, larch and Douglas-fir. However, in the course of their development, the above-mentioned species were exposed to various anthropogenic impact, and responded differently to microhabitat conditions, which was largely reflected in their floristic composition. As a result of the late thinning, trees with a high slimness coefficient were formed in all coniferous stands, which contributed to infliction of severe damage caused by snow and wind, to which those species are particularly sensitive. As a consequence, an increased diversity of ground species was created, whereas in the larch stand, on the account of larch being a species with a thin crown, it resulted in an increased number of accessory species in the shrub storey.

A submontane beech forest *Fagetum submontanum* Jov., which occurs at the immediate vicinity of the investigated stands, is orographically conditioned in this area and it appears in shaded and humid stands, where it remains as a permanent stadium. That is the reason for the appearance of certain species of ground flora, typical of beech forests, in the phytocoenological records.

4. CONCLUSION

The investigated stands are located at the altitude of 207-212m, at different slope expositions and mild elevations of 3-8°. The parent substrate of the Bogovađa complex soil is composed of marl and claystone (bedded and laminated), conglomerates and sandstones (bedded and thick-bedded) and reef limestone, a complex of lake sediments of Older Neogene and Oligocene, contorted and strongly cracked, whereas the soil in all investigated stands is pseudogleyed luvisol. By means of a detailed investigation, it has been established that the examined natural stands phytocoenologically belong to a Hungarian Oak and Turkey Oak with hornbeam forest *Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979, whereas the artificially established eastern white pine, Douglas-fir and larch stands are also set up at this forest site. This variant of a Hungarian Oak and Turkey Oak with hornbeam forest belongs to a more mesophilic variant of Hungarian Oak and Turkey Oak forest, and it is characterised by a larger proportion of mesophilic species in its composition. A differential species is hornbeam, which, in addition to edificator species of Hungarian Oak and Turkey Oak, dominates in the tree storey.

The depletion of floristic composition that occurred in artificially established coniferous stands, is evident when compared to natural stands. The decrease of floristic composition diversity is, to some extent the result of morphological properties of introduced coniferous species. In the course of their development, the above-stated cultures were exposed to various anthropogenic impact and responded differently to microhabitat conditions, which was largely reflected in their floristic composition. The presence of large-leaved linden and silver linden was observed in the tree storey of all artificially established stands. The shrub storey is poorly developed, except in the artificially established larch stand. The ground layer has a cover of 0.3-0.5.

Thinning was not performed in due time in the artificially established stands, whereas the late thinning was not of adequate intensity, which resulted in presence of a large number of larch trees with reduced crowns and a high slimness coefficient. Such state of the investigated stands led to the occurrence of snowbreak, which caused severe damage. That was most evident in the artificially established larch stand in which, as a result of snowbreak, a sudden opening of canopy occurred and conditioned the presence of a large number of accessory species in the shrub storey.

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CHANGES IN THE GROUND FLORA COMPOSITION OF ARTIFICIALLY ESTABLISHED EASTERN WHITE PINE, DOUGLAS-FIR AND LARCH STANDS AT THE SITE OF HUNAGRIAN OAK AND TURKEY OAK WITH HORNBEAM

Snežana STAJIĆ, Vlado ČOKEŠA, Zoran MILETIĆ, Ljubinko RAKONJAC

Summary

The terrain of Bogovađa forests is situated in the area of climatologically conditioned Hungarian Oak and Turkey Oak forest (*Quercetum farnetto-cerris*). Based on their floristic composition, it has been established that the investigated natural stands phytocoenologically belong to a Hungarian Oak and Turkey Oak with hornbeam forest community *Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979, whereas the artificially established eastern white pine, Douglas-fir and larch stands were also set up at this forest site.

Hornbeam, as a differential species, is present in the tree storey of natural stands of Hungarian Oak and Turkey Oak, along with Hungarian Oak and Turkey Oak. Linden, common hawthorn, field maple, flowering ash, Tatar maple, honeysuckle and blackberries, etc. are most commonly present in the shrub layer, in addition to edificator species. The species characterised by the most permanent presence in the ground layer, along with the young growth of the main edificators, Hungarian Oak and Turkey Oak, are the following: *Ruscus aculeatus, Carpinus betulus, Lonicera caprifolium, Hedera helix, Glechoma hirsuta, Helleborus odorus, Ligustrum vulgare, Veronica chamaedrys, Acer tataricum, Polygonatum multiflorum, Rosa arvense, Tammus communis.*

The depletion of floristic composition occurred in the artificially established stands. The reduction of floristic composition diversity is to some extent the result of morphological properties of introduced coniferous species, and partly it is due to the different response to microhabitat conditions, which is largely reflected in their floristic composition.

The late thinning in the artificially established stands conditioned the presence of a large number of trees with reduced crowns and a high slimness coefficient, which led to a snowbreak, causing a severe damage. That was most evident in the artificially established larch stand, where a sudden opening of the canopy occurred, conditioning the presence of a large number of accessory species in the shrub storey.

PROMENE SASTAVA PRIZEMNE FLORE U VEŠTAČKI PODIGNUTIM SASTOJINAMA BOROVCA, DUGLAZIJE I ARIŠA NA STANIŠTU SLADUNA I CERA SA GRABOM

Snežana STAJIĆ, Vlado ČOKEŠA, Zoran MILETIĆ, Ljubinko RAKONJAC

Rezime

Tereni bogovađskih šuma nalaze se u području gde je šuma hrastova sladuna i cera (*Quercetum farneto-cerris*) klimatogeno uslovljena. Na osnovu floističkog sastava utvrđeno je da istraživane prirodne sastojine fitocenološki pripadaju šuma sladuna i cera sa grabom *Carpino betuli-Quercetum farnetto-cerris* (Rud.1949) Jov.1979., a veštački podignute sastojine borovca, duglazije i ariša osnovane su takođe na staništu ove šume.

U prirodnim sastojinama sladuna i cera u spratu drveća pored sladuna i cera, kao diferencijalna vrsta javlja se i grab. U spratu žbunja pored edifikatora javljaju se najčešće lipa, grab, klen, glog, crni jasen, žešlja, orlovi nokti i kupina, itd. U sloju prizemnog bilja, pored podmlatka glavnih edifikatora, sladuna i cera, najveću stalnost imaju: *Ruscus aculeatus, Carpinus betulus, Lonicera caprifolium, Hedera helix, Glechoma hirsuta, Helleborus odorus, Ligustrum vulgare, Veronica chamaedrys, Acer tataricum, Polygonatum multiflorum, Rosa arvense, Tammus communis.*

Kod veštački podignutih sastojina četinara došlo je od osiromašenja u floističkom sastavu. Smanjenje brojnosti floističkog sastava posledica je delom morfoloških osobina unešenih vrsta četinara, a i različito su reagovale na mikrostanišne uslove, što se takođe u znatnoj meri odrazilo i na njihov floristički sastav.

U veštački podignutim sastojinama neblagovremeno izvođenje proreda je uslovilo prisustvo velikog broja stabala sa redukovanim krošnjama i velikim koeficijentom vitkosti, što je dovelo do snegoloma, koji su prouzrokovali znatne štete. To se najviše ispoljilo u veštački podignutoj sastojini ariša (*Larix decidua* Mill.), gde je došlo do naglog otvaranja sklopa, i istovremeno uslovilo prisustvo većeg broja pratećih vrsta u spratu žbunja.

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SEED GERMINATION ANALYSIS IN ORDER TO IMPROVE THE PRODUCTION OF SEEDLINGS

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Abstract: *Base of mass production of seedlings In the forest nursery production is the production from seeds. The mature seed dormancy is main problem in the production of seedlings of Tilia tomentosa Moench. Germination exceeds the usual period of several months, from the time of maturation, collecting and sowing seeds until next spring. If the sowing of the seeds is in the next spring after the harvest the problem is even greater. That type of seed germination results a numerous negative consequences for conducting of production process. Difficulties in growing of white lime caused to it lose from production in nurseries.*

The paper presents the results of research of mature seeds germination subjected to wet and cold stratification and immature seeds germination. The mature seeds subjected to wet-cold stratification had significantly less technical germination of seeds picked in immature stage. The results also indicate that the method of preparation of seeds through wet-cold stratification is much more complicated method of sowing the seeds at an early stage of maturing.

Key words: nursery plant production, white lime, seed dormancy, stratification.

1. INTRODUCTION

Since ancient times for the people of the Balkan Peninsula, the lime tree has had special value. For the Slavs was the sacred tree. As the material for the multiple use has greatly contributed to the development and progress the Slavic

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peoples. White lime submitted drier and less humus soil (Jovanović, 1985). With its roots and leaf fall which is fast degraded has the ability to improve the land (Lutz and Chandler, 1946). Thanks to the dense trees affect the microclimate environment.

Lime trees can be successfully grown in the habitats of community *Quercetum montanum serbicum* Ćer-Jov, *Quercetum conferte cerris* Rudski, *Carpinetum orientalis serbicum* Rudski which are usually highly degraded and is influenced by many extreme environmental factors. It can thrive only pioneering species of conifers and white lime is one of the few broadleaf species that can be used to create a mixed forest of deciduous trees and conifers. White lime should be one of the main species in the reclamation of degraded oak and beech forests. Because it white lime tree has far greater importance in forestry from the other lime species.

Wherever we want to contribute to the beauty of appearance and create the conditions for pleasant people, white lime is irreplaceable.

2. METHODOLOGY

Seeds „achene“ were collected each year from 10 locations during three years of research. Location of trees was in urban conditions of Belgrade. Collected seeds from selected of linden tree was sown right after harvest (autumn sowing) and in the spring after the cold-wet stratification.

According to the survey (Veselinović 1989) determined the state of collected seeds by monitoring the morphological characteristics and on the basis of them is divided in the six developmental stages.

During the three year study was carried out. Seed was sowed in all developmental stages from august to september. 100 of seed was sowed from each developmental stage and each location.

In the next spring seed, stratified by cold-wet stratification method to 5°C for a period of 5.5 months (Stilinovic, 1985) was sowed .

Germination depending on the picking time and stratification treatment were analyzed.

3. RESULTS AND DISCUSION

Percent of the germinated seeds from the field. during the tree year research is shown in tablele 1.

Table 1. *Result of seed germination (%) at the field*

stage	Date	First year										sum	average
		1	2	3	4	5	6	7	8	9	10		
1	06.08	0	0	0	0	0	0	0	0	0	0	0	0
2	15.08	0	0	0	0	0	0	0	0	0	0	0	0
3	22.08	8	13	11	10	12	12	13	11	9	10	109	10,9
4	04.09	12	29	19	23	14	23	25	24	19	26	214	21,4
5	11.09	56	60	53	55	58	60	54	58	57	55	565	56,5

6	19.09	6	12	11	13	8	9	11	12	8	10	100	10,0
		Second year											
		1	2	3	4	5	6	7	8	9	10		
1	03.08	0	0	0	0	0	0	0	0	0	0	0	0
2	11.08	0	0	0	0	0	0	0	0	0	0	0	0
3	20.08	14	21	17	22	19	18	20	16	21	15	183	18,3
4	29.08	48	32	36	33	45	37	44	47	35	43	400	40,0
5	07.09	60	64	65	62	61	64	62	63	60	65	626	62,6
6	17.09	13	21	19	18	17	16	15	20	14	17	170	17,0
		Third year											
		1	2	3	4	5	6	7	8	9	10		
1	06.08	0	0	0	0	0	0	0	0	0	0	0	0
2	14.08	0	0	0	0	0	0	0	0	0	0	0	0
3	23.08	8	11	18	9	5	15	16	13	6	12	168	16,8
4	04.09	37	41	30	23	40	35	43	39	44	29	361	36,1
5	14.09	60	62	53	49	46	55	59	50	61	57	562	56,2
6	22.09	13	13	11	10	11	12	11	10	13	12	116	11,6

The results showed that the germination varies by age and from tree to tree. According to many authors optimal time for white lime seed collecting can not determine with certainty, Soljanik (1961), Zaborovski and Varasova (1961), Stilinović (1985), Vanstone (1978), Nygren (1987), Dirr and Heuser (1987), Suszka Bet all., (1996), Hartman et all., (2002).

Table 2. *Seed germination in different phase of development*

stage	Seed germination
1	0,00
2	0,00
3	$13,50 \pm 1,83^{b}$
4	$32,50 \pm 0,87^{c}$
5	$58,13 \pm 0,67^{d}$
6	$12,87 \pm 0,84^{b}$

Multifactorial test in ranges – amounts recorded with the same letters in columnns do not show difference on a significance level of $p < 0,05$

Counting of germinated seeds was done in the next spring. Data from the Table 2. show that there were statistically significan influence of picking time on seed germination in development phase 4 and 5.

Linking these results of success rate of germination (Table 2) with morphological characteristics (Table 3), the greatests seed germination in the field is achieved in the development stage characterized by dark grey color of seed coat, yellowish white endosperm and embryo from the reddish color of cotyledons, define as stage 5.

During the three-year research seed picked in October were subjected to the cold-wet stratification of 5°C in the length of 5.5 months. Issues important to stratification of white lime seeds are numerous. Because of complexity of structure, mechanically disturbances (solid wooded pericarp, seedling soon after harvest becomes impermeable to water) and biochemical disturbances (creating

unfavorable conditions for the hydrolysis of fats, synthesis and breakdown of starch, protein and sugar).

Table 3. *Morphological characteristics of different stages of seed development and maturation (Veselinovic, 1989)*

stage	Pericarp			Seedcoat (testa)		Endosperm consistency	Embryo	
	Color		Consis-tence	Color	Consistence		Formed, %	Coty-ledon color
	egzo	endo						
1	pale green	white, grainy	soft, easy to cut	white, oxidize in brown	soft, easy to cut	liquid	0	-
2	pale green	white, grainy	soft, easy to cut	pale brown	soft, easy to cut	gel	10	green
3	pale green	white, grainy	soft, easy to cut	pale brown	soft, easily to separated from endosperm	tight as a rubber	100	green
4	olive	white, brown, open	easy to cut, harder	pale to dark brown	solid, difficult to cut and separated from endosperm	tight as a rubber, yellow and elastic	100	green
5	olive	brown	easy to cut, harder	dark brown	solid, difficult to cut and separated from endosperm	pale yellow, high consistency	100	yellow
6	olive	brown, woody	difficult to cut	black	solid, difficult to cut and separated from endosperm	tight, consistency resin	100	yellow

The seed was germinated in a very small percentage. The reason is the rapid draining ahenija swelling and loss of power due to anatomical changes in parenchima cells of seed. In order to identify the cause of this low germinaton, after completion of emergence, non germinated seed was picked up from the soil and analyse the cross section of the seeds (Table 4).

Table 4. *Anlise of non germinated seeds after cold-wet stratification process*

Tree	Germinated (%)	Not germinated (%)	Not germinated (%)		
			Solid	Poorly	Rotten
1	19	81	70	10	20
2	12	88	75	15	10
3	19	81	68	10	22
4	10	90	70	8	22
5	12	88	68	12	20

We can see that the 70% of non germinated seed was hard and not absorb moisture, so that most of the seeds could not be cut with a knife. Pericarp is easily took of, but the seedcoat was completely black, very hard and impermeable to water.

Fig. 1. *Microscop cross section of immature seed*

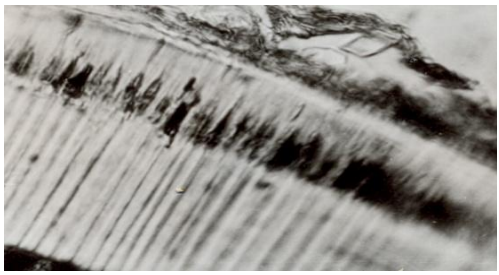

Fig. 2. *Microscop cross section of mature seed*

At the microscopic preparation can be observed (Fig. 1 and 2) that the parenchymal cells completely lost their protoplasm and cell walls are thicker (Fig. 1). Thus the failure of the stratification can be explained by a larger amount of hard seeds in a later picking, because only sweling „achene“ of immature seeds can be carried out biochemical processes that cause germination of seeds. .

The results indicate that the method of preparation of seeds through cold-wet stratification is much more complicated method of sowing the seeds and less succesful in germination compare with sowing the seed at an early stage of maturing.

4. CONCLUSION

Field experiments showed that the largest percentage of seed germination achieve when the seed was picked in the fifth stage of development witch is characterized with a dark grey color of seedling and yelow color of cotiledones.

On this basis we can conclude that seeds with dark grey color of seedling and yelow color of cotiledones is the reliable factor for determining the most appropriate time in practice for the collection of seeds for early autumn sowing.

Seeds collected in October as a mature and prepared with cold-wet stratification process at 5°C in the total length of 5.5 months have a lower technical germination of seeds harvested by the V development phase and immediately sown.

Since the seeds of white lime does not achieve fifth development phase for some time, it is not fixed a specific date, the practice may be required to recommend control seeds from 1-15 September. When the seed has the highest percentage of dark grey color of seedling and yellow color of cotyledons it is the right time for picking and immediate sowing.

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THE INTENSITY OF EROSION IN THE CATCHMENT OF THE TORRENT LEŠJANSKI DO

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Abstract: *This paper defines the state of erosion process in the catchments of the torrent Lešjanski Do and provides mean annual erosion sediment yield and discharge values. The mean coefficient of erosion for the catchment area of the torrent Lešjanski do amounts to Z=0.44, which classifies this area in the third category of destructiveness. The total sediment yield in the catchment area of Lešjanski do is* W_{ann}*=7 246.10* $m^3 year^{-1}$*, while the specific sediment yield amounts to* W_{year}*=620.92* $m^3 \cdot km^{-2} year^{-1}$*. The amount of sediment discharge in the catchments area is* G_{year}*=3 458.26* $m^3 year^{-1}$*.*

Key words: erosion processes, coefficient of erosion, sediment yield, sediment discharge

INTENZITET EROZIJE U SLIVU BUJICE LEŠJANSKI DO

Abstract: *U radu je definisano stanje erozionih procesa na području sliva bujice Lješjanski do i obračunata srednje godišnja produkcija i pronos erozionog nanosa. Srednja vrednost koeficijenta erozije za područje sliva bujice Lješjanski do iznosi Z=0,44 pa se područje može svrstati u III kategoriju razornosti. Ukupna produkcija nanosa na području sliva Lešjanskog dola iznosi* W_{god}*=7.246,10* $m^3 god^{-1}$*, a specifična produkcija nanosa* W_{god}*=620,92* $m^3 \cdot km^{-2} god^{-1}$*. Količina pronosa nanosa koja se odnosi sa područja sliva iznose* G_{god}*=3.458,26* $m^3 god^{-1}$*.*

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Ključne reči: erozioni procesi, koeficijent erozije, produkcija nanosa, pronos nanosa

1. INTRODUCTION

Hugh Bennet, an American protagonist of the battle against soil erosion said: „Erosion is one of the most complex problems and at the same time one of the most vicious enemies of human economy. Erosion processes gradually degrade and destroy soil, take away nutrients and disturb the water regime. They can bring poverty and privation to the population of many, often vast areas and force people to migrate. Therefore many branches of economy must be simultaneously involved in the battle against soil erosion and its devastating consequences` (Gavrilovic S., 1972).

In recent times, the problem of soil erosion has become more evident due to the continuous growth of population and the increase in pressure on land resources.

2. THE AREA OF INVESTIGATION AND METHODS

Lešjanski do is a left tributary of the river Trgoviški Timok. The basin of the torrent is on the territory of the cadastral municipality of Donja Kamenica. It empties into the river Trgoviški Timok in the village Donja Kamrnica, situated 275 meters above sea level. It originates in the place called Goleme Livade (meaning vast meadows), at 650 m above sea level. Its flowing direction is southeast-northwest. The catchment is hilly with the average slope inclination of 30%. The area of the catchment is 11.67 km^2, the watercourse length 6.65 km, while the mean watercourse drop amounts to 5.5%

The investigations presented in this paper consist of three phases:

1. Investigation of the natural characteristics of the catchment
2. Assessments of the state and intensity of erosion
3. Calculation of the sediment yield.

Natural characteristics of the catchment Lešjanski do were investigated on the basis of digital cartographic material combined with field research.

Its climatic characteristics were determined using The National Hydro-meteorological Service dataset, obtained from the weather station Knjaževac and the precipitation station Donja Kamenica.

A digital geological map was created from a basic geological map at 1:100.000 scale.

A dataset on spatial and quantitative distribution of certain soil types in the catchment area Lešjanski do was obtained on the basis of previously digitalized pedological map on a scale R=1:50000 and The Pedological Study of the Timok basin.

A land use map was made by using a 1:25000 scale topographic map and satellite photos and by direct recognition of the terrain.

The intensity and distribution of erosion processes were determined on the basis of a digitalized map of erosion, made by the method of prof. Gavrilovic. It combines the use of satellite photos and terrain recognition.

The total amount of the sediment produced in the catchments was calculated by the erosion potential method of prof.dr Gavrilovic.

3. RESEARCH RESULTS

The shape and the size of the catchment area are the parameters that indicate a potential occurrence of a sudden and concurrent concentration of flood water from the catchment area.

The main catchment parameters that affect the genesis of the erosion processes and sediment discharge are shown in Table 1.

Table 1. *Analysis of the natural characteristics of the catchment*

Parameter	Symbol	Torrent Leršjanski do
Catchment area	F (km^2)	11,67
Catchment perimeter	O (km)	19,12
Watercourse length	L (km)	6,65
Coefficient of the catchment shape by prof. Gavrilovic	A	0,561
Module of the basin watershed development	E	1,561
Morphological coefficient	n	0,264
Density of the hydrographic network	G ($km\ km^{-2}$)	1,839
Coefficient of the catchment asymmetry	a	0,848
Coefficient of the watercourse meandering	K	1,120
Mean catchment altitude	N_{mean} (m)	508,14

The presented catchment parameters indicate that intensive erosion processes and sediment discharge can be expected.

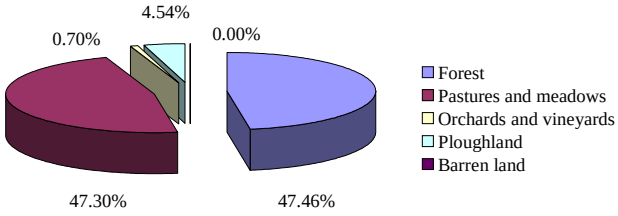
The parent rock of the catchment consists of sandstone, limestone and claystone. The soil types registered on the left bank of the catchment are acid brown soil and loessivized acid brown soil, while humus and brownised humus are present on the right bank.

The mean air temperature measured over a longer period of time at the weather station Knjaževac is 10.2^0C. The coldest month is January, with the mean monthly temperature of -1.2^0C, while July is the hottest with the mean monthly air temperature of 20.5^0C. Mean annual precipitation for the relevant precipitation station in Donja Kamenica is H_{mean} = 639.90 mm.

The hydrographic network is well-developed. The main stream has nine tributaries, seven left and two right ones.

The vegetation cover is comprised mainly of forest (47.46%), meadows and pastures (47.30%), ploughland (4.54%) and orchards and vineyards (0.7%).

Diagram 1. *Land use types in the catchment Lešjanski do*



The data on the state of erosion processes were obtained by visiting the terrain and mapping the occurrences of erosion. Recognition of the terrain was carried out in 2008 and 2009. It was done in summer and autumn in order to make the assessment of the erosion intensity on the areas covered by broadleaved species as accurate as possible.

Mapping the intensity of the erosion processes was done in the field, visually, on a topographic map, on a scale R=1:50.000. In order to obtain the best possible description of the terrain characteristics, a detailed office analysis of topographic maps and satellite photos of the investigated area was carried out prior to the collection of field data on the intensity and distribution of erosion processes.

Table 2. *Mean erosion coefficient (Z_{mean}) in the catchment Lešjanski do*

Categories of erosion	Area km^2	%	Mean coefficient of erosion Z
Excessive	0,00	0,00	1,25
Strong	0,19	1,63	0,85
Medium	6,24	53,47	0,55
Weak	5,24	44,90	0,30
Very weak	0,00	0,00	0,10
Total	11,67	100,0	0,44

By visiting the terrain and classifying the investigated area according to the level of erosion endangerment, it was concluded that erosion processes of all categories of destructiveness (from strong to very weak) are present in the area, in different degrees.

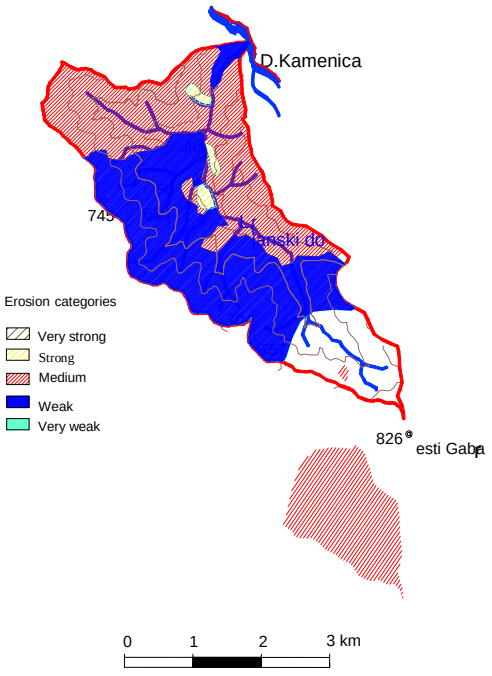


Figure 1. *Erosion map of the catchment Lešjanski do*

There is no area in the catchment subjected to excessive erosion, while the strong erosion processes are reported on only 1.63% of the catchment area. Medium erosion is reported on 53.47% of the area, while 44.90% of the catchment area is affected by weak erosion. The mean coefficient of erosion for the whole catchment is $Z_{mean} = 0.44$, which shows that it is prevailed by medium erosion.

The analysis of the state of erosion processes in the catchment and the dataset on distribution of erosion processes of different categories of destructiveness enable us to calculate the sediment yield or the volume of the sediment, which Lešjanski do discharges into the river Trgoviški Timok.

The total amount of the sediment produced in the catchments is calculated by prof. Gavrilovic`s method.

The analytical-quantitative-qualitative determination of the total mean annual amount of sediment produced in the catchment was done according to the following formula of prof. S.Gavrilovic:

$$W_{year} = T \times H_{year} \times \pi \times \sqrt{Z_{mean}^3} \times F$$

where:

W_{year} – total annual sediment yield in $m^3 \cdot god^{-1}$

T – temperature coefficient of the area

$$T = \sqrt{\frac{t_0}{10} + 0.1}$$

t_0 – mean annual air temperature, ^0S

H_{ann} – mean annual precipitation, in mm

Z_{sr} – coefficient of the catchment erosion

F – catchment area, in km^2

Out of this amount of sediment, produced in the catchment, the following sediment amount reaches the investigated profile:

$$G_{year} = W_{year} \times R_t$$

where:

G_{year} – total amount of sediment that reaches the investigated profile, in $m^3 \cdot god^{-1}$

R_t – coefficient of sediment retention

$$R_t = \frac{(O \times D)^{0.5}}{0.25(L + 10.0)}$$

O – catchment perimeter, in km

D – mean altitude range of the catchment, in km

L – main watercourse length , in km

The total sediment yield in the area of Lešjanski do catchment is 7246.10 $m^3 year^{-1}$, while the specific sediment yield amounts to 620.92 $m^3 \cdot km^{-2} year^{-1}$.

Out of the amount of sediment produced in the investigated catchment, 3 458.26 $m^3 god^{-1}$ reaches the Trgoviški Timok.

4. CONCLUSION

The mean erosion coefficient of the catchment area of the torrent Lešjanski do amounts to Z_{mean}=0.44, which classifies this catchment in the third category of destructiveness. Regarding the type of erosion, surface and combined erosion types are dominant, with the sporadic presence of deep erosion.

The total sediment yield in the catchment Lešjanski do is W_{year}=7 246.10 $m^3 year^{-1}$, while the specific sediment yield amounts to W_{year}=620,92 $m^3 \cdot km^{-2} year^{-1}$.

The amount of the sediment discharge that refers to this area amounts to G_{year}=3 458.26 $m^3 year^{-1}$.

On the basis of the calculated values of the erosion coefficient Z, sediment yield and discharge of the studied area, it can be concluded that medium erosion is the most dominant category of erosion.

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Summary

This paper defines the state of erosion processes in the catchment Lešjanski do and calculates the mean annual erosion sediment yield and discharge.

Lešjanski do is a left tributary of the river Trgoviški Timok. The catchment area is 11.67 km^2, the watercourse length is 6.65 km, and the mean watercourse drop is 5.5%.

The parent rock of the catchment consists of sandstone, limestone and claystone. The soil types registered on the left bank of the catchment are acid brown soil and loessived acid brown soil, while humus and brownised humus are present on the right bank.

The mean air temperature measured over a longer period of time at the weather station Knjaževac is 10.2^0C. The mean annual precipitation for the relevant precipitation station in Donja Kamenica is H_{mean} = 639.90 mm.

The hydrographic network is well-developed. The main stream has nine tributaries, seven left and two right ones.

The vegetation cover is comprised mainly of forest (47.46%), meadows and pastures (47.30%), ploughland (4.54%) and orchards and vineyards (0.7%).

The intensity and distribution of the erosion processes were determined by using the digitalized map of erosion, made by the method of prof. Gavrilovic. It combines the use of satellite photos with the field mapping of erosion processes.

The total amount of the sediment produced in the catchment was calculated by the erosion potential method of prof. dr Gavrilovic.

The total sediment yield in the catchment area of Lešjanski do is 7 246.10 $m^3 year^{-}$

^{1}, while the specific sediment yield amounts to 620.92 $m^3 \cdot km^{-2} year^{-1}$. Out of the amount of sediment produced in the investigated catchment, 3 458.26 $m^3 god^{-1}$ reaches the river Trgoviški Timok.

On the basis of the calculated values of the erosion coefficient Z, sediment yield and discharge in the studied area, it can be concluded that medium erosion is the most dominant category of erosion.

INTENZITET EROZIJE U SLIVU BUJICE LEŠJANSKI DO

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Rezime

U ovom radu je definisano stanje erozionih procesa na području sliva bujice Lešjanski do i obračunata srednje godišnja produkcija i pronos erozionog nanosa.

Lešjanski do je leva pritoka Trgoviškog Timoka. Površina sliva iznosi 11,67 km^2, dužina toka je 6,65 km, a srednji pad toka je 5,5%.

Geološku podlogu u slivu grade peščari, krečnjaci i glinci. Od tipova zemljišta na levoj strani sliva su rasprostranjena kiselo smeđa i lesivirano kiselosmeđa zemljišta a na desnoj strani crnica i posmeđena crnica.

Srednja temperatura vazduha u višegodišnjem periodu na klimatološkoj stanici Knjaževac iznosi 10.2^0C. Srednja godišnjih suma padavina za merodavnu padavinsku stanicu Donja Kamenica iznosi H_{sr} = 639,90 mm.

Hidrografska mreža je razvijena. Glavni tok prima devet pritoka i to sedam levih i dve desne.

Vegetacioni pokrivač čine pretežno šume (47,46%), livade i pašnjaci (47,30%), oranice (4,54%) i voćnjaci i vinogradi (0,7%).

Intenzitet i rasprostranjenost erozionih procesa definisani su na osnovu digitalizovane karte erozije koja je urađena po metodi prof.Gavrilovića korišćenjem satelitskih snimaka, obilaskom terena i kartiranjem erozionih pojava.

Srednji koeficijent erozije za sliv iznosi Z_{sr} = 0,44 pa se područje može svrstati u III kategoriju razornosti.

Ukupna količina nanosa koja se produkuje u slivu sračunata je po metodi potencijala erozije prof.dr.Gavrilovića.

Ukupna produkcija nanosa na području sliva Lešjanskog dola iznosi 7.246,10 $m^3 god^{-1}$, odnosno specifična produkcija nanosa iznosi 620,92 $m^3 \cdot km^{-2} god^{-1}$. Od količine nanosa koja se produkuje u istraživanom slivu u Trgoviški Timok dospeva 3.458,26 $m^3 god^{-1}$.

Na osnovu sračunatih vrednosti koeficijenta erozije Z, produkcije i pronosa nanosa na istraživanom području najzastupljenija kategorija erozije je srednja erozija.

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Preliminary communication

ADAPTATION OF FOREST ECOSYSTEMS ON NEGATIVE CLIMATE CHANGE IMPACTS IN SERBIA

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Abstract: *The environmental pollution causes many ecological problems, climate changes and global warming, with adverse effect on forest ecosystems in the whole world, and Serbia also. Global warming and the potential changes of temperature and humidity, point out to a very wide range of the effects, both on the forest system in general and on the individual trees. Since the effects of global warming can be so intense in some regions that they can cause the changes in the forest productivity in composition of the plant and animal species in them, the forest cover would become unsustainable. Such reactions to the climate change would lead to numerous consequences and adverse effects on the preservation of biodiversity and water integrity, environmental protection, protection of the natural areas from erosion, as well as on the commercial forestry, wood processing industry, tourism, recreation, etc. This paper analyzes a significance, problems and challenges in forest ecosystems in Serbia caused by climate change and the impacts of the climate change on the forests and forest management. In order to predict new changes and adaptability of the forest ecosystems, it is necessary to initiate scientific researches, modernize forest policies, and apply more adaptive forest management practices in Serbia.*

Key words: The impact of climate change /Forest ecosystems /Adaptive measures /Sustainability.

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ADAPTACIJA ŠUMSKIH EKOSISTEMA NA NEGATIVAN UTICAJ KLIMATSKIH PROMENA U SRBIJI

Izvod: *Zagađivanje životne sredine dovodi do brojnih ekoloških problema, klimatskih promena i globalnog zagrevanja, koji negativno utiču na šumske ekosisteme u celom svetu, pa i u Srbiji. Globalno zagrevanje i potencijalne promene temperature i vlažnosti ukazuju na vrlo širok spektar efekata kako na šumske ekosisteme u celini tako i na pojedinačna stabla. Efekti globalnog zagrevanja mogli bi da budu toliko jaki u pojedinim regionima da bi došlo do promena produktivnosti šuma i sastava biljnih i životinjskih zajednica u njima, pa održavanje šumskog pokrivača ne bi bilo moguće. Ovakve reakcije na promenu klimatskih prilika uslovile bi niz posledica i negativnih uticaja na očuvanje biodiverziteta i integriteta voda, zaštitu životne sredine, zaštitu prirodnih predela i zemljišta od erozije, zatim na komercijalno šumarstvo, drvnu industriju, turizam, rekreaciju i drugo. U radu će se analizirati značaj, problemi i izazovi sa kojima se suočavaju šumski ekosistemi u Srbiji usled klimatskih promena, kao i posledice uticaja promene klime na šume i gazdovanje šumama. U cilju predviđanja novonastalih promena i prilagođavanja šumskih ekosistema neophodno je započeti nova naučna istraživanja, inovirati šumarsku politiku i primenjivati adaptivnu praksu gazdovanja šumama u Srbiji.*

Ključne reči: *Šumski ekosistemi /Klimatske promene /Adaptivne mere /Održivost.*

1. INTRODUCTION

It has been foreseen that the global temperature in the World increase from 1.1°C to 6.4°C and humidity increase from 7.1% to 15.8% in 21st century will lead to serious and rapid changes in forest ecosystems [1-3].

Based on the analysis of the air temperature trend in Serbia over the period 1950-2008 it can be concluded that the trend of increase of mean air temperature (by about 1.2 °C in the twentieth century) is present in the greatest part of the territory, except in southeast Serbia, where the trend of the decrease of mean air temperature was reported. In Serbia over the period 1950-2008, the greatest reduction in annual precipitation (120 mm) was recorded in Negotinska Krajina, whereas in Vojvodina the decrease in the rainfall was considerably smaller. It is expected that these trends of climate change in Serbia will continue in the future, which will significantly alter the structure and function of forest ecosystems, thereby imposing the need for the change of the previous forest management.

This paper is aimed at pointing out to the possible conditions of the forest ecosystems in Serbia due to global warming and the type of actions which can be taken, based on the study of the trend of the changes of air temperatures in Serbia.

2. MATERIALS AND METHODS

The multi-decade data obtained by the systematic meteorological measurements are the only way in which the valid assessment of the current condition and the comparison of it with the previous periods can be made. In order to analyze the climate characteristics and climate change in Serbia, the arithmetic means of the numerous available data related to time and area are used.

Based on the data provided by the Republic Hydrometeorological Service of Serbia, the thermal conditions in Serbia in period 1950-2008. were assessed by using the normalized deviations from the annual air temperatures. The deviations were determined based on the climate standards over the period 1961-1990. The period was analyzed as a whole.

The normalized deviations, which point how many standard deviations the individual value is above or below the normal level, are used for the presentation of the deviation from the normal level.

The analytical method, which implied the use of the results of the previous researches on the climate parameters, their change and effects on the condition of forest ecosystems in Serbia, was applied. The data provided by the Republic Hydrometeorological Service of Serbia, Public Enterprise „Srbijasume", The Ministry of Agriculture, Forestry and Water Management - Forest Directorate, Republic Agency for Spatial Planning, Spatial Development Strategy of Serbia from 2009 to 2020, Spatial Plan of the Republic of Serbia until 2020, as well as the suitable scientific papers, studies, projects and monographs dealing with this problem, were analyzed and processed.

The proposed measures are based on the previous works and experiences that have proved effective.

3. THE CLIMATE CHARACTERISTICS AND CLIMATE CHANGE IN SERBIA

It is known that the occurrence and survival of vegetation in certain area, its distribution and altitudinal differentiation, along with the other ecological conditions, to a great extent also depends on the climate characteristics of the area. The numerous researches point out to this fact: Kolic [4,5], Jovanovic and Kolic [6], Krstic [7], Krstic et al. [8], Smailagic et al. [9], Krstic and Cirkovic [10] etc.

According to Rakicevic [11], three climate regions are singled out in Serbia: continental, moderate-continental and alternated continental. The greatest part of Central Serbia is characterized by the moderate-continental climate.

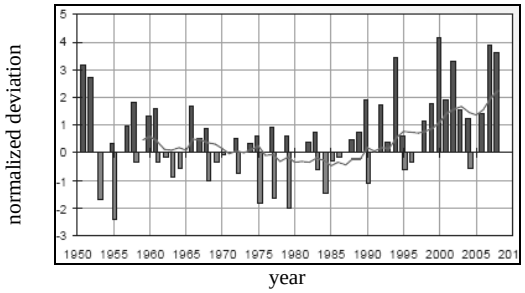
Over the period 1950-2008 the following climate parameters were reported in Serbia:

- trend of the increase of the mean annual air temperature (about 1.2 °C in the 20th century) in most parts of the territory, except for southeast Serbia, where the less negative trend of air temperature was reported;
- decrease of the annual amount of precipitation (the highest decrease – about 120 mm was reported in Negotinska Krajina);
- occurrence of the extreme precipitation,
- increase of soil erodibility,
- deterioration of the physical soil characteristics,
- decrease of the protective role of vegetation cover
- less favourable conditions for natural and artificial regeneration of mainly forest vegetation.

The scenario of partial application of measures aimed at decrease of emission of greenhouse gases (*A1B, SRES/IPCC*) implies that the mean air temperature in Serbia would increase by 3-4°C compared to the reference period

1961-1990, and the amount of precipitation would decrease by about 12% per a year, compared to the reference period, i.e. by about 24% in summer. However, if no measures are taken (Scenario *A2, SRES/IPCC*), considerably higher increase of air temperature is anticipated, particularly in summer (by 4-5 °C), as well as the greater decrease of precipitation, which would be equal to -30%, particularly in spring.

The normalized deviation of mean annual air temperature in Serbia over the period 1951-2008 is presented on the Graph 1.



Graph 1. *The normalized deviations, with ten-year average relative variability over the period 1950-2008 (data from RHMS of Serbia)*

The normalized deviation of the mean annual air temperature in 2008 is positive and higher than 3, which points out to the fact that it was extreme warmer than the normal value. It is visible that from 1998 to 2008 each year was warmer than the average (except for 2004-2005), so based on the results it can be concluded that in the Republic of Serbia the trend of increase of mean air temperatures will continue.

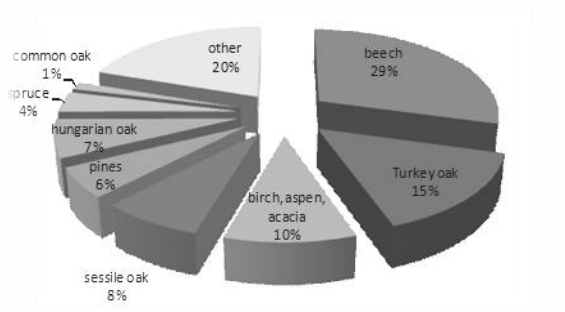
4. FOREST AREAS AND PERCENT OF SOME TREE SPECIES IN SERBIA

Serbia is considered to be a medium forested country. Forests account for 29.1% of the total area of Serbia (7.1% in Vojvodina, 37.6% in central Serbia). The other forest land, which by the international definition also includes bushes and scrubs, accounts for 4.9% of the territory, which in total accounts for 34.0% or 36.3% of the productive soil of Serbia [12].

Table 1. *The structure of areas (the way of use) by type of land in Serbia [12]*

Type of land	**Area**	
	ha	**%**
Forest	2,252,400.0	29.1
Other forest land	382,400.0	4.9
Unfertile soil	92,000.0	1.2
Agricultural land	3,594,800.0	46.4
Meadows and pastures	1,029,600.0	13.3
Urban land	312,000.0	4.0
Water areas	85,200.0	1.1
TOTAL AREA	**7,748,400.0**	**100.0**

By Bankovic et al. [12], 40 broadleaf and 9 conifer tree species were reported, as well as the uneven presence of the reported tree species in the total growing stock.



Graph 2. *The percent of some tree species in the total forest area in Serbia*

The beech is dominant, since it accounts for 29.0% of the total area, for 40.5% of the total volume, and it accounts for 30.6% of the total volume increment, the second dominant species is Turkey oak, which accounts for 15.0% of the total area, for 13.0% of the total volume, and for 11.4% of the volume increment. The most dominant conifer trees are Scots and Austrian pine, accounting for 6.0% of the total area. The pines account for 4.5% of the total volume, and 9.8% of the volume increment. Spruce accounts for 4.0% of the total forest areas, for 5.2% of the volume and for 6.7% of the volume increment.

In the forests of the primary natural origin, the beech, which accounts for 56.5% of the total area, is the most dominant species, whereas the percent of other categories ranges from 0.7% (ash and maple forests) to 8.7 % (spruce forests). In coppice forests of Serbia, the most dominant category of forest are the Turkey oak forests, accounting for 22.4%, beech forests, accounting for 21.3%, black locust forests (aspen and birch forests), accounting for 13.5%, Hungarian oak forests, accounting for 9.7%, sessile oak forests, accounting for 8.8%, and hornbeam oak forests, accounting for 7.8% of the total forest area.

The beech, as the most dominant broadleaf species in Serbia, is a mesothermal species, well-adapted to the moderate temperatures, quantities of moisture, and shady conditions (sciophytes). In contrast to the beech, most oaks in Serbia are xerothermic (they grow at dry and warm sites) and light-loving species (heliophytes). Regarding conifers, pines are light-loving species, adaptable to the ecological condition of temperature, moisture and soil. The spruce and fir are sciophilic, i.e. shade-loving species.

Based on the calculations and analysis, it can be concluded that the Serbian forests are characterized by the relatively high potential carbon-dioxide absorption from the atmosphere and thereby they significantly contribute to the alleviation of the adverse effects of the climate change. Based on the preliminary calculation, there are around 120,237.000 tonnes of carbon-dioxide in the Serbian forests, and around 5,000.000 tonnes of CO_2 is absorbed annually (NFI). Given the flexible mechanisms of Kyoto Protocol, above all the Emissions Trading, it is clear that this potential is important, particularly when the fact that the price of tonne of CO_2 continuously increases at the world market is taken into account. Since the price

per ton of CO_2 is around 29 Euros, in the financial sense, it is easy to demonstrate the importance of forests regarding the absorption of CO_2 from the atmosphere in this way.

5. ADAPTIVE MEASURES OF FOREST MANAGEMENT

Environmental pollution leads to numerous ecological problems, climate changes and global warming, creating negative impact on forest ecosystems: rapid deforestation and forest degradation, biodiversity loss, occupation of habitats by allochthonous species, change in pollination system, change in plant dispersion and regeneration, change in forest growth and ecosystem biomass, change in relation between species/habitat, change in ecosystem nitrogen cycle, increased mortality due to climatic stress and reduced forest ecosystem vitality and health due to cumulative impact of different stresses [13].

Roberts et al. [14] provide survey of current forest management trends which are promoting forest and forestry adaptation to new climate changes. The proposed management measures are mainly oriented to creation of stable, resistant to negative climate changes, forests. The management model which aims at preserving forests in their most natural form, avoiding mono-cultures and creating mixed forests, both in the structure of species and age, is supported. Furthermore, it aims at maintaining natural or nature appropriate regeneration, as methods of maintaining genetic diversity, and consequently, forest ecosystems sensitivity reduction.

There is a large number of potential methods, related to resolving issues that have arisen in forestry owing to global climate change and forest adaptation to new environmental conditions [15-27].

Surveys of potential strategic and operational methods of adaptation, which can be implemented as adaptive measures of forest management are:

- strictly comply with legal provisions concerning prevention of unlimited and unrestrained wood felling;
- protect climate refugia by different measures;
- minimise habitat fragmentation and maintain connectivity;
- protect high forests;
- strategically increase the size and number of protected areas, particularly in exceptionally valuable habitats;
- protect most endangered ex-situ species;
- create artificial forest reservations or arboreta for the purpose of rare species preservation;
- improve regional co-operation concerning species management and protection;
- support changes in distribution of endangered and sensitive species by means of their introduction to new areas;
- in artificially planted woods and mixed cultures, encourage natural genetic diversity, imitate the structure of neighbouring forests and avoid direct substitute of natural ecosystem;
- maintain seed sources (seed banks and seed facilities);
- allow forest regeneration through natural succession after large disturbances wherever possible;

- plant and sow genotypes resistant to draught and other climate extremes, insects and diseases;
- increase genetic diversity of trees used in setting up plantations;
- reduce stress factors not linked to climate conditions, in particular air pollution, in order to increase ecosystem ability to respond to climate change;
- re-cultivate degraded area in order to preserve genetic diversity and improve ecosystem health;
- carry out monitoring of all forests by means of establishing and improving national, regional and operational network for monitoring forest health condition, and subsequently, diagnostic – forecast services, as well as services for invasive species distribution monitoring;
- actively implement control measures against pests and diseases;
- improve plantation stability by means of increasing species and structure diversity;
- increase use of commercial thinning in draught areas in order to increase tolerance of remaining trees and to introduce species tolerant of draught, where possible;
- increase people's awareness in regard to potential impact of climate changes on fire regime and promote proactive actions in regard to fuel management and community protection.
- include climate parameters in forest growth and production models;
- apply thinning or selective removal of suppressed, damaged trees of poor quality;
- adapt the time of annual wood felling in such a way that forest processes remain in a state of most possible balance.

It is certain that implementation of number of measures aiming at adapting forests to climatic changes conveys a degree of uncertainty. Essentially, adaptive forest management can be understood as a systematic process aiming at constant improving of management policy and practice itself by monitoring, and later, learning by means of analyses of operative programmes results [28].

6. CONCLUSION

Given the fact that the previous global warming of the atmosphere equal to about 1°C caused the significant global, regional and global climate change, and taking into account the anticipations and effects of climate change, it can be concluded that Serbia is one of the world regions which are very susceptible to the climate change.

The above climate parameters point out to the increased risk of the desiccation of forest plantations and natural forest occupying great areas. Given the possible irreversible processes in the climate system with the immeasurable consequences to the living world, it is necessary to take the preventive measures aimed at alleviation of the effects of the climate change and adaptation to the altered climate conditions. All activities regarding the monitoring and studying of the climate change and its influence should be designed in order to provide the long-term systematic, comprehensive and continuous monitoring and forecasting of the conditions of the local and regional climate. The suitable anticipations of the

climate change and update of the database will point out to the needs and application of the sector strategies and action plans for the adaptation and measures aimed at alleviation.

The fact that the climate change occurs much more rapidly than it was anticipated has pointed out to the need to incorporate the problems regarding the adverse climate change on the natural resources in the priorities of the National Strategy of Scientific and Technological Development of Serbia. It is needed to conduct the continuous researches and monitor the influence of the climate change on the vertical and horizontal zoning of vegetation, alternations in the current forest ecosystems and effects of this change during the establishment of new forests.

The previous activities aimed at reforestation, tending and regeneration of forest ecosystems were based on the climate parameters from the previous multi-annual period and did not take into account the recent climate change which was reported in Serbia as well.

The complexity of forest ecosystems and numerous ways in which the society use and misuse them, as well as the fact that the forest ecosystems in Serbia are endangered by different factors, requires the application of the range of different protective measures. These measures, above all, include the suitable normative-legal and organizational-institutional mechanisms, suitable standards and practice in the domains of forestry. By integrating all these measures it is possible to achieve the higher degree of the environmental protection and sustainable forest management, even under the altered climate conditions, which are the results of the global warming.

The concept of the spatial development of the Republic, aimed at the alleviation of the effects of global warming and climate change on the forest ecosystems in Serbia, should include the determination of the effects of climate change on the availability of the natural resources, above all forest ecosystems and biodiversity aimed at planning sustainable development and ecologically acceptable activities in the domains susceptible to the climate change. It implies the adoption and application of new measures aimed at preservation and protection of forest land in accord with international conventions, national plans and sector strategies, as well as legal regulations from the domain of spatial planning.

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Original scientific paper

INDIAN SHOOT (*CANNA INDICA* L.) IN PHYTOREMEDIATION OF WATER CONTAMINATED WITH HEAVY METALS

Nevena CULE[1], Ljubinko JOVANOVIC[2], Dragana DRAZIC[1],
Milorad VESELINOVIC[1], Suzana MITROVIC[1], Marija NESIC[3]

Abstract: *This paper presents the results of experiments with the plant indian shoot (Canna indica L.), which were conducted in order to obtain the exact indicators of the plant potential for the removal of heavy metals (lead) from the aquatic environment and biomass production. Heavy metals such as Cd, Hg, Pb, As, Tl and U, which can be detected in industrial and other wastewaters have no biological value for living organisms, but are extremely toxic even in relatively low concentrations. Alternative methods that use plants to remove pollutants from contaminated water, soil and air, can be named as phytoremediation. This term refers to the diverse complex of technologies based on the use of natural or genetically created plants for the purpose of removal of pollutants from the environment or their transformation into nontoxic forms. Indian shoot is just one of the plants that have been used recently in constructed aquatic ecosystems. This plant has experimentally been proved to be very tolerant to the absence of nutrients, and able to produce large amounts of biomass. In the water it develops a very thick strong fibrous root system with a large area for the adoption of heavy metals. It is highly tolerant to the presence of lead and is able to absorb and store it in the root and rhizome due to low translocation to aboveground parts.*

Key words: *Canna indica* L., phytoremediation, heavy metals, aquatic environment, biomass

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KANA (*CANNA INDICA* L.) U FITOREMEDIJACIJI VODA ZAGAĐENIH TEŠKIM METALIMA

Izvod: *U radu su predstavljeni rezultat eksperimenata sa biljkom kana (Canna indica L.), koji su postavljeni u cilju dobijanja egzaktnih pokazatelja o potencijalu ove biljke za uklanjanje teških metala (olova) iz akvatičnih sredina i produkciji biomase. Teški metali, kao što su Cd, Hg, Pb, As, Tl i U i koji mogu da se detektuju u industrijskim i drugi otpadnim vodama nemaju biološku vrednost za žive organizme, već su izuzetno toksični i u relativno malim koncentracijama. Alternativne metode, koje koriste biljke za uklanjanje polutanata iz kontaminiranih voda, zemljišta i vazduha bi jednim imenom mogle da se nazovu fitoremedijacija. Ovaj pojam se odnosi na raznovrsan kompleks tehnologija, koje se baziraju na upotrebi biljaka, prirodnih ili genetski stvorenih, radi uklanjanje polutanata iz životne sredine ili radi njihovog pretvaranja u netoksične oblike. Kana je samo jedna od biljaka, koja se u poslednje vreme sve više koristi u konstruisanim akvatičnim ekosistemima. Ona se u eksperimentima pokazala kao biljka vrlo tolerantna na odsustvo hranljivih materija i biljka koja može da stvara veliku količinu biomase. U vodi razvija izuzetno gust, jak i žiličast korenov sistem sa velikom površinom za usvajanje teških metala.Vrlo je tolerantna na prisustvo olova, koje lako usvaja i koncentriše u korenu i rizomu, jer je translokacija u nadzemne delove slaba.*

Ključne reči: *Canna indica* L., fitoremedijacija, teški metali, akvatična sredina, biomasa

1. INTRODUCTION

The soil and water contaminated with heavy metals present a major environmental problem, which has an extremely negative impact on the environment and people, and is still in need of an efficient and cost-effective technological solution. The basic idea that plants can be used for environmental remediation is certainly very old and there is no information regarding its first-time use to remove various pollutants from contaminated media. However, a series of scientific discoveries, combined with interdisciplinary and multidisciplinary research supported the development of this idea into a promising environmental protection technology called phytoremediation. Phytoremediation is defined as the use of plants for the removal or immobilization of contaminants from the environment (Cunningham and Ow, 1996).

Phytoremediation of metals is a cost-effective green technology based on the use of specially selected plants that can accumulate and remove heavy metals, including radionuclides from soil and water. This technology takes advantage of the fact that a living plant can be compared to a solar-powered pump that can extract certain elements from the environment and concentrate them in its tissues. This method is becoming possible thanks to the successful basic and applied research.

Metals that can be removed through various processes of phytoremediation include lead, cadmium, chromium, nickel, arsenic and various radionuclides. Removed plants, rich in accumulated pollutants, can easily and safely be processed by drying, burning or composting. Some of the metals can be re-extracted from the

ashes, which further reduces the generation of hazardous waste and accelerates the creation of profit.

A particularly significant method in the phytoremediation of water is rhizofiltration. This method is based on the use of plant roots for the absorption and adsorption of pollutants, mainly metals, from water. A particular type of *ex situ* rhizofiltration facility is a constructed aquatic ecosystem.

Wastewater treatment using these alternative systems is a process that is far cheaper than conventional wastewater treatment. With minimal maintenance and minor consumption of labor as well as no expenditure of electrical energy, these systems provide second category water - technical water, which can be used as drinking water after a minimal additional treatment. Through further development, this technology could become the future leading technology in wastewater treatment and the recovery of water bodies.

To date, over 400 plant species that can hyperaccumulate metals have been identified. Families with the largest number of such representatives are: *Asteraceae, Brassicaceae, Caryophyllaceae, Cyperaceae, Cunouniaceae, Fabaceae, Flacourtiaceae, Lamiaceae, Poaceae, Violaceae* and *Euphorbiaceae* (Prasad and Freitas, 2003).

Most of these plants can successfully be used in the local climatic conditions of Serbia. The most significant species which stand out are: reed (*Phragmites communis* Trin.) bulrush (*Schoenoplectus lacustris* (L.) Palla), broadleaf cattail (*Typha latifolia* L.), yellow flag (*Iris pseudoacorus* L.), soft rush (*Juncus effuses* L.), duckweed (*Lemna minor* L.), water mint (*Mentha aquatica* L.) and water plantain (*Alisma plantago - aquatica* L.).

According to literature data, wastewater treatment also involves the use of other plants, including: *Butomus umbellatus* L., *Carex hirta* L., *Menyanthes trifoliata* L., *Bidens tripartita* L., *Carex rostrata* Stokes, *Myosotis scorpioides* L., *Caltha palustris* L., *Deschampsia cespitosa* (L.) P.Beauv., *Nasturtium officinale* L., *Canna indica* L., *Eupatorium cannabinum* L., *Phalaris arundinacea* L., *Carex vulpinoidea* Michx., *Euphorbia palustris* L., *Persicaria hydropiper* (L.) Delabre, *Carex vesucaria* L., *Filipendula ulmaria* (L.) Maxim., *Polygonum bistorta* L., *Carex pseudocyperus* L., *Gladiolus palustris* Gaudin., *Rumex hydrolapathum* Huds., *Carex pendula* Huds., *Gratiola officinalis* L., *Sagittaria sagittifolia* L., *Carex acutiformis* Ehrh., *Humulus lupulus* L., *Scirpus palustris* L., *Carex elata* All., *Lychnis flos-cuculi* L., *Solanum dulcamara* L., *Carex gracilis* R.Br., *Lysimachia nummularia* L., *Symphytum officinale* L., *Carex disticha* Huds., *Lysimachia vulgaris* L., *Valeriana officinalis* L., *Carex riparia* Curtis, *Lythrum salicaria* L., *Veronica beccabunga* L., and others (Gawronski and Gawronska, 2007, Matagi *et al.*, 1998, Kamal *et al*., 2004, Prasad and Freitas, 2003, Kumar *et al*., 1995).

In addition to the above plants, various edible plants, agricultural and vegetable crops and ornamental and woody plants are used in phytoremediation. Various biofilters are also in use (Gawronski and Gawronska, 2007).

Indian shoot (*Canna indica* L.) is one of the plants, which has several important characteristics suitable for phytoremediation.

1.1 Indian shoot (Canna indica L.)

Canna species constitute important floral material of all urban areas. They are most often planted over large areas, such as for example, squares, areas along roads, parks and parterres of representative green spaces, thereby increasing their aesthetic effect. In addition to their exceptional decorativeness, they are important for phytoremediation because they successfully remove heavy metals and other pollutants from soil and water. Cannas are known for their leaves, on whose large surface areas various pollutants from the air (dioxins, polycyclic aromatic hydrocarbons and polychlorinated biphenyls) are deposited and thus removed from the atmosphere (Gawronski and Gawronska, 2007). The plants of this family are particularly interesting because of the high biomass that they develop in different soils and especially in the aquatic environment.

Indian shoot (*Canna indica* L.) is a perennial tropical and subtropical plant growing to a height of 0.5 m to 2.5 m, with an underground stem (rhizome) (Maas-van de Kamer and Maas, 2008). The natural range of this plant are South America and India, but it is widespread in almost all cities of the world, where it is used as a decorative floral species in different categories of green areas and their various compositions.

Table 1. *Systematics of the Canna species (Canna indica L.)*

Regnum	*Plantae*
Clade	*Angiospermae*
Clade	*Monocotyledoneae*
Clade	*Commelinidae*
Ordo	*Zingiberales*
Familia	*Cannaceae*
Genus	*Canna sp.*
Species	*Canna indica* L. - indian shoot

It has a very wide application. It is used in medicine, and its starchy rhizome is used in nutrition. Paper is made from the fibers of its leaves and stems. The seed is used in jewelry making, and it used to be used instead of rifle bullets. Purple color is obtained from the seeds. Young seeds and young shoots can be used in nutrition (Maas-van de Kamer and Maas, 2008). The fibers obtained from stems are used as a substitute for jute. This plant has a large biomass production and in some countries is used for thermal energy production i.e. as biofuel (State Master, 2010).

In recent years, indian shoot is increasingly grown in constructed aquatic ecosystems, in order to improve the quality of lakes and rivers and remove various pollutants from wastewater (Zhang *et al*., 2008). An example of such usage are floating islands made of indian shoot, which are ever more widely used for the refining of eutrophic water, mainly because of their low cost and easy construction.

Fig. 1. *Floating islands with indian shoot (Canna indica L.)*

Such floating islands can remove nitrogen from polluted water to a large extent, especially if the medium is supplemented with denitrifying bacteria and if aeration is introduced into the system (Sun *et al.*, 2009). Five days after the onset of the experiment the total removal of nitrogen (N) in the combined islands is 72.1%, oxidation of ammonia nitrogen (NH4 +-N) 100%, oxidation of nitrate nitrogen (NO3 - N) 75.8%, oxidation of nitrite nitrogen (NO2 - N) 95.9% and chemical oxygen consumption is reduced by 94.6% (*Sun et al.*, 2009).

In their experiment Bose *et al.* (2008) proved that *Canna indica* L. absorbs different heavy metals (Cr, Fe, Cd, Cu, Ni, Zn, Mn and Pb) well, when grown on contaminated soils supplemented with different amounts of industrial sludge. The order of absorbed metals in indian shoots, on the 90^{th} day from the experiment setup, was Fe> Cr> Mn> Zn> Ni> Cu> Cd> Pb, whereas the translocation was almost two times higher in roots than in shoots. With the increasing percentage of sludge in the soil, the concentration of the metal in different parts of the plant grows. The length of roots and shoots also depends on the changes in soil sludge. The growth is good in the soil supplemented with 10% of sludge, whereas at 20% and 30% concentrations of sludge, a slow decline in root and stem growth can be observed, although without visible toxic signs. The decline in root growth suggests that most of the metals are accumulated in the underground parts of these plants.

In their study, Cheng *et al.* (2002) showed the effects of Cd^{+} on the growth of the plant *Canna indica* L., its chlorophyll content, photochemical efficiency and photosynthetic intensity. It is shown that this species can tolerate concentrations from 0.4 to 0.8 mg L^{-1} Cd^{2+}, which indicates that it can be used in the phytoremediation of heavy metals.

The field of research of indian shoot, as a plant for the production of biofuels, is still relatively new, but many studies have shown that it has great potential, due to its extremely high starch production and equally successful cultivation in tropical and temperate climates (State Master, 2010).

For the purpose of the project "Research opportunities for the production of biomass for the energy from short rotation plantations within the electrical power system of Serbia" (TR 18201A) several experiments were set up by the Institute of Forestry in Belgrade in order to determine the ability of indian shoot to remove heavy metals from wastewater and determine the amount of biomass produced by this plant in contaminated water.

2. MATERIAL AND METHOD

Plant material was obtained from the rhizome of the species *Canna indica* L. - indian shoot. In early April rhizomes were planted in peat in order to get well-cultivated seedlings, which can be transferred to aqueous solutions.

An experiment in the open was set up, within the research area of the Institute of Forestry in Belgrade, to monitor the growth of indian shoot in the aquatic environment. In late July each plant was transferred to a 10 l volume bucket, which was half-filled with tap water. The experiment lasted until mid-September, and the water was changed several times. The measuring of the parameters of growth to determine biomass production was carried out at the beginning and the end of the experiment.

The efficiency of indian shoot in the removal of heavy metals was tested in an experiment under laboratory conditions. In early May, seedlings of indian shoot were transferred to buckets with 5 l of modified 50% Hoagland solution. In late May, this nutrient solution was changed and supplemented with three different concentrations of lead (10μM, 50μM and 150μM). Two parallel experiments were set up, in which lead was supplemented to one group of plants in the form of $Pb(NO_3)_2$, and to the other in the form of $Pb(CH_3COO)_2 \times 3H_2O$. The experiments lasted 20 days. The measurements of lead content in the solution and the plants were carried out every 5 days.

The plants were taken out from the solution and divided into roots, rhizomes, stems and leaves. The solution was sampled to determine the residual Pb. All plant parts were washed three times in distilled water. The fresh weights of stems, leaves, rhizomes and roots were measured, as well as the volumes of the rhizomes and roots. The leaves and shoots of the rhizomes were counted and leaf area was determined. Plant parts were then dried for 24 hours at 80^{o}C. Dry weights of the stems, leaves, rhizomes and roots were measured after drying.

Microwave digestion (CEM MDS 2000, Berghof, Germany, Mod. Speedwave MWS3 +) was used for sample preparation. About 250-300 mg of dried homogenized plant material was added to special Teflon vessels and the quantities of 5 ml of 69% HNO_3 and 2 ml of 30% H_2O_2 were used for destruction. After microwave digestion the samples were diluted in distilled H_2O (total volume 25 ml). The measuring of lead content was performed using an ICP-AES spectrometer (Spectro Genesis FEE, Germany).

3. RESULTS AND DISCUSSION

The two most important characteristics that a plant suitable for phytoremediation should have are the ability to quickly produce large amounts of

biomass and the ability to absorb metal in large quantities in the shoots (Kumar *et al*., 1995, Cunningham and Ow, 1996, Blaylock *et al*., 1997). So, the combination of high metal accumulation and high biomass production provides the best results in the removal of metals.

Other desirable characteristics of plants are tolerance to poor environmental conditions, production of a dense root system, the ease of establishment and growing and resistance to pests and diseases. Dushenkov and Kapulnik (2000) describe the characteristics of an ideal plant for rhizofiltration. These plants have to be able to accumulate and tolerate significant amounts of targeted metals, but should also be easy to handle, have low maintenance costs and low production of secondary waste that requires disposal. It is desirable that these plants produce significant amounts of root biomass or have large root area.

The results of the experiment that examined the growth of indian shoot in the aquatic environment suggested that *Canna indica* L. possesses one of the most important characteristics of the plants suitable for phytoremediation and that is high biomass production in a short time. In mid-September, after a month and a half of growth without fertilization, the Canna plants produced a significant amount of biomass both of the aboveground and underground parts.

Fig 2. *The beginning of the experiment in late July (left), the size of plants at the beginning of the experiment (middle) and the size of plants in mid-September (right).*

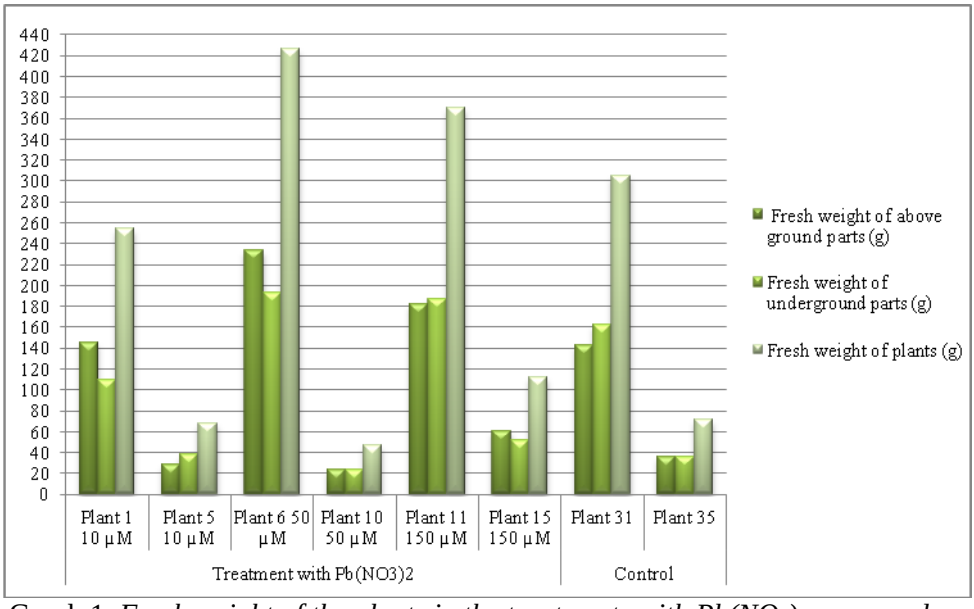
Besides that, these plants developed very dense strong fibrous roots with a large area for the sorption of metals. This further confirmed the fact that terrestrial plants are more suitable for rhizofiltration than aquatic plants. Aquatic macrophytes often have limited rhizofiltration potential, because of their insufficient effectiveness in the removal of metals due to their relatively small root and its slow growth (Dushenkov *et al.*, 1995). The same authors argue that the high water content in these plants complicates their drying, composting or burning.

In this experiment indian shoot revealed its tolerance to the absence of plant nutrients in the solution (plants were grown in pure water without fertilizers). The establishment and cultivation of the seedlings was very easy. The total absence of pests and diseases that could threaten the plant was observed.

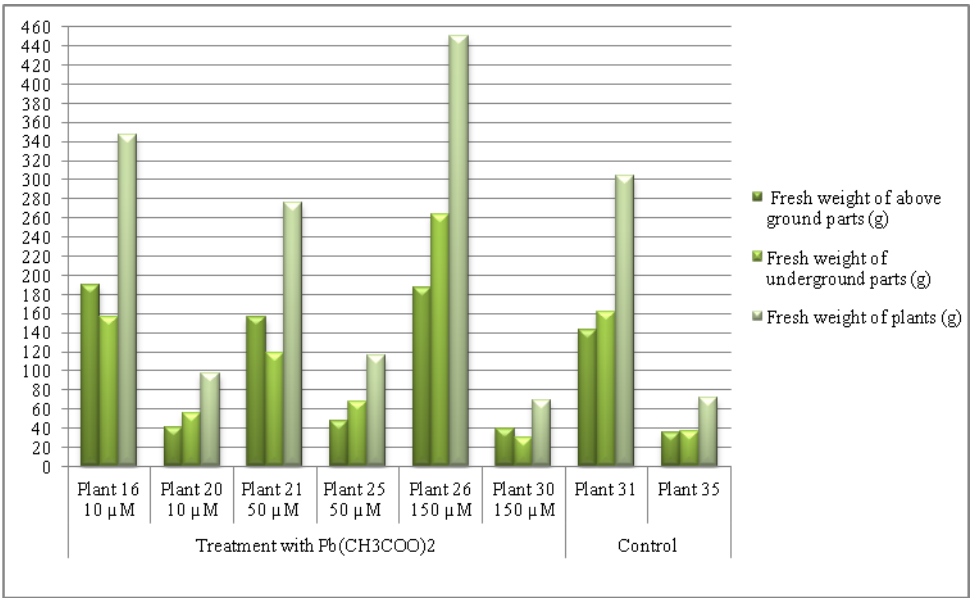
The second experiment indicated that *Canna indica* L. plants were extremely tolerant to the presence of heavy metals, in this case lead, in the medium in which they grew. Specifically, they revealed excellent growth even in the medium with the highest lead concentration (150μM $Pb(NO_3)_2$ and $Pb(CH_3COO)_2 \times 3H_2O$).

Fig. 3. *A part of Canna indica L. plants at the beginning of the experiment (left) and the appearance of the plants in the mid-experimental period (right).*

The graphs below show the results of the measurements of fresh and dry weights of the aboveground and underground parts of the *Canna indica* L. plants on the 9th day of the experiment.



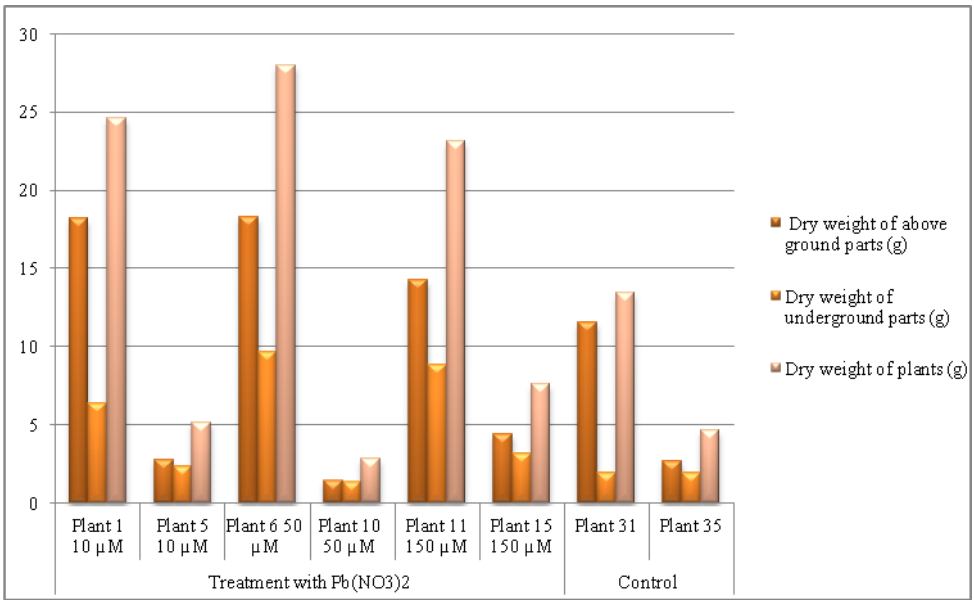
Graph 1. *Fresh weight of the plants in the treatments with $Pb(NO_3)_2$ measured on the 9th day of the experiment*



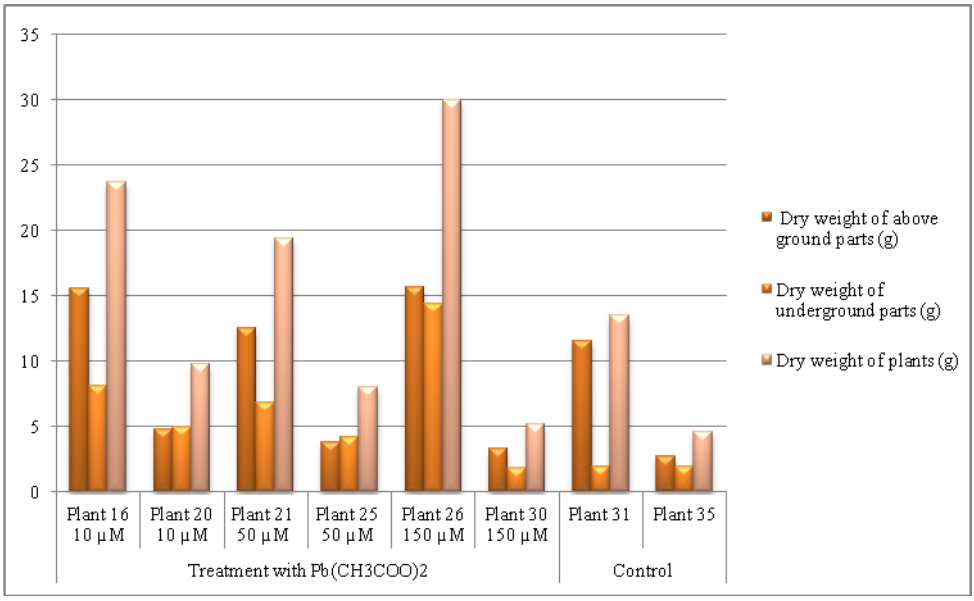
Graph 2. *Fresh weight of the plants in the treatments with $Pb(CH_3COO_2$ measured on the 9^{th} day of the experiment.*

As can be seen from the results, fresh weight ratio of the aboveground and underground parts of the plants does not vary and it is on average 50:50. This is another indication that, in water, *Canna indica* L. plants tend to develop good root system and rhizome in which they storage substances.

The ratio of the dry weights of the aboveground and underground parts of the plant is slightly different. In small plants (plants 5, 10, 15 and 35) this ratio is retained, i.e. on average amounts to 55:45, whereas in large plants (plants 1, 6, 11 and 31), which have a larger rhizome, the ratio is different (on average 70:30), indicating that the underground parts of these plants contain plenty of water. This may be an aggravating circumstance in the further processing of biomass after the process of refining. On the other hand, this water content is far lower than that of the aquatic plants used for the same purpose, whose drying, composting or burning often consumes more energy. The most frequently-mentioned examples of these plants are *Eichhornia crassiper* (Mart.) Solms. (water hyacinth), *Hydrocotyle umbellata* L., and *Lemna minor L.* (duckweed), which have a high ability to absorb heavy metals, but a limited rhizofiltration potential due to their relatively small root, its slow growth and high water content (Dushenkov *et al.*, 1995)

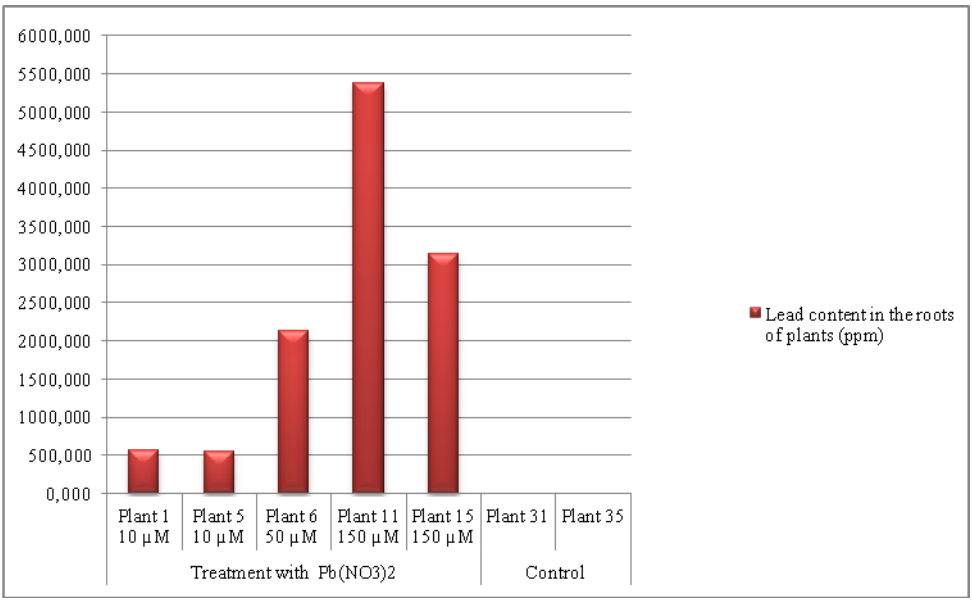


Graph 3. *Dry weight of the plants in the treatments with $Pb(NO_3)_2$ measured on the 9^{th} day of the experiment.*

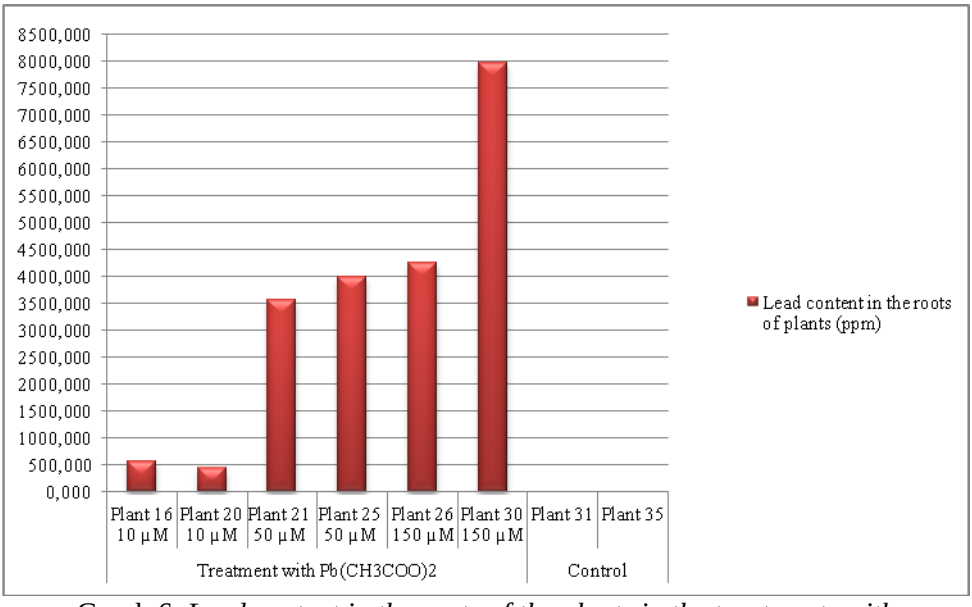


Graph 4. *Dry weight of the plants in the treatments with $Pb(CH_3COO)_2$ measured on the 9^{th} day of the experiment.*

According to the analysis of lead content in the plants and the solution it was observed that the *Canna indica* L. plants absorbed most of the lead from the solution until the fifth day of the experiment. The absorption was continued until the last day, and the highest lead content in plant tissue was recorded in the root.



Graph 5. *Lead content in the roots of the plants in the treatments with $Pb(NO_3)_2$ measured on the 9th day of the experiment.*



Graph 6. *Lead content in the roots of the plants in the treatments with $Pb(CH_3COO)_2$ measured on the 9th day of the experiment.*

As can be seen from the results shown in graphs 5 and 6, the plants were slightly more successful in the absorption of lead from the treatment with $Pb(CH_3COO)_2$. This can be explained by the fact that lead (II) acetate dissolves well in water. The maximum absorption of lead until the 9th day of the experiment occurred in the roots of plant 11 from the treatment with 150µM $Pb(NO_3)_2$ and it

amounted to 5369.384 ppm of lead and the root of plant 30 from the treatment with 150μM Pb $(CH_3COO)_2$, which amounted to 7973.518 ppm of lead. The concentration of lead was the lowest in the leaves, which indicates low mobility of this heavy metal through the plant.

Plants used for phytoremediation have to be tolerant to the metal or metals, which are being removed, as mentioned before. In addition to that, they also have to be efficient in the translocation of the metals absorbed by the roots to the aboveground parts of plants that are to be mowed (Blaylock and Huang, 2000). It should be noted that there are different opinions regarding the benefits of the translocation of absorbed metals from the roots to other parts of plants, especially when rhizofiltration is concerned. Many researchers believe that plants used for phytoremediation should accumulate metals only in their root system (Dushenkov *et al*., 1995, Salt *et al.,* 1995; Flathman and Lanza, 1998). Dushenkov *et al.* (1995) explained that the translocation of metals to the aboveground shoots would decrease the efficiency of rhizofiltration by increasing the amounts of contaminated plant residues, which would have to be disposed of. In contrast, Zhu *et al.* (1999) suggest that the efficiency of the process can be increased if plants have an increased capacity for the absorption and translocation of metals in the plant. Despite these differences in opinions, it is obvious that proper selection of plants is the key in ensuring the success of rhizofiltration as a strategy for water refining.

If further experiments confirm that the translocation of lead from root to leaves in indian shoot is low, this will indicate the possibility of using the aboveground biomass of this plant for a variety of purposes, and not only for the production of biofuels.

4. CONCLUSION

Heavy metals, radionuclides and other inorganic pollutants are some of the prevailing forms of environmental pollutants and their remediation in soil, sediments and water is very hard. Unlike many organic pollutants most heavy metals cannot be eliminated from the environment by chemical and biological transformation. Therefore attention should be paid to the prevention of their entry into the environment and there is a need to work on new alternative methods for their removal.

The accumulation of metals and especially hyperaccumulation using plants have caused a lot of interest in recent years. Ebbs *et al.* (1997) argued that, in order to achieve successful phytoremediation, it is necessary to apply a combined strategy of rapid screening of the plant species with an ability to tolerate and accumulate heavy metals and agronomic practices that would increase the biomass of shoots and the availability of metals in the rhizosphere (Kamal *et al* ., 2004). Finding the right plants remains the main goal of many researchers involved in plant breeding and genetic engineering.

In the experiments, Canna (*Canna indica L.)* proved to be a very promising plant. Although it is a terrestrial plant, which has so far mainly been used as a decorative floral species in green areas and needs some kind of support in the water

for refining, such as floating platforms, it generally removes larger quantities of pollutants than many aquatic plants capable of phytoremediation.

As shown this plant is very tolerant to the lack of nutrients. It can produce a large amount of biomass in a short time. It develops a very dense, strong fibrous root system in water, with a large surface area for the filtration and absorption of heavy metals. It is easy to produce and cultivate, and is resistant to pests and diseases. It is highly tolerant to the presence of lead, which is easily absorbed and concentrated in its root and rhizome, due to the low translocation to aboveground parts.

Rhizofiltration is a competitive technology in terms of cost, when used for the treatment of surface and ground waters, which contain low but significant concentrations of heavy metals such as Cr, Pb and Zn. The commercialization of this technology is supported by the economic and technical advantages such as its applicability to different metals, the possibility to treat large quantities of water, decreased need for a variety of toxic chemicals, reduced volume of secondary waste, the possibility of recycling and the likelihood of acceptance of this technology by the public and authorities.

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FOREST CONDITION MONITORING: INTENSIVE MONITORING OF AIR POLLUTION IMPACT ON FOREST ECOSYSTEMS AT LEVEL II SAMPLE PLOT KOPAONIK

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Abstract: *Rational use of different sources of raw nature materials is the primary postulate of the environment conservation. Sustainable development provides the basis for this approach, which in addition to striving for optimization of technological processes, includes the optimum nature protection and prevention of adverse effects of mining sub-product resulting from natural resource exploitation.*

The prosperity of human society through economic growth should be achieved in such a way that its consequences remain limited within the boundaries of the capacity of the environment to accept the loading and avoid permanent disorders. ICP Forests program is implemented in order to prevent specific effects of pollution and the impact of pollutants on forest ecosystems and forest land put under surveillance, through Levels I & II, so as to form a high-quality, usable and functional database on these phenomena, for the territory of the European continent. Level II monitoring of forest vitality is a versatile system of research of many different subjects. Forest ecosystems are highly complex entities characterized by different variation due to continuous activity inherent in biotic and biotic factors.

Evaluation criteria for intensive monitoring are all in compliance so that upon recording and statistical analysis, the obtained data on forest conditions, are easy to compare analytically and logically, providing the basis for a variety of comparative studies. Dedicated sample plots for intensive monitoring of trans- boundary air pollution impacts on forest ecosystems in Serbia – Level II sample plot was established in Kopaonik National Park in 2010, with eleven panels – from 11 separate forestry research areas, grouped according to the research subjects, which methodology is prescribed by ICP Forest Manual.

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Key words: air pollution, intensive monitoring, database, Serbia

PRAĆENJE UTICAJA AEROZAGAĐENJA NA ŠUMSKE EKOSISTEME - INTENZIVNI MONITORING NA OGLEDNOM POLJU NIVO-A II "KOPAONIK"

Izvod. *Racionalno korišćenje različitih izvora energetskih sirovina primarni je postulat u očuvanju životne sredine. Osnova ovakvog pristupa je održivi razvoj, koji pored težnje ka optimizaciji tehnoloških procesa, uključuje i optimalnu zaštitu prirode, odnosno prevenciju štetnog uticaja nuzprodukata nastalih eksploatacijom resursa iz prirode. Prosperitet ljudskog društva kroz ekonomski rast trebalo bi postići na način da posledice ostanu u granicama mogućnosti okoline da prihvati data opterećenja, i pri tome ne dođe do trajnih poremećaja. ICP forests je program implementiran kako bi se konkretni efekti zagađenja i uticaja polutanata na šumke ekosisteme i šumsko zemljište stavili pod nadzor, i kroz monitoring Nivo-a I i II, formirala kvalitetna, upotrebljiva i funkcionalana baza podataka o ovoj pojavi, na teritoriji Evropskog kontinenta. Monitoring vitalnosti šuma Nivo-a II, predstavlja višenamenski sistem predmetnih istraživanja. Šumski ekosistem, kao izuzetno složen entitet, odlikuju različiti parametri podložni konstatnim varijacijama usled neprestanog i neodvojivog delovanja abiotičkih i biotičkih činilaca. Kriterijumi procene koje intenzivni monitoring podrazumeva, usaglašeni su i tako određeni da se dobijeni podaci o stanju šuma, nakon unosa i statističke obrade analitički i logički lako porede, dajući osnovu za različite komparativne studije. Namenska ogledna površina za intenzivni monitoring uticaja prekograničnog vazdušnog zagađenja na šumske ekosisteme u Srbiji-bioindikacijska tačka Nivo-a II osnovana je u 2010. godini na Kopaoniku, sa deset radnih panela – iz 10 zasebnih stručnih oblasti šumarstva, grupisanih prema predmetu istraživanja, a metodološki propisanim Manual-om ICP-a za šume.*

Ključne reči. aerozagađenje, intenzivni monitoring, baza podataka, Srbija

1. INTRODUCTION

Air pollution created by burning of fossil fuels and industrialization in expansion coupled with the emission of enormous quantities of aerosols in the atmosphere are not characteristic only of large urban and industrial centres. Owing to natural processes of air mass movement, the air pollution does not «recognize» administrative and regional borders. Plants and forest trees as the base of the food chain develop under the conditions that have been altered in this way only up to a certain level of load. In broader zones of large city areas, and further on over huge territories of leading European countries, where excessive pollution and uncontrolled emission of harmful matter was present, massive dieback of forests occurred over the last few decades of the 20th century.

Regardless of whether they are located on the territory of economically developed or developing countries, almost all existing ecosystems on the planet are followed by deposits of large quantities of harmful phytotoxic substances or substances resisting degradation. Harmful matter such as heavy metals (sources include heavy industry and busy traffic arteries) and deposits of nitrogen and sulphur salts, as well as ammonia, were first recognized as direct factors in the following occurrences: dying out of the living world in the immediate surroundings

of factories and in water flows into which products of processing were released; indirect influence of pollution emitted into the atmosphere. Toxic matter gets into the nature through subterranean waters or acid rain from great distances. The origin of the pollution appears to be unknown, it is difficult to be directly recognized, the emitter of the pollution remains unidentified or under the jurisdiction of the neighbouring county or state, under «somebody else's» management or responsibility – in plain words, «someone else's» fault. Such occurrences on a massive scale caused decay of forest communities and separation of tree species with stronger resistance to air pollution that survived pushing back more sensitive species. During the 1970s and 1980s, forest dieback on a large scale spread through forests in Central and Western Europe, and became particularly notable in developed European countries.

Developed economy in these countries at the time included a multitude of plants for heavy industry, factories for processing of ores, coal and oil derivatives. Under such cumulative negative anthropogenic influence, the decay of forests in Europe, as extremely sensitive biocenoses and complex ecosystems, was inevitable. Over a period of time that was much too short for adaptation, fir proved to be the most sensitive species and decay of fir forests was the first to start. The political framework – evidence of the awareness of wider scientific and professional public on the escalating problem on the alarming scale, was provided by the Convention on Long-range Trans-boundary Air Pollution (CLRTAP) in 1979, which came into effect in 1983. Monitoring the dieback, first of fir forests and then forests of other coniferous species, slowly became a point of interest for creators of forestry policies in Europe, representing the beginning – awakening of collective awareness on the importance of preservation of forests and at least preventing the entire forest complexes from dying out (Nevenić et al, 2005). The foundation of the manual for continuous coordinated monitoring of forests was laid down at the working session of European Commission for forests in Freiburg in 1984, while in December of the same year the ICP forest program (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests - ICP Forests) held its first meeting. The next step was adoption of the Resolution no. 1 at the Ministerial Conference on Protection of Forests in Europe, which marked the beginning of implementation of Level II, the intensive monitoring programme.

To date, the condition of forests on the territory of Europe have been monitored at about 6,000 points at Level I, and since 1994 at about 800 testing plots separated for intensive monitoring. The assessment of health condition of forests in our country was conducted through assessing the condition of tree crowns on testing plots, bio-indication points of Level 1, when soil testing was performed for about 150 points (chemical and mechanical properties) (Kadović & Knežević, 2004) and chemical content of nutrition of the forest trees was analyzed.

2. METHODOLOGY

In order to preserve the forests through instruments of the politics and changes of laws regulating emissions of harmful matter, a way to stop the decay of forests was recognized. Nonetheless, the existence of the causal connection

between air pollution and forest decay may be proven only by means of authoritative and fundamental results of scientific research on a representative sample, according to the methodology designed for this specific task, through continuous intensive monitoring. The next step would be to put the polluters recognized in the wider or general surroundings under control by sanctions if the plants emit harmful matter into the environment without appropriate mandatory protective technology in the form of filters etc.

By setting up testing stations in Kopaonik National Park (2010) and in Fruska Gora last year, Serbia has joined the European network of over 800 Level II points. On the test plot in NP Kopaonik, the operative plan according to methodology for the stipulated assignments commenced immediately upon placement of the wire fence and geodetic survey of each tree on the plot. Level II sample plot in Kopaonik National Park covers an area of 0.5 ha (100 x50 m). During each visit to the plot, every team kept detailed records containing dates of works on continuous measuring or sampling of the materials, in the form of a field journal. A working version of the journal is provided in Table 1.

According to the set distribution plan of the test plots and specification of equipment necessary for conducting the experiment of intensive monitoring of the forest condition, the equipment for following the moist deposition process was set up: collectors passing through the tree crowns, collectors for sampling the depositions pouring down the trees, and collectors gathering forest leaf waste. Soil profiles were dug up and soil samples taken, while herborized material was collected in order to prepare phytocenological surveys from the spring, summer and fall aspects. Within the entire test plot, subplots for customized sampling were distributed and assigned as permanent to the same continuous measuring (3 subplots, 4 sub-fields in the middle one).

Table 1. *Working version of the field journal during the first year upon establishment of the Intensive Monitoring Test Plot – Level 2*

PUBLIC COMPANY "KOPAONIK NATIONAL PARK"				
Sequence	Test plot no. 2 (GJ Samokovska Reka, dept. 75)	Date of field visit	Team members	Type of the measured parameter or sampling
1				
2				
...				
n				

The Level II monitoring program comprised the following parameter groups: crown condition, foliar analyses, soil chemistry, soil solution chemistry, growth and yield, ground vegetation, atmospheric deposition, air quality, meteorology, phenology and forest litterfall. Given that not all monitoring is

continuous or annual, numbers of plots in European countries that submit reports vary from one year to the next (ICP Forests, 2010a). Frequency of monitoring the individual parameters is shown in *Table 2*.

Table 2. *Parameters, frequency of survey monitoring intensity for Level II (ICP Forests, 2010a)*

Parameter type	Frequency of sampling
Crown condition	At least annually
Foliar analysis	Every two years
Soil chemistry	Every ten years
Soil solution chemistry	Continuous
Growth and yield	Every five years
Ground vegetation	Every five years
Atmospheric deposition	Continuous
Air quality	Continuous
Ozone injuries	Annually
Meteorology	Continuous
Phenology	Several times a year
Forest litterfall	Continuous

3. RESULTS AND DISCUSION

Assessment of the crown condition: Assessing the crown condition on Level 1 has been practiced at the Institute for Forestry for many years, while the methodology of assessment served as basis for developing and perfecting the intensive monitoring methodological approach (Nevenić et al, 2011). The research in intensive monitoring for assessing the crown condition, as well as for the Level I, focuses on assessment of decolouration, defoliation and detecting the injuries, which are then used to derive the tree condition, crown shadow (damage), crown visibility, fructiferousness of the visible part of the crown, presence of secondary new branches. The trees are marked with permanent markings on the bark, bearing ordinal numbers 1-195, on 3 subplots and within the «buffer» zone (Nevenić et al, 2011). Out of the total number of spruce trees marked for the purpose, 30 spruce trees were selected within the subplot 2.

Sampling and analyses of assimilation organs for testing nutrition of the forest trees: Sampling of the leaves for testing the nutritive condition of forest trees was conducted using five dominant spruce trees. Concentrations of nutritive matter in the assimilation organs had highly notable seasonal variability. For this reason, sampling of spruce needles was carried out in late October, which is the period of stagnation of the vegetation in Kopaonik, when the assimilation organs comprise the representative concentration of nutritive matter. Sampling was conducted from the top third of the trees, where the assimilation organs had developed under favourable light conditions. For the foliar analysis, only one-year

needles were selected. The air pollutants are possible to detect by measuring the chemistry and quantity concentrations of certain matter in the plants (their living tissue and litterfall).

Floristic and vegetation research: Study of the ground vegetation was carried out in three aspects: spring, summer and fall. During the first year, floristic and vegetation research was conducted according to the prescribed methodology for data collecting and processing (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests - ICP Forests). Assessment of crown coverage of the present species on the levels of trees, shrubs and ground flora was carried out on 16th September 2010. For this purpose, four square-shaped test plots (10 x 10 m) were set up, covering the total area of 400 m^2 (ICP Forests, 2010a). Positions of the test plots are shown on the as-built plan for the Kopaonik station. In the field, the described plots are visibly marked.

Phenological observations: At Level II sample plot 15 spruce trees (*Picea abies* L.) were selected for phenological observation. Phenophases were observed continuously, in succession, and the following parameters were detected and monitored: budding, change in colour of conifer needles, significant indications of needle or crown damage, other damages (broken branches and trees and uprooted trees), secondary budding and blooming. The aforesaid parameters were monitored in the trees located within the sample plot, starting from the first field visit.

Litterfall sampling and analysis: 15 collector pads for collection of dead organic remnants of forest trees (waste) were placed at the sample plot. The average collection surface area was500 cm^2 per pad and the total collection surface area amounted to 0.75 m^2. In addition to dead organic remnants of spruce trees, those of European rowan were also present in the overall litterfall at the sample plot. During waste collection, of all the waste fractions, only that of spruce needles was collected in the amount sufficient for performance of laboratory analyses in the year 2010, whereas in 2011 European rowan (*Sorbus aucuparia* L.) waste amount collected allowed laboratory analyses as well.

Deposition collection and analysis: According to the planned arrangement of the wet deposition collectors, instruments for deposition process monitoring were placed in positions. They included collectors of precipitation falling through the tree crowns – "Throughfall" (15 pcs.), collectors of deposition sliding down the tree trunks – "Steamflow" (5 pcs.) and snow collectors (3 pcs.), the so-called "Bulk" collectors. Materials used to make the collectors include: wire structures, plastic containers, pipes and mesh PVC canvass. These materials were used according to the concept designs in the manual so that functional equipment was obtained. The iron was protected from corrosion and the containers for precipitation collection were buried into the ground (the soil temperatures prevent evaporation). The elements of the collectors were joined by means of silicone glue to avoid contamination from the environment. At Level II sample plots special attention is paid to wet deposition, particularly deposition affecting the chemistry of the deposit in direct contact with plant organs where air pollutants are retained (ICP Forests, 2010c).

Growth gain and yield determination: Growth gain is defined as periodical tree growth. The primary aim of the growth gain element measurement at the Level II sample plot was to obtain data for each individual tree as well as for

the whole sample plot area. At Kopaonik sample plot 28 trees were measured, all of them were spruce trees (*Picea abies* L.*)*. The following elements were measured: tree diameter at breast height (two intersecting diameters, one from the north and the other from the west), tree height and crown height. Based on the measurements of these elements, other parameters relevant to growth gain and yield were calculated: volume per tree and total plot volume. Mortality of the measured trees was also assessed as a descriptive dimension (ICP Forests, 2010a).

Assessment of ozone injury to foliage: There is more and more evidence that the concentrations of ozone (a very unstable highly reactive gas with molecules consisting of three oxygen atoms) measured at different locations in Europe particularly affect deciduous vegetation. This refers to direct, visible damages to the assimilation tissues of leaves and, less frequently, conifer needles, which indirectly reduce development and result in yield decrease (1). Ozone induced injuries affect the usual ability of the plants to resist the impact of both biotic and abiotic environmental factors. As "ozone pollution" produces no consequences detectable by analytical techniques, the only easily measurable evidence at field are visible damages to the conifer needles of spruce, in this case. Although these visible damages lack their common traits, they do have harmful effects on the living plant organs (physiological changes, reduced growth) (2). Based on the results of studies dealing with this problem, field observation and recognition of the typical symptoms turned out to be the major factor in ozone impact assessment. The goal was to collect needles (sampling by means of a sporting rifle or tree climbing and picking) from the selected trees at the experimental plot where sampling is conducted two times during the vegetation period. Conifer needle samples then ought to be categorized as annual and biennial. Upon successful sampling, assessment was conducted: for each of the 5 trees 3 samples in clusters originally coming from three branches. Visible ozone induced damages in conifers are mostly manifest at upper crown parts which are most exposed to the sun, i.e. upper parts of the twigs and needle tips (Nevenić et al. 2011). These numbers (of trees and branches) comprise the minimum amount for relevant sampling (3 branches per tree and 5 trees per quadrat). Evaluation differs significantly for deciduous trees on one hand and conifers on the other. The samples taken at Kopaonik plot belong to the dominant species – spruce. The results need to be confirmed by a validation centre and a special expert team issues a certificate on the findings on the examined species (ozone induced injuries were detected in pines), followed by further monitoring of the same phenomenon. Researchers familiar with the issue and plant protection experts competent to eliminate all the empirically determined damages caused by the usual instigators (mites, insects and fungus fruiting bodies, burns, frost, etc.) are educated for recognition of damages on economically significant species given the increase in ozone concentrations in the atmosphere, which will in future bring now evident climate changes of the magnitude we cannot predict (3).

Soil sampling and analysis: At sample plot on Kopaonik three pedological profiles were opened for the purpose of soil type determination. Out of these profiles samples were taken for chemical analyses by pedological horizons in order to determine soil type according to the World Reference Base for Soil Recourses. The same profiles provided unspoiled soil samples in Kopecky

cylinders of 100 cm^3 volume for determination of volume density, specific density, total porosity and water retention at pressure values of 0, -1, -33 and -1500 KPa. Within subplot 1, soil sampling was performed by means of a probe across the total area with uniform average samples by layers of 0-10, 10-20, 20-40, 40-80 cm (ICP Forests, 2010b). Soil samples were chemically analyzed and the results of laboratory sample testing were obtained (physical properties).

Analysis of soil solution chemistry: In addition to groundwater flows, forest soil, as both the starting and ending point for the process of matter and energy circulation in nature, contains basal deposits of pollution from all anthropogenic sources. These substances are accumulated within plant organisms themselves – parts of tree trunks, twigs and assimilation organs, on the surface and inside living plant tissues. In the horizons of the soil are also deposited pollutants dissolved in precipitation, of which rain and snow are quantitatively the most significant. Certain amounts of atmospheric deposits, which rinse assimilation organs, branches and trunks of the trees and are practically "filtered" through the crowns, are collected into special collectors. Analysis of such deposit chemistry is to determine the presence of a certain harmful substance and its concentration per area unit. It is possible to monitor plants' reactions to the impact of such a factor over a course of time, and recognize the connection between the trees' susceptibility to diseases and pests and air pollution. The aim is to derive various conclusions on the forest vitality condition or to prove the undeniable harmful effects on particular species. One of the aims is also to achieve possible differentiation among species in respect to their resistance to such substances and thus favour and promote more resistant woody species in long-term planning of cultivation.

Picture 1.
Gravitational lysimeter below the organic soil layer ~ 18cm (Orig.)

Picture 2.
Installed lysimeter with a collector for soil solution at depth of ~ 25cm (Orig.)

Intensive studies are continuously conducted by installing gravitational lysimeters into the front vertical wall of the existing pedological profiles at defined depths below the organic layer horizon, varying for all three profiles (Picture 1 and Picture 2). Soil solution deposit samples were collected together with other parameter samples for continuous monitoring at experimental plot Kopaonik, and out of all three, one summary sample was made (4). Soil chemistry monitoring in forest ecosystems is aimed at verification of the hypothesis about the depth of soil damage as well as forecast of the future soil development and transformation.

Research and sampling by means of suction soil lysimeters for different layers and sampling from different depths are yet to be conducted at field with appropriate equipment, which will be used in our country for the first time for the purpose of forest soil examination. By means of special pressure modification pumps, which consist of two tubes made of very hard plastic, with different diameters so that one is inserted into the other, an interspace with extremely low air pressure is created - almost a vacuum. Suction lysimeters are inserted into the ground with a steel probe in order to prevent possible damage to the parts of equipment made of fragile materials (ceramics). The ceramic tip, which is in direct contact with the wet ground, due to the differences in osmotic pressures in the wet soil, which may be in solid or colloid state, extracts a sample of the liquid with dissolved matter that reached the given depth in the soil either by deposition or due to groundwater level rising. The aim of this research is to provide results on the origin of harmful substances and the manner and mechanism of their entrance into the forest soil.

Meteorological monitoring: For meteorological monitoring performed in order to obtain information on microclimatic conditions for the year 2010, data provided by Kopaonik automatic weather station, which is situated near the Level II sample plot on Mt. Kopaonik. The location of the weather station ensured representative meteorological data (ICP Forests, 2010a). The following mandatory parameters were monitored during 2010: precipitation (PR), air temperature (AT), relative air humidity (RH), wind speed (WS), wind direction (WD) and solar radiation (SR) from 1 July 2010 to 22 November 2010. Weather stations with special measurement performances were placed beneath the crowns of centennial spruce trees within the sample plot to automatically record and memorize data comparable to the data provided by the Kopaonik synoptic unit. Comparative studies would provide insights into the impact of forest complexes on the parameter values, whether they be measured in the open areas or within thick forest. Such studies would also better define forest capacity to regulate inevitable future climatic changes, i. e. underline the role of forests as man's chief ally in preservation of elementary conditions for survival in a healthier environment.

4. CONCLUSION

For each group of parameters monitored, the ICP Manual for Forests version from May 2010 contains a set of precise instructions for synchronized sampling, various field data collection, measuring equipment installation and guidelines for obtaining valid and useful results as the ultimate goal.

Intensive forest monitoring is conducted by institutions with adequate expert staff. Its particular feature is team work of different background and expertise researchers. Field tasks and laboratory tasks are performed in cycles, which means that each cycle begins with more experience gained (ICP Forests, 2010d). Contrary to the established stereotype that repetitive actions are inflexible, monotonous and compelling, coordination system offers possibilities for introduction of new ideas due to the very dynamics and necessity to monitor changes in nature.

Due to the complexity of combined sciences that study forests as intricate natural units, the obtained insights and results of forest monitoring differ considerably from the approaches applied in research of the properties of an isolated subject and its direct and indirect relations to the environment.

Conclusions are made as feedback information and are based on the system of observed connections and causal relations in many directions. Such multidisciplinary approach provides room for implemented methodology improvement as well as for the enthusiasm to introduce new methods, which typically occurs during continuous forest monitoring at the same locations and experimental sample plots over several years or decades.

The process of obtaining raw field data, which are there entered into worksheets, logs and tables, is followed by their conversion into numerical codes acceptable by the unique IT database. The database with measured parameter data has the same coding system for the whole network of intensive monitoring experimental field stations in Europe, where the same methodology principles are applied in scientific research (Fischer, 2010.)

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TEMPORARY DEPOSITED OF DEPOSOL AS THE POSSIBLE AREA FOR SHORT ROTATION PLANTATION ESTABLISHMENT – MODEL CASE

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Abstract. *Open pit mine exploitation of lignite in the locality RB Kolubara is a major source of fossil fuels for electricity production in Serbia. Exploitation area in the space of RB Kolubara consists of several fields. The fields are in various stages of exploitation. One of the oldest and largest is the field of D. It is anticipated that the exploitation of this field will be completed in near future. Then the area becomes a place for depositing the excavated overburden from the other fields.*

This paper shows the model of the possible production of biomass for energy. Biomass was estimated in the short rotation plantations (SRP) of fast growing trees. The model provides cultivation of plantations at ten year long lasting depositing of the each 30 meters thick layer. In the model was used plants of Paulownia sp. and Populus sp..

The analyzed parameters in the model indicate that the potential of a temporary surface are good for biomass production and that the cultivation of such plantations is justified.

Key words: wood biomass, energy crops, *Paulownia* sp., *Populus* sp., deposol.

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1. INTRODUCTION

Faced with increasing negative changes caused by man's activities, the Earth comes in real danger of the collapse of all ecosystems (Stern, 2006). Disasters of Earth where it came to destruction of the existing ecosystems so far were a result of natural disasters. Nature is once again every time after that ensured that life back and develop in new forms and in a stronger intensity. The current situation is the consequence of one single species in the planet - man, one of the million species of life on earth. This is undoubtedly the greatest obligation to the people to take all possible actions to preserve the collapse of the planet.

Global warming, the greenhouse gas effect have for result a drastic destruction of biodiversity and finally poverty and hunger of the arcitect of these negative processes (Brown, 2008, MacCracken, 2008). The use of fossil fuels is one of the major causes of the negative effects of the present time. In regard to that biomass as a renewable fuel which is able to replace fossil fuels is part of an positive effort and a part of the solution. (Börjesson *et al*., 1997., Dubuisson and Sintzoff, 1998., Cannell, 2003.). Biomass is a fuel that does not have such a negative impact, and its use would preserve the negative effects of global warming and excessive issuance of greenhouse gases would be largely reduced. (Börjesson, 1999a., Börjesson, 1999b., Aronsson and Perttu, 2001., Keolian and Volk, 2005., Börjesson and Berndes, 2006.) In relation to that on the globally level have adopted a number of declarations, conclusions and initiatives for action. Based on these, the signatory states have assumed certain obligations. One of the most important is the obligations under the Kyoto Protocol. In order to meet the obligations under the Kyoto Protocol/following international agreements, the European countries has the target to reach a 20% share of the EU energy mix by renewable energy sources by the year of 2020.

In this sense, the real possibilities of individual countries are already estimated. In most cases, the signatory states have a problem to fulfill commitments. In regard to that, research and evaluation of the possibilities of production of woody biomass as a fuel, in terms of increasing its amount in the total needs of the country, the Kolubara open pit with a new approach and accessible areas become very topical. Commence research in the future will make possible biomass production technology and reclamation of degraded areas, just exactly caused by digging fossil fuels - coal, are in immediate synergy to ensure maximum utilization of potentiality which are used according to selection of tree species as well as the area in which it establishing. The estimates of the European Environmental Agency (EEA, 2006) show that most of the potential biomass production in the EU during the next few years will rely on energy crops on agricultural land, which can account for more than half of the total biomass potential by the year of 2030.

2. METODOLOGY

Modeling of the case was conducted in the area of open pit RB Kolubara field D (Fig. 1) as one of the oldest exploitation field that is still in operation. It is assumed that in near future will stop exploitation of coal in this area and that area

will be further used for a process of internal dumping of overburden. Considering the deep of the field (150m) and field size (2000ha) assumption is that the barren soil will be deposited in layers. In our case, the assumption is that one layer will be formed over ten years. (Fig. 2)). These areas are temporary, limited with short life span so that until the final layer the definitive reclamation of the area is not possible. In the model are calculated quantity of biomass that can be produced during filling of the internal waste disposal to its final shape.

Fig. 1. *Open pit RB Kolubara – area of field D*

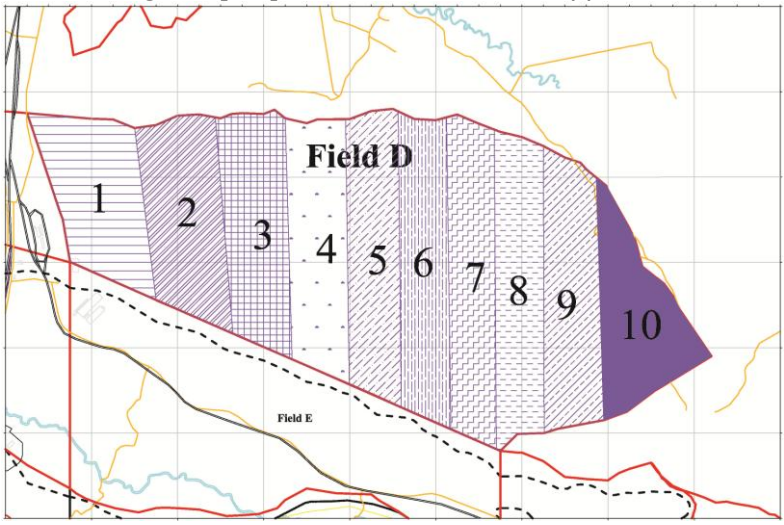
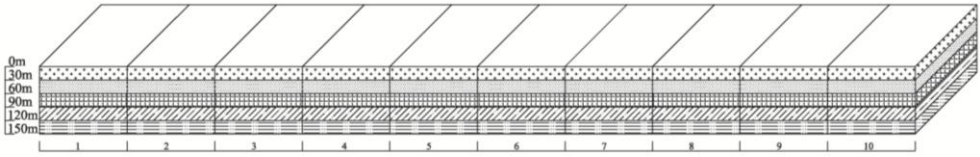


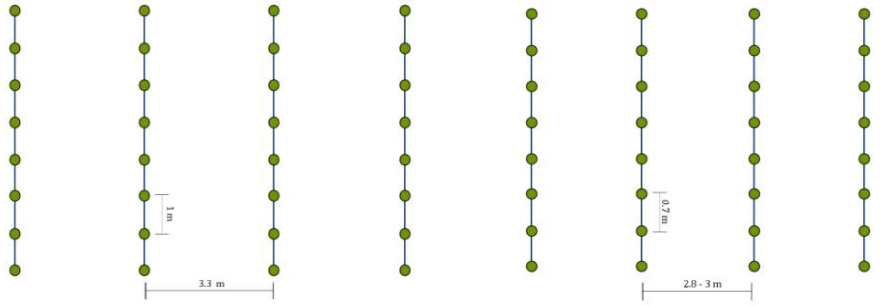
Fig. 2. *Schematic view of filling the field with deposol*



Based on our research (Veselinovic et al., 2010) and literature data was calculated potential of the space by planting species *Paulownia* sp. The obtained results were compared with potential production at the same space of the amounts of biomass poplar species that is planted in the experimental nursery areas Barosevac enhanced on the deposited overburden.

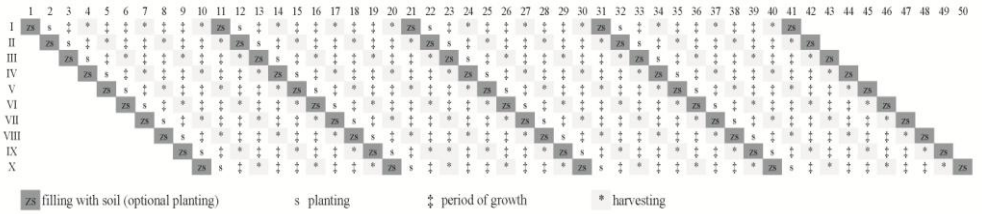
The predicted density of planting (Fig. 3) is adapted to the tree species that were used and the harvest, which is planned to be carried out every three years during the period of ten years of each of four predicted layers (Fig. 4).

Fig. 3. *Schema of planting density – a-Paulownia sp.; b-Populu sp.*



a b

Fig. 4. *Dynamics of development of plantations over a period of 50 years*



3. RESULTS AND DISCUSION

The experiment of growth and suitability for raising energy plantations for biomass production of poplar species was performed in the nursery Barosevac. In Tab. 1 has shown the min and max and mean values obtained in the neck root diameter and height of the three-year monitoring of seedling growth parameters.

Table 1. *Seedling growth parameters of Poplar species*

	Year of growth					
	First		Second		Third	
parameters	neck root diameter (R/cm)	Height (H/m)	neck root diameter (R/cm)	height (H/m)	neck root diameter (R/cm)	Height (H/m)
Min	1,0	41	1,25	120	1,4	132
Max	2,95	315	5,7	461	7,7	610
Average	1,75	2,17	2,47	2,67	2,88	3,47

According to Hassanzad et all, (2007) for *Paulownia* sp. (Tab.2) has shown the min and max and mean values obtained in the neck root diameter and height of the three-year monitoring of seedling growth parameters.

Table 2. Seedling growth parameters of Paulownia species (Hassanzad et al., 2007)

	Year of growth					
	first		second		third	
parameters	neck root diameter (R/cm)	height (H/m)	neck root diameter (R/cm)	Height (H/m)	neck root diameter (R/cm)	Height (H/m)
Min	0,13	0,23	0,94	1,19	3,36	3,1
Max	2,64	2,28	6,94	5,35	12,1	7,7
Average	0,31	0,99	3,57	2,87	8,53	6,19

On the basis of the displayed values is evident that the *Paulownia* seedlings in the second year of growth exceed the values of height and values in the neck root diameter of *Poplar* seedlings. In the third year the difference is far more important. *Paulownia* seedling have double higher values in height and three time higher values of the diameter at the neck of the root then poplar seedlings.

In the third year -year of harvest in the experiment field, on a sample of 100 trees, was measured the weight of above-ground fresh biomass and weight of above-ground dry state of biomass of poplar trees (Tab.3). Conversion of biomass weight was based on the number of units of 7000 per hectare for planting density of 0,7 spacing in the row and 3m space between the rows.

Table 3. *Average values of the analyzed parameters of poplar trees*

weight of above-ground fresh biomass					weight of above-ground dry state of biomass				
(g)				t/ha	(g)				t/ha
trunk	branches	leaves	sum/stem	sum/ha	trunk	branches	leaves	sum/stem	sum/ha
860,33	189,17	485,33	1534,83	10,74	447,67	86,67	176,67	711,01	4,98

According to the Lawrence, J.S., (2011) model *Paulownia* sp. can be planted using mechanized or hand tool methods at 1m spacing in the row and 3,3 m space between the rows. In Tab. 4 is estimation of possible biomass production per each harvest.

Table 4. *Paulownia sp. biomas plantation model (1m x 3.3m spacing – 3000 stem/ha)*

Age et first harvest (year)	Age at each subsequent harvest (year)	Estimate average DBH at harvest (cm)	Estimate average volume yield /tree (m^3)		Estimate average volume yield /ha (m^3)		Estimate average dry matter yield /ha (t)	
			Trunk	total	Trunk	total	Trunk	total
3-4	2-3	10 (cautious)	0,035	0,045	105	136	27.3	35.36
3-4	2-3	12,5	0,059	0,077	177	231	40.02	60.06
3-4	2-3	15 (potential)	0,089	0,116	267	348	69.42	90.48

Taking into account that the deposol Kolubara basin is very poor with nutrients (Veselinovic et al., 2006.) to model our case we used the minimum value of the above models. According to our model in Tab.5 has shown the potential of quantities of biomass produced during the filling field D with deposol. The difference in the quantity of biomass of tested species was multiple for the benefit of Paulownia. In the model amount of biomass crops earned energy crops of *Paulownia* sp. during one layer cycle is more than whole established crops of poplar during the full filling of field D. This indicates that, in further development of our research *Paulownia* sp. have to be tested on the ground within the ecological conditions of habitats.

Table 5. *Model estimation of biomass potential production during the filling field D with deposol*

Species	Estimate average dry matter yield /ha (t)	Annual space (ha)	Estimate average dry matter yield /ha (t)/year	Estimate average dry matter yield /ha (t)/cycle	Estimate average dry matter yield /ha (t)/layer	Estimate average dry matter yield /ha (t)/field D
Poplar	4,98	200	996	2.988	29.880	119.520
Paulownia sp.	35,36	200	7072	21,216	212,160	848,640

Soil fertility is a characteristic that can be modified by adding fertilizers in order to improve crop productivity. Our studies with poplars (Tab.6) indicate that additional fertilizing increases the growth parameters (R - root collar diameter and height - H) above-ground parts of plants and that the differences are significant in the third year. These results are very significant because it is the third year which is the harvest year.

Further studies will define the methodology which has to achieve optimal biomass production in the sense of invested assets / value of the product.

Table 6. *The differences in measured properties of the Poplar seedlings between fertilizing (treatment) and non fertilizing (control)*

	Year of growth							
	Second				Third			
Parameters	R (mm)		H (cm)		R (mm)		H (cm)	
	treatment	control	treatment	control	treatment	control	treatment	control
sample	434	167	434	167	447	168	447	168
X ± Sx	14,67^{a}± 0,29	14,24^{a}±0,15	257,44^{a}±3,26	255,01^{a}±2,85	16,15^{a}±0,29	16,01^{a}±0,33	284,1^{b}±4,00	269,71^{a}±2,91
X ± Ss	4,03±0,16	3,62±0,10	59,74±2,30	70,81±2,02	4,47±0,21	7,75±0,23	61,52±2,83	69,11±2,06
V ± Sv	29,1±1,12	25,44±0,72	23,21±0,90	27,77±0,79	27,67±1,27	48,40±1,44	21,66±1,00	25,62±0,76

Other researchers have come to the same results that the fertility and other management is important for high biomass production in SRP (Tahvanainen and Rytkönen, 1999, Nixon et al., 2001, Jug et al., 1999, Hofmann-Schielle et al., 1999, Heaton et al., 1999, Vilotic et al., 2006).

4. CONCLUSION

Previous studies with fast growing species for raising energy plantations for biomass production indicate that the overburden dump area has great potential. Particularly suitable are "temporary" surface that lasts for ten years and cover again with a new layer of overburden. On such areas SRP have an irreplaceable role in the production of biomass but also as a means of biological reclamation of such terrains. Upon completion of filling the fields with spoil it possible to continue production of biomass from energy plantations and a longer period of time.

According to literature data SRP give a satisfactory amount of biomass and up to thirty years of the same plantation (Best Practice Guidelines, 2007) and after that can be accessed by a durable solution to the final biological reclamation. In this sense and in the sense of technological processes that can increase the amount of biomass research will be continued.

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TEMPORARY DEPOSITED OF DEPOSOL AS THE POSSIBLE AREA FOR SHORT ROTATION PLANTATION ESTABLISHMENT – MODEL CASE

Suzana MITROVIĆ, Milorad VESELINOVIĆ, Dragica VILOTIĆ, Nevena ČULE[1], Dragana DRAŽIĆ, Biljana NIKOLIĆ, Marija NEŠIĆ

Summary

Global warming, the greenhouse gas effect have for result a drastic destruction of biodiversity. The use of fossil fuels is one of the major causes of those negative effects of the present time. In regard to that biomass as a renewable fuel which is able to replace fossil fuels is part of an positive effort and a part of the solution. Research and evaluation of the possibilities of production of woody biomass as a fuel, in terms of increasing its amount in the total needs of the country, the Kolubara open pit with a new approach and accessible areas become very topical.

Open pit mine exploitation of lignite in the locality RB Kolubara is a major source of fossil fuels for electricity production in Serbia. Exploitation area in the space of RB Kolubara consists of several fields. The fields are in various stages of exploitation. One of the oldest and largest is the field of D. It is anticipated that the exploitation of this field will be completed in near future. That area will be further used for a process of internal dumping of overburden. Considering the deep of the field (150m) and field size (2000ha) assumption is that the barren soil will be deposited in 30 meters thick layers. In our case, the assumption is that one layer will be formed over ten years. These areas are temporary, limited with short life span so that until the final layer the definitive reclamation of the area is not possible.

In the model are calculated quantity of biomass that can be produced during filling of the internal waste disposal to its final shape. According to our model the potential of quantities of biomass produced from SRP of Poplar and Paulownia during the filling field D with deposol was estimated. The difference in the quantity of biomass of tested species

was multiple for the benefit of Paulownia. In the model amount of biomass crops earned energy crops of Paulownia during one layer cycle is more than whole established crops of Poplar during the full filling of field D. This indicates that, in further development of our research Paulownia have to be tested on the ground within the ecological conditions of habitats. Also further studies will define the methodology which has to achieve optimal biomass production in the sense of invested assets/value of the product.

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RELIABILITY OF THE STAND REGRESSION MODELS DEVELOPED ON THE BASIS OF SAMPLE PLOTS

Miloš KOPRIVICA, Bratislav MATOVIĆ[1]

Abstract: *The paper addresses the problem of reliability of the stand regression models developed on the basis of sample plots as basic sample units. The aggregate values of estimation elements, determined on sample plots are usually extrapolated per hectare before they are used for the estimation of stand elements or as variables in the construction of regression models. Other sample plot estimation values, which are not aggregate, are used in these models as individual values or as average values of the sample plots established in the stands. We tested the reliability of the models for estimating form factor, form height and volume of high beech stands in Serbia. It was concluded that the stand models obtained on the basis of a large sample of sample plots were always sufficiently reliable. When regression models used stands as basic units of the sample, instead of sample plots, the obtained models did not have a significantly greater degree of reliability.*

Key words: model, stand, sample plot, beech, sample, reliability

POUZDANOST SASTOJINSKIH REGRESIONIONIH MODELA RAZVIJENIH NA BAZI PROBNIH POVRŠINA

Apstrakt: U radu je razmatran problem pouzdanosti sastojinskih regresionih modela razvijenih na bazi probnih površina kao osnovnih elemenata uzorka. Naime, agregatne veličine taksacionih elmenata utvrđene na probnim površinama se obično prvo ekstarpoliraju na hektar a zatim služe za procenu taksacionih elemenata sastojine ili kao promenljive prilikom konstrukcije regresionih modela. Ostale taksacione veličine utvrđene na probnim površinama, koje nisu agregatne, koriste se u modelima kao individualne veličine ili kao prosečne veličine probnih površina postavljenih u sastojini. Proverena je

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pouzdanost modela za procenu zapreminskog koeficijenta, oblikovisine i zapremine visokih sastojina bukve u Srbiji. Zaključeno je da su u svim slučajevima sastojinski modeli dobijeni na bazi velikog uzorka probnih površina dovoljno pouzdani. U slučaju kada su osnovne jedinice uzorka korišćenog za dobijanje regresionih modela bile sastojine, a ne probne površine, nisu dobijeni značajno pouzdaniji modeli.

Ključne reči: model, sastojina, probna površina, bukva, uzorak, pouzdanost

1. INTRODUCTION

This paper includes a thorough analysis of the reliability of the sample plot based models, previously constructed for the estimation of the form factor, form height and volume of high beech stands in Serbia (Koprivica, M., Matovic, B. 2009; Koprivica, M. et al. 2010). In fact, this research poses the following question: Can the stand models developed on the basis of sample plots be applied on stands or they can be used only for sample plots?

It is considered that the models, based on data on trees, sample plots and stands, can be in practice applied only to these observation units, while the independent variables have to be determined in the same way they were determined in the construction of the model. However, in the construction of these stand models in Serbia, we assumed that the models based on sample plot data could be successfully used to estimate the elements of beech high stands: form factor, form height and volume. This assumption was based on strong internal heterogeneity of beech high stands and on the smaller error of the average values of independent variables, or stand estimation elements in comparison to the individual values of independent variables of the sample plots.

Because of a small number of stands in the sample, it was assumed that the sample plot characteristics (estimation elements and site characteristics) can be provisionally equated with the characteristics of hypothetical stands. In our opinion, this is statistically justified because the variability of the individual values of all elements in the plot sample is higher than the variability of the average values of the same elements in the stand sample.

This attitude is confirmed by the papers dealing with theoretical analysis of the sample structure intended for modelling in forestry (Box, G.E.P. and Draper, N.R., 1987, Vancelay, J.K. *et al*. 1993, Rennolls, K. 1997). Among other things, these papers study the issue of optimal data collection, assuming that the regression method will be used in modelling. It can be concluded that the best results of modelling can be achieved if the variables include different magnitudes within the scope of their variation, taking into account the extreme magnitudes, not only those that slightly deviate from the average. Furthermore, the data needed for the stand-level modelling should be collected on sample plots.

2. MATERIAL AND METHOD

The same method and material was used in the construction of these new regression models based on a stand sample as in the earlier construction of regression models based on a plot sample (Koprivica, M., Matović, B. 2009;

Koprivica, M. *et al*. 2010). Stand models used the average values of the variables (estimation elements), obtained on the basis of the sample plots that were established within them. Furthermore, separate regression models were constructed for each stand, based on their sample plots. The comparison of the models was done using the indices, calculated as the ratio of the estimation element predicted value, as obtained in a specific model, and its empirical value obtained in the sample.

The research material consists of numerous data on high uneven-aged beech stands and their site, collected within the project "Method of evaluation of quality and assortment structure of beech high stands in Serbia". The selection of the study stands, as well as the methods of data collection and processing are described in detail in Koprivica, *et al.* (2005). The characteristics of the investigated stands are also described in several papers (Koprivica, M., Matovic, B. 2006, Koprivica, M. *et al*. 2006 i 2007). The research covered eleven representative high stands of beech, selected in six forest regions: Severno Kučajsko, Podrinjsko-Kolubarsko, Jablaničko, Golijsko, Donje Ibarsko and Rasinsko. A systematic sample of circular sample plots was established in all stands. Altogether 241 sample plots of 500 m^2, spacing 100 m were established. The data were processed separately for each sample plot, as average or aggregate values converted into a hectare. The aplication programme SORTIMENT (Markovic, N. *et al*. 2007) was used for this purpose. The regression models were developed by using the programme STATGRAPHICS, version 5.0.

3. RESULTS AND DISCUSSION

3.1. Models for estimating beech stand elements obtained in earlier studies

Our earlier studies (Koprivica, M., Matovic, B. 2009; Koprivica, M. *et al*. 2010) provide regression models for estimating form factor, form height and volume of beech high stands in Serbia:

$F=1{,}1948 - 0{,}0136869H_L - 2{,}31108/H_L - 0{,}0320255TN - 4{,}1527/D_g$
$S_e = 0{,}01301$ $R^2 = 0{,}7849$ n = 241

$H_LF=15{,}5566 + 0{,}176377H_L - 0{,}929592TN - 115{,}761/D_g$
$S_e = 0.3823$ m $R^2 = 0{,}9800$ n = 241

$V = - 113{,}725 - 2{,}47698G + 8{,}93191H_L - 0{,}17812H_L^2 + 0{,}592762GH_L$
$S_e = 16{,}74$ m^3/ha $R^2 = 0{,}9897$ n = 241

These models were obtained on the basis of all sample plots (n=241), measured in eleven selected representative beech stands. The reliability of the models was tested and it was concluded that they can be successfully applied in practice.

New regression models for stands were produced in this research and their reliability was tested. We first used the sample plots of each stand separately (n=10-33) and then the respective stands (n=11) as sample elements.

3.2 Models for estimating the form factor and the form height of each beech stand separately

The general form of the model obtained in earlier researches was used for stands,

$$F = a + bH_L + c/H_L + dTN + e/D_g \quad (1)$$

$$H_LF = a + bH_L + cTN + d/D_g \quad (2)$$

where:
F – stand form factor,
H_LF – stand form height,
H_L – Lorey`s mean height of a stand,
TN – stand tariff series and
D_g – stand quadratic mean diameter

The obtained results are presented in Tables 1 and 2.

Table 1. *Statistical parameters of the model for estimating the stand form factor (F)*

Stand.	n	a	b	c	d	e	R^2	S_e
33a	23	1,6298	-0,026247	-7,69154	-0,0360115	-5,42466	0,837	0,0105
42a	18	2,1025	-0,032807	-13,5006	-0,0305938	-3,76320	0,492	0,0177
42b	10	1,6147	-0,023360	-4,23753	-0,0522183	-3,60243	0,921	0,0083
122a	29	0,5592	-0,004225	+7,40660	-0,0254734	-3,47685	0,642	0,0120
27a	20	0,9725	-0,009613	+0,12913	-0,0219942	-4,39587	0,611	0,0136
31a	32	1,2711	-0,015342	-3,08991	-0,0328527	-4,35832	0,962	0,0089
46a	28	0,9510	-0,008879	+0,17846	-0,0299203	-3,68993	0,804	0,0133
8a	16	1,4704	-0,020863	-0,44285	-0,0515007	-7,45019	0.901	0,0067
8b	10	5,2032	-0,094348	-50,1793	-0,0381785	-5,43781	0,866	0,0096
44a	22	1,3763	-0,017479	-2,69444	-0,0387479	-5,20886	0,915	0,0086
116a	33	1,1910	-0,013013	-4,12448	-0,0267675	-3,00477	0,817	0,0120

Table 2. *Statistical parameters of the model for estimating the stand form height (H_LF)*

Stand	n	a	b	c	d	R^2	S_e
33a	23	21,1459	+0,076076	-1,200300	-180,834	0,974	0,345
42a	18	12,2661	+0,240807	-0,718457	-93,7982	0,829	0,433
42b	10	16,2097	+0,175545	-1,158860	-80,5615	0,986	0,169
122a	29	15,9923	+0,154575	-0,811108	-108,806	0,920	0,433
27a	20	12,5666	+0,247172	-0,622988	-110,310	0,972	0,388
31a	32	17,1870	+0,127288	-0,961311	-127,231	0,991	0,274
46a	28	12,5581	+0,248259	-0,783059	-96,6339	0,984	0,317
8a	16	24,1729	-0,024457	-1,338050	-189,259	0,991	0,137
8b	10	16,1490	+0,096465	-0,666206	-104,888	0,846	0,270
44a	22	22,8011	+0,021667	-1,287620	-165,173	0,968	0,289
116a	33	11,7725	+0,262541	-0,781075	-85,8152	0,983	0,363

3.3 Models for estimating the form factor and the form height of all beech stands together

The general form of the model is the same as in the first case. By applying the multiple regression with fixed independent variables, the following regression equations were obtained,

$$F = - 0{,}104732 + 0{,}0116884H_L + 4{,}93375/H_L + 0{,}00872387TN + 2{,}13421/Dg \quad (3)$$
$S_e = 0{,}00488 \qquad R^2 = 0{,}805 \qquad n = 11$

$$H_LF = -6{,}68446 + 0{,}653604H_L + 0{,}307627TN + 39{,}8059/D_g \quad (4)$$
$S_e = 0{,}165$ m $\qquad R^2 = 0{,}995 \qquad n = 11$

Since only the value of the parameter *b* is statistically significant in equations (3) and (4), the method of stepwise multiple regression was applied too (Hadzivukovic, S. *et al*. 1982).

A simpler forms of regression equation were obtained,

$$F = 0{,}449008 + 0{,}00162813H_L \quad (5)$$
$S_e = 0{,}00630 \qquad R^2 = 0{,}512$

$$H_LF = -1{,}32257 + 0{,}542605H_L \quad (6)$$
$S_e = 0{,}18 \qquad R^2 = 0{,}993$

There is a linear dependence of the form factor (5) and the form height (6) of beech high stands on Lorey`s mean stand height. The difference in the values of the parameter *b*, i.e. in the inclination of the lines that represent the graphic expression of these equations, is great. The stand form factor slightly increases with the increase of Lorey's mean stand height (with the coefficient of variation $CV_F = 1.73\%$). The form height of the stands rapidly increases with the increase of Lorey's mean stand height (with the coefficient of variation $CV_{HF} = 14.84\%$). The relatioship is extremely strong and the standard error of regression is small.

It follows that the application of regression equations (5) and (6) enables us to derive new formulas for approximate estimation of the beech stand volume per hectare from the basic stand volume formula $V = G\,H_L\,F$:

$$V = 0{,}449008\ GH_L + 0{,}00162813\ GH_L^2 \quad (7)$$

$$V = - 1{,}32257\ G + 0{,}542605\ GH_L \quad (8)$$

For the practical implementation of these formulas, it is necessary to determine the stand basal area (G) and Lorey`s mean stand height ($H_L$). In order to do this, either classical or *relascopy method* should be applied to establish 3 to 5 competently selected sample areas and measure the diameter at breast height of all trees above the estimation limit (10cm). The accuracy of the basal area and Lorey`s mean stand height determination directly affects the accuracy of the estimated stand volume per hectare. Distribution of the stand volume per diameter degrees is similar to the basal area distribution, i.e. the relative proportion of the basal area per diameter degrees in the stand basal area roughly corresponds to the relative proportion of the volume per diameter classes in the stand volume (Koprivica, M., Matović, B. 2010).

3.4 Comparison of the empirical value of the form factor and the form height of beech stands with the values calculated by different models

For the purpose of this comparison, the following models were used:
- Models based on sample plots for all stands together,
- Models based on sample plots for each separate stand,
- Models based on stands with three independent variables,
- Models based on stands with one independent variable

The comparison is shown in Tables 3.1, 3.2 and 4.1 and 4.2

Table 3.1. *Beech stand form factor (F) – empirical and model values*

Stand	n	$^{*}F_0$	F_1	F_2	F_3	F_4
33a	23	0,50369	0,50235	0,49617	0,49734	0,49955
42a	18	0,48993	0,49170	0,48883	0,48673	0,48885
42b	10	0,48687	0,47442	0,49993	0,48773	0,48435
122a	29	0,50509	0,50003	0,49510	0,50918	0,50493
27a	20	0,50236	0,49315	0,48965	0,50135	0,49823
31a	32	0,48199	0,50919	0,50803	0,48592	0,49461
46a	28	0,49421	0,48388	0,47582	0,49849	0,49386
8a	16	0,48386	0,49453	0,48398	0,48730	0,49111
8b	10	0,49828	0,49696	0,51226	0,49474	0,48904
44a	22	0,50332	0,49416	0,51075	0,50019	0,50132
116a	33	0,48875	0,50043	0,49511	0,48871	0,49250

Tabela 3.2. *Form factor index (F) of the beech stands - modelled/empirical*

Stand	n	F_0/F_0	F_1/F_0	F_2/F_0	F_3/F_0	F_4/F_0
33a	23	1,000	0,997	0,985	0,987	0,992
42a	18	1,000	1.004	0,998	0,993	0,998
42b	10	1,000	0,974	1,027	1,002	0,995
122a	29	1,000	0,990	0,980	1,008	1,000
27a	20	1,000	0,982	0,975	0,998	0,992
31a	32	1,000	1,056	1,054	1,008	1,026
46a	28	1,000	0,979	0,963	1,009	0,999
8a	16	1,000	1,022	1,000	1,007	1,015
8b	10	1,000	0,997	1,028	0,993	0,981
44a	22	1,000	0,982	1,014	0,994	0,996
116a	33	1,000	1,024	1,013	1,000	1,008

F_0 – empirical value of the stand form factor
F_1 – value of the form factor calculated by the model of all sample plots together (n = 241)
F_2 – value of the form factor calculated by the model of the sample plots for each separate stand (n = 10 - 33)
F_3 – value of the form factor calculated by the multiple model for all stands (n = 11)
F_4 – value of the form factor calculated by the simple model for all stands (n = 11)

The most accurate model for estimating the beech stand form factor is the one in which the index value has the slightest deviation from the index 1.000. As can be seen from the data in Table 3.2, Model F_3 is the most efficient, because it has the greatest number of accurate results (the smallest deviation of the empirical values F_0 from the estimated values F_3). However, it is of special importance to compare the accuracy of Model F_3, or the model obtained on the basis of all sample plots (n = 241) with the accuracy of the model that is based on all stands (n=11). There is no significant difference between these two models, although the model F_3 is slightly more accurate. However, Model F_1 has a better practical application because of the small number of stands in the sample.

On the whole, it can be concluded that none of the models for estimating the stand form factor show a systematic deviation. The deviations are randomly distributed.

Table 4.1. *Form height (H_LF) of beech stands – empirical and modelled*

Stand	n	$^*H_LF_0$	H_LF_1	H_LF_2	H_LF_3	H_LF_4
33a	23	15,634	15,543	15,319	15,536	15,520
42a	18	11,991	12,062	11,920	11,970	11,955
42b	10	10,568	10,321	10,837	10,453	10,457
122a	29	17,350	17,157	17,062	17,340	17,316
27a	20	15,185	14,890	14,894	15,179	15,080
31a	32	13,500	14,257	14,235	13,682	13,876
46a	28	13,615	13,309	13,193	13,818	13,626
8a	16	12,512	12,803	12,505	12,644	12,709
8b	10	12,254	12,311	12,095	12,045	12,020
44a	22	16,173	15,864	16,404	16,020	16,111
116a	33	13,057	13,374	13,179	13,154	13,170

Table 4.2. *Form height index (H_LF) of beech stands – modelled/empirical*

Stand	n	HF_0/HF_0	HF_1/HF_0	HF_2/HF_0	HF_3/HF_0	HF_4/HF_0
33a	23	1,000	0,994	0,980	0,994	0,993
42a	18	1,000	1,006	0,994	0,998	0,997
42b	10	1,000	0,977	1,025	0,989	0,989
122a	29	1,000	0,989	0,983	0,999	0,998
27a	20	1,000	0,981	0,981	1,000	0,993
31a	32	1,000	1,056	1,054	1,013	1,027
46a	28	1,000	0,978	0,969	1,015	1,001
8a	16	1,000	1,023	0,999	1,010	1,016
8b	10	1,000	1,005	0,987	0,983	0,981
44a	22	1,000	0,981	1,014	0,991	0,996
116a	33	1,000	1,024	1,009	1,007	1,009

HF_0 – empirical value of the stand form height
HF_1 – value of the form height calculated by the model of all sample plots together (n = 241)
HF_2 – value of the form height calculated by the model of the sample plots for each separate stand (n = 10 - 33)
HF_3 – value of the form height calculated by the multiple model for all stands (n = 11)
HF_4 – value of the form height calculated by the simple model for all stands (n = 11)

As can be seen from the data in Table 4.2, Models HF_3 and HF_4 are the most efficient, because they have the greatest number of accurate results. However, it is of great importance to compare the accuracy of Models HF_3 and HF_4 ,i.e. the model obtained on the basis of all sample plots (n = 241) and the model obtained on the basis of all stands (n = 11). There is no significant difference between these two models, although Model HF_3 is slightly more accurate. However, Model HF_1 has a better practical application because of the small number of stands in the sample.

Again, it can be concluded that none of the models for estimating the stand form height show a systematic deviation, but the deviations are randomly distributed.

3.5 Models for estimating volume of each beech stands separately

The general form of the model, developed in earlier investigations, was used for stands,

$$V = a + bG + cH_L + dH_L^2 + eGH_L \quad (9)$$

The obtained results are presented in Table 5.

Table 5. *Statistical parameters of the model for estimating beech stand volume per hectare (V)*

Stand	n	a	b	c	d	e	R^2	S_e
33a	23	-701,940	-4,59352	48,9302	-0,839607	0,652192	0,981	24,814
42a	18	768,021	-5,00893	-56,3465	1,04262	0,674438	0,963	19,518
42b	10	185,023	-0,80250	-20,2999	0,455949	0,582039	0,989	12,434
122a	29	-485,939	3,17787	29,0765	-0,441584	0,424898	0,992	17,579
27a	20	74,656	-0,03031	-6,41145	0,124742	0,507891	0,995	13,487
31a	32	170,106	-8,97200	-6,54878	0,011962	0,817302	0,986	13,118
46a	28	118,315	-4,95033	-8,04861	0,126982	0,681550	0,994	10,858
8a	16	34,0822	-34,3601	40,5958	-1,64826	1,83144	0,990	13,581
8b	10	2420,12	-30,0461	-149,138	2,0776	1,70767	0,979	12,697
44a	22	198,223	-1,20807	-12,6801	0,159614	0,588235	0,990	19,386
116a	33	-81,3943	-3,24981	6,91556	-0,140404	0,609576	0,993	11,369

3.6 Models for estimating volume of all beech stands together

The general form of the model is still the same as in the first case. By applying the multiply regression with fixed independent variables, the following regression equation was produced,

$$V = 6{,}00118 + 0{,}108797G - 2{,}40954H_L + 0{,}0632384H_L^2 + 0{,}505875GH_L \quad (10)$$

$S_e = 4{,}861\ m^3/ha \qquad R^2 = 0{,}998 \qquad n = 11$

Since some of the parameters in equation (10) are not statistically significant, the method of stepwise multiply regression was applied to develop the following equation,

$$V = -26{,}7355 + 0{,}0173008H_L^2 + 0{,}512172GH_L \quad (11)$$

$S_e = 4{,}261\ m^3/ha \qquad R^2 = 0{,}998 \qquad n = 11$

For practical implementation of equations (10) and (11), it is necessary to determine the basal area (G) and Lorey`s mean height (H_L) of the stand for which the volume (V) has to be estimated. In that case, the derived simple formulas (7) and (8) can be used.

3.7 Comparison of the empirical values of the beech stand volume with the values calculated by different models

For the purpose of this comparison, the following models were used:
- models based on sample plots for all stands together,
- models based on sample plots for each stand separately,
- models based on stands with four independent variables,
- models based on stands with two independent variables

The comparison is shown in Tables 6.1 and 6.2.

As can be seen from the data in Table 6.2, Models V_3 and V_4 are the most efficient because they have the greatest number of accurate results. However, it is again of great importance to compare the accuracy of Models V_1 and V_3, or the

model obtained on the basis of all sample plots (n = 241) and the model obtained on the basis of all stands (n = 11). There is no significant difference between these two models, although Model V_3 is slightly more accurate. However, Model V_1 has a better practical application because of the small number of stands in the sample.

Table 6.1. *Beech stand volume per hectare (V) – empirical and modelled*

Stand	n	$^*V_0$	V_1	V_2	V_3	V_4
33a	23	522,52	524,03	530,96	520,56	521,25
42a	18	379,57	379,11	377,59	380,42	380,58
42b	10	333,22	323,89	332,32	333,21	332,01
122a	29	503,68	502,10	507,82	505,52	504,46
27a	20	350,38	349,76	348,40	346,32	346,33
31a	32	290,89	301,13	295,98	295,75	295,92
46a	28	316,04	318,70	313,88	313,63	313,91
8a	16	385,19	393,72	381,85	392,04	392,56
8b	10	360,83	354,52	360,51	354,47	354,56
44a	22	502,25	499,83	504,99	501,99	502,15
116a	33	289,90	294,27	293,80	290,54	290,71

Table 6.2. *Beech stand volume index, per hectare (V) – modelled/ empirical*

Stand	n	V_0/V_0	V_1/V_0	V_2/V_0	V_3/V_0	V_4/V_0
33a	23	1,000	1,003	1,016	0,996	0,998
42a	18	1,000	0,999	0,995	1,002	1,003
42b	10	1,000	0,972	0,997	1,000	0,996
122a	29	1,000	0,997	1,008	1,004	1,002
27a	20	1,000	0,998	0,994	0,988	0,988
31a	32	1,000	1,035	1,017	1,017	1,017
46a	28	1,000	1,008	0,993	0,992	0,993
8a	16	1,000	1,022	0,991	1,018	1,019
8b	10	1,000	0,983	0,999	0,982	0,983
44a	22	1,000	0,995	1,005	0,999	1,000
116a	33	1,000	1,015	1,013	1,002	1,003

V_0 – empirical value of the stand volume
V_1 – the value of the volume calculated by the model of all sample plots together (n = 241)
V_2 – the value of the volume calculated by the model of sample plots for each separate stand (n = 10 - 33)
V_3 – the value of the volume calculated by the model with four independent variables for all stands (n = 11)
V_4 – the value of the volume calculated by the model with two independent variables for all stands (n = 11)

On the whole, it can be concluded that none of the models for estimating the beech stand volume per hectare show a systematic deviation, but the deviations are randomly distributed.

3.8 Average values of form factor, form height and volume of all beech stands together

Average values of form factor, form height and volume of all beech stands together (management classes) were obtained as weighted values of these estimation elements determined in the stands (weight – the number of sample plots in a stand).

The results are presented in Table 7.

Table 7. *Average values of form factor, form height and volume of all beech stands together, per hectare*

Model	F	Index	H_LF	Index	V	Index
Original	0,49442	1,0000	14,1580	1,0000	382,88	1,0000
Model 1	0,49636	1,0039	14,1923	1,0024	384,99	1,0055
Model 2	0,49536	1,0019	14,1481	0,9993	385,09	1,0058
Model 3	0,49483	1,0008	14,1816	1,0017	383,54	1,0017
Model 4	0,49463	1,0004	14,1852	1,0019	383,57	1,0018

The data in Table 7 show that there is no significant difference between the average values of form factor, form height and volume when they refer to a set of all study beech stands (management class). Yet, the most accurate results are achieved in Models 3 and 4, i.e. the models with stands as sample elements. However, we must bear in mind that the sample of the study beech stands was very small and that the models used the average values of all investigated stand estimation elements obtained from the data set on sample plots. Therefore, the best practice is to use the models derived on the basis of all sample plots (Model 1).

4. CONCLUSION

The main purpose of this paper was to resolve the crucial issue of construction and application of the regression models and tables intended for fast volume estimation in high beech stands in Serbia. These models and tables were previously constructed on the basis of a sample with sample plots as basic observation units, instead of stands. As a matter of fact, a lot of authors agree that if the models are constructed using a sample of trees, sample plots or stands, they should be applied at the respective level of observation. However, a stand model would be both money and time consuming and it would require extensive measurements. It is rarely feasible in investigations that are time limited and have modest financial resources. Therefore, when developing these regression models in Serbia, sample plot characteristics were extrapolated (converted) into a hectare and then observed as characteristics of hypothetical stands.

Beech stands are proved to have strong internal heterogeneity and it is assumed that within beech high forests in Serbia, there are stands with average estimation and site characteristics similar to the estimation and site characteristics of randomly selected sample plots. Model efficiacy testing showed that the initial hypothesis was justified. Namely, there is no significant difference between the estimated average values of stand form factor, form height and volume per hectare, calculated by the models based on the characteristics of a great number of sample areas (n = 241) and the models based on the characteristics of a small number of stands (n = 11).

The main question of this study – whether the plot-based stand models can be practically applied on stands, or they are limited to sample plots only – is resolved. The final answer is that they can. It is ascertained by comparing the values calculated by the models for all sample plots and for all stands with the empirical values of form factor, form height and volume per hectare for each separate stand and for all stands together (management class).

There are differences between the studied models in all cases. However , they are not systematic, but random and their magnitude cannot have a significant influence on the final result when estimating stand volume either per hectare or on its whole area. It was proved in two ways: indirectly, through the models for stand volume elements (form factor and form height) and directly, through the models for stand volume. Thus, the obtained models can be applied in practice and their accuracy will primarily depend on the accuracy of the estimated stand elements, needed for model implementation, not on the accuracy of the model parameters, because they are determined as accurately as possible.

Finally, the models based on the sample of all plots established in beech high stands should be favoured. In our opinion, these models are flexible and they can include all variations of beech high stand characterictics that might occur in practice.

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RELIABILITY OF THE STAND REGRESSION MODELS DEVELOPED ON THE BASIS OF SAMPLE PLOTS

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Summary

This paper addresses the problem of reliability of previously constructed stand regression models for beech high forests in Serbia, based on sample plots as basic sample elements. A lot of authors agree that stand models should use stands as basic sample elements, not sample plots, because in practice they are usually applied at that level. The main hypothesis of this study is that stand models based on sample plots are reliable enough. This hypothesis is based on strong internal heterogeneity of beech high stands, so that characteristics of sample plots can provisionally be equated with characteristics of hypothetical stands. It is well-known that in forest inventories, the aggregate values of estimation elements, determined on the sample plots, are usually extrapolated per hectare before they are used for the estimation of stand elements or as variables in the construction of regression models. Other estimation values determined on the sample plots, which are not aggregate, are used in these models as individual values or as average values of the sample plots established in the stands.

The reliability of the models for estimating form factor, form height and volume of beech high stands in Serbia was tested by comparing their empirical values obtained in the sample with the values obtained in different models: (1) models based on sample plots for all stands together, (2) models based on sample plots for each stand separately, (3) models based on stands with several independent variables and (4) models based on stands with one or two independent variables. It was concluded that the stand models constructed on the basis of a great number of sample plots were in all cases sufficiently reliable. In the cases where the basic units of the sample, which was used for obtaining regression models, were stands instead of sample plots, the resulting models were not significantly more reliable. Therefore, previously constructed stand models for estimating form factor and form height (Koprivica, M., Matović, B. 2009) or directly volume per hectare (Koprivica, M. *et al*. 2010) are recommended to be used in practice.

POUZDANOST SASTOJINSKIH REGRESIONIONIH MODELA RAZVIJENIH NA BAZI PROBNIH POVRŠINA

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Rezime

U radu je razmatran problem pouzdanosti ranije razvijenih sastojinskih regresionih modela za visoke bukove šume u Srbiji, na bazi probnih površina kao osnovnih elemenata uzorka. Prema mišljenju mnogih autora sastojinski modeli bi trebali biti razvijeni na bazi uzorka sastojina kao osnovnih elemenata uzorka, a ne probnih površina, jer se u praksi obično primenjuju na tom nivou. Osnovna hipoteza u ovom istraživanju bila je da su i sastojinski modeli dobijeni na bazi probnih površina dovoljno pouzdani. Hipoteza je zasnovana na velikoj unutrašnjoj heterogenosti visokih sastojina bukve, tako da se

karakteristike probnih površina uslovno mnogu izjednačiti sa karakteristikama hipotetičkih sastojina. Naime, poznato je da se u inventuri šuma agregatne veličine taksacionih elmenata utvrđene na probnim površinama prvo ekstrapoliraju na hektar a zatim koriste za procenu taksacionih elemenata sastojine ili kao promenljive prilikom konstrukcije regresionih modela. Ostale taksacione veličine utvrđene na probnim površinama, koje nisu agregatne, koriste se u modelima kao individualne veličine ili kao prosečne veličine probnih površina postavljenih u sastojini.

Proverena je pouzdanost modela za procenu zapreminskog koeficijenta, oblikovisine i zapremine visokih sastojina bukve u Srbiji, upoređenjem njihovih stvarnih veličina dobijenih u uzorku sa veličinama dobijenim po različitim modelima: (1) - modeli na bazi probnih površina za sve sastojine zajedno, (2) - modeli na bazi probnih površina za svaku sastojinu posebno, (3) - modeli na bazi sastojina sa više nezavisno promenljivih, i (4) - modeli na bazi sastojina sa jednom ili dve nezavisno promenljive. Zaključeno je da su u svim slučajevima sastojinski modeli dobijeni na bazi velikog uzorka probnih površina dovoljno pouzdani. U slučaju kada su osnovne jedinice uzorka korišćenog za dobijanje regresionih modela bile sastojine, a ne probne površine, nisu dobijeni značajno pouzdaniji modeli. Zbog toga su za primenu u praksi preporučeni ranije konstruisani sastojinski modeli za procenu zapreminskog koeficijenta i oblikovisine (Koprivica, M., Matović, B. 2009) ili direktno zapremine po hektaru (Koprivica, M. et al. 2010).

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GYPSY MOTH PREDATORS, PARASITES AND PATHOGENS IN BELGRADE FORESTS IN THE PERIOD 2010-2011

Mara TABAKOVIĆ-TOŠIĆ[1]

Abstract: *In the autumn 2010, the gypsy moth occupied an area of 4,066.74 hectares and 1,418.95 hectares, respectively, of the Forest Administrations Avala and Lipovica, managed by the Forest Estate Belgrade. Regarding the intensity of the infestation in 2010, the area of 2,066.68 hectares (50.8%) was subject to the moderate infestation, the area of 984.80 hectares (24.2%) was subject to the severe infestation, and the area of 922.37 hectares (22.7%) was subject to the light infestation. A relatively small area, i.e. 92.89 hectares (2.3%), was subject to the very severe infestation, i.e. there was a few hundred egg masses/hectare, which was expected as it is typical for the progradation phase of the outbreak. In the autumn 2011 the considerable decrease in the area infested by the gypsy moth and the considerable lower intensity of the infestation were reported, which reflected the retrogradation phase and implied that the gypsy moth reported in these two forest administrations would be in the latency phase in the following year. The area of 912.67 hectares (64.3%) was subject to the light infestation, the area of 291.66 hectares (20.55%) was subject to the moderate infestation, the area of 94.38 hectares (6.65%) was subject to the severe infestation, and the area of 120.24 hectares (8.5%) was subject to the very severe infestation. The total area infested by the gypsy moth in these two forest administrations was 1,418.95.*

During the observed period, in the gypsy moth population, the activity of 24 natural enemies of this insect - twelve predators, eleven parasites and one pathogen were reported. The egg and larval instars of the gypsy moth were infested by the same number (6 species) of predators. There were 6 parasitic species of the gypsy moth larvae, 2 parasitic species of the gypsy moth eggs, and 3 parasitic species of the gypsy moth pupae. Regarding the density of some species, the most abundant predators were Allotrombium fuliginosum (Hermann) and Calosoma sycophanta Linnaeus, while the most abundant parasites were Anastatus japonicus Ashmead and Oencyrtus kuwanae (Howard). In addition, at some sites

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Lymantrya dispar nucleopolyhedrosis virus had the dominant role in the reduction of the gypsy moth density.

Key words: the gypsy moth, outbreak, natural enemies

PREDATORI, PARASITI I PATOGENI GUBARA U ŠUMAMA BEOGRADSKOG PODRUČJA U PERIODU 2010-2011. GODINE

Izvod: *U jesen 2010. godine u šumama kojima gazduje šumsko gazdinstvo Beograd, Šumske uprave Avala i Lipovica, prisustvo gubara je ustanovljeno na 4066,74 ha, dnosno 1418,95. Kada su u pitanju intenziteti napada, u 2010. Godini na 2066.68 ha (50.8%) je registrovan srednji, na 984.80 ha (24.2%) jak i slab na 922.37 ha (22.7%). Vrlo jak intenzitet, sa više hiljada legala/ha, zabeležen je na relativno maloj površini od 92.89 ha (2.3%), što je i očekivano budući da se radi o progradacionoj fazi gradacije. U jesen 2011 godine evidentirano je značajno umanjenje površina pod napadom, kao i intenziteta napada, što ukazuje na to da je nastupila retrogradaciona faza i da će gubar u narednoj godini u području ove dve šumske uprave ući u fazu latence. Slab intenzitet napada registrovan je na površini od 912.67 ha (64.3%), srednji na 291.66 ha (20.55%), jak na 94.38 (6.65%) i vrlo jak na 120.24 (8.5%) ha. Ukupna napadnuta površina u području navedene dve šumske uprave iznosila je 1418.95 ha.*

U istraživačkom periodu, u populacijama gubara, registrovana je aktivnost 24 vrste njegovih prirodnih neprijatelja i to dvanaest predatora, jedanaest parasita i jedan pathogen. Stadijumi jajeta i larve gubara bili su na udaru jednakog broja (po 6 vrsta) predatora. Parasitskih vrsta larvi gubara je bilo 6, jaja 2, a lutki 3. Za sada je identifikovan samo jedan pathogen. Kada je u pitanju brojnost pojedinih vrsta, najvišu abundanciju od predatora su imali Allotrombium fuliginosum (Hermann) i Calosoma sycophanta Linnaeus, a od parazita Anastatus japonicus Ashmead i Oencyrtus kuwanae (Howard). Takođe, na pojedinim lokalitetima dominantnu ulogu u redukciji brojnosti gubara imao je Lymantrya dispar nucleopolyhedrosis virus.

Ključne reči: gubar, gradacija prirodni neprijatelji

1. INTRODUCTION

The gypsy moth (*Lymantria dispar* L.), insect in the order *Lepidoptera*, is one of the major serious pests of broadleaf forests and orchards. It is characterised by a high reproductive capacity, considerable ecological plasticity and polyphagia. It occurs periodically in high numbers (outbreak). Although it is found on four Continents (North Africa, Asia, Europe, North America), the greatest damage is caused to the forests of the Balkan Peninsula, which have all the favourable environmental conditions for the gypsy moth development, and it often occurs in outbreaks. The outbreaks do not occur in regular intervals.

The damage caused by the gypsy moth is twofold: direct – defoliation or the loss of leaf mass, and indirect, expressed as the consequences. Defoliation caused by caterpillar feeding lead to the loss of increment, absence of fructification, physiological wakening and tree dying, as well as to the creation of favourable conditions for the infestation of phytopathogenic microorganisms, fungi and xilophagous insects, disturbance of the aesthetical appearance, etc.

The integral protection of forest implies the continuous application of the protective measures in the aim of the undisturbed growth and increment of trees, as well as the creation of the wood volume of the best possible quality, which implies the inclusive and maximum protection from the harmful effect of various abiotic and biotic factors (Tabakovic-Tosic, 2006).

For the control of the gypsy moth the expensive bacterial and chemical insecticides, which not only affect the target species, but other representatives of entomofauna as well, were frequently used. The necessity of the reduction of the adverse effect of insecticides and preservation of the biological diversity in the natural ecosystems, have imposed the need for the study and use of the new types of the peculiar biological agents and methods for the control of this and other species of pests (Tabakovic-Tosic *et al*., 2011).

Biological control, as the part of the forest integrated protection, is defined as the use of natural enemies (parasitoids, predators, and pathogens) to regulate or control pests. Various strategies have been used for the deployment of biological control agents.

Recent emphasis on the development of an integrated control program for the gypsy moth has necessitated an understanding of its mortality-causing biological agents. Throughout the holarctic region there is a wide range of natural enemies of this insect. Natural enemies (parasitic and predatory insects, many species of spider, several species of birds and common woodland mammals) play an important role during periods when gypsy moth populations are sparse. Disease caused by viruses, bacteria or fungi contribute to the decline of gypsy moth populations. For example, baculovirus – *Lymantria dispar* nucleopolyhedrosis virus (*Ld*NPV) is specific to the gypsy moth, the most devastating natural diseases, and it causes a dramatic collapse of outbreak populations by killing both the larvae and pupae. Infection by *Ld*NPV is the most common source of mortality in high density populations and *Ld*NPV epizootics usually cause the collapse of host populations.

This paper presents the results of survey of the natural enemies (predators, parasitoids) and pathogens of gypsy moth in the Belgrade forests in the period 2010-2011.

2. MATERIALS AND METHODS

In Belgrade region, forest complexes cover an area of 32,444 hectares **(**www.srbijasume.rs**).** This area is a natural site for broadleaf tree species (*Quercus cerris* L**.,** *Quercus petraea* (Matt.) Lieblein, *Quercus frainetto* Tenore, *Fagus moesiaca* (Domin, Maly) Czeczott., *Carpinus betulus* L., *Fraxinus excelsior* L., *Fraxinus ornus* L. and other), whereas the conifers were introduced in some places and occupy a small area.

During the observed period at some sites in the broadleaf forests in the Forest Administrations Lipovica (Management Units Lipovica, Kosmaj, Košutnjačke šume) and Avala (Management Unit Avala), which belong to the Forest Enterprise Belgrade (Public Enterprise Srbijašume), the gypsy moth density was controlled pursuant to the guidelines of the Report-diagnose-forecast service in the domains of plant protection - forest protection. The gypsy moth density in

forests was controlled by the method of sample plots (25x25 m), as well as by the march-route method. A survey of main predators, parasitoids and pathogens was conducted from May to late November of 2010-2011 in the observed area during studies of the population dynamics and outbreaks of the gypsy moth.

The studies of the presence and density of the main predator species of the gypsy moth were conducted by using the method of hunting, typical for some families to which the insects belong (different kinds of traps, manual method, method of mowing by using the entomological net).

The detailed quantitative and qualitative studies of the parasitisation rate of the sampled egg masses were conducted in the laboratory of the Institute of Forestry, and, depending on the observed parameter, either ocular method or method of the survey by using binocular magnifier was applied. In addition, the dynamics of the emergence of the imago parasitoids of the gypsy moth eggs from 50 (10 from each sample plot) previously analyzed egg masses was observed under the laboratory conditions in February and November 2011. From each egg mass, 100 randomly sampled, previously cleaned eggs, were placed in the specially prepared test tubes (with the distilled water on the bottom and absorbent cotton wool in the middle, aimed at preventing soaking of the eggs).). The test tubes with the sampled gypsy moth eggs were kept in the climate chamber. During the experiment, temperature and light conditions were constant (temperature 19°C, light regime – 10 hours night, 14 hours a day). The emergence was reported every day until the end of the process.

The general technique applied for the study of the parasitisation rate of the gypsy moth in larval and pupae instars consisted of weekly collections of up to 100 larvae or pupae per site from all sites in each area. The larvae were collected from understory and overstory foliage, ground litter, and tree trunks throughout the site. The burlap-band technique involved collecting from one tree, at least 15 cm dbh and part of the overstory, closest to each point marked for sampling. Each of 10 labeled tree per site had a 25-cm-wide burlap band placed around the trunk at breast height. The burlap-bands for the gypsy moth caterpillars at the selected sites were placed in April 2010. Once a week all larvae under each band were collected.

The field-collected larvae were grown under the laboratory conditions in the climate chamber. During the experiment, temperature and light conditions were constant (temperature 21°C, light regime – 8 hours night, 16 hours a day). The larvae were on daily basis fed on the fresh leaves of the main type of the host plant, brought from the sample plots (oak or beech). The field-collected pupae were transferred to 500 g plastic containers (maximum of 10 to a container) and held at room temperature.

Larvae and pupae were examined twice a week, and upon indication of being parasitized were removed from the containers and placed in Petri dishes. The immature and adult stages of the parasites were identified at a later stage.

The studies of the presence of entomopathogenic viruses, bacteria and fungi in the dead gypsy moth larvae were conducted in the field and laboratory conditions. In the field conditions the characteristic symptoms of some diseases were identified by using ocular method, while in the laboratory conditions, they were identified by dissection of the dead larvae and the microscope survey. Prior to

this stage, the dead larvae were placed in Petri dishes with wet filter paper, kept 7 days in the laboratory and then stored in the refrigerator.

3. RESULTS AND DISCUSSION

In August 2010, by the detailed survey of the sample plot, and the application of the march-route method in the forests managed by Forest Estate Belgrade, Forest Administrations Avala and Lipovica, it was reported that the gypsy moth occupied an area of 4,066.74 hectares. Regarding the intensity of the infestation, the area of 2,066.68 hectares (50.8%) was subject to the moderate infestation, the area of 984.80 hectares (24.2%) was subject to the severe infestation, and the area of 922.37 hectares (22.7%) was subject to the light infestation. A relatively small area, i.e. 92.89 hectares (2.3%) was subject to the very severe infestation, which implied a few hundred egg masses/hectare, which was expected, since it is typical for the progradation phase of the outbreak. In the autumn 2011 the considerable decrease in the area infested by the gypsy moth and the considerable lower intensity of the infestation were reported, which reflected the retrogradation phase and implied that the gypsy moth reported in these two forest administrations would be in the latency phase in the following year. The area of 912.67 hectares (64.3%) was subject to the light infestation, the area of 291.66 hectares (20.55%) was subject to the moderate infestation, the area of 94.38 hectares (6.65%) was subject to the severe infestation, and the area of 120.24 hectares (8.5%) was subject to the very severe infestation. The total area infested by the gypsy moth in these two forest administrations was equal to 1,418.95.

It is a rare organism that has no natural enemies, if indeed there are any such. Natural enemy populations have the unique ability of being able to interact with their prey or host populations and to regulate them at lower levels than would occur otherwise. Some are effective at extremely low prey levels, other only at higher levels, such as *Lymantria dispar* nucleopolyhedrosis virus.

In biological control parlance, natural enemies are referred to as parasites, predators or pathogens. Parasites may have one generation to one of the host (univolutine) or two or more generations to one of the host (multivolutine), and they tend to attack only one host stage, although there is also some overlapping in certain cases – adult insects do not serve as hosts very often (Debach, 1974). Predatory insects differ from parasitic ones in that the larvae or nymphs, as the case may be, require several to many prey individuals to attain maturity. Adults of many if not most species are also predatory. There may be one or several generations to one of the prey. Pathogenic micro-organisms attack insects and have life cycles more or less characteristic of similar micro-organisms developing in other groups of animals. Insects are probably subject to as wide a variety of diseases. A number of pathogenic microorganisms – viruses, bacteria, fungi, and microsporidia (for example: *Lymantria dispar* nucleopolyhedrosis virus, *Bacillus thuringiensis* Berliner, *Entomophaga maimaiga* Humber, Shimazu & Soper, *Nosema lymantriae* (Weiser), *Nosema serbica* Weiser*)* – infect the gypsy moth (Stiles *et al*., 1983; Weiser, 1998; Pilarska and Vávra, 1991; Sidor, 1979; Sidor and Jodal, 1983; Tabakovic-Tosic, 2008). The epizootics of them are often spectacular, and mortality is most prevalent during gypsy moth outbreaks.

During the observed period, in the gypsy moth populations, the activity of 24 natural enemies of this insect - twelve predators, eleven parasites and one pathogen -was reported (Table 1). The gypsy moth eggs and larvae were infested by the same number of the predators (6 species).

Table 1. *Natural enemies of gypsy moth in the Belgrade region in the period 2010-2011*

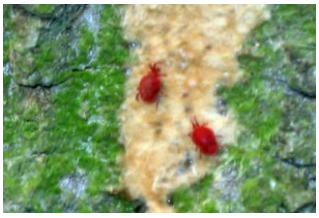
Gypsy moth natural enemies	Taxonomy	Type of the interaction with the gypsy moth	Gypsy moth instar	Significance
Allotrombium fuliginosum (Hermann)	Prostigmata: Trombidiidae	predator	egg	+++
Carabus latus Dejean	Coleoptera: Carabidae	predator	egg	+
Dermestes sp.	Coleoptera: Dermestidae	predator	egg	++
Dermestes erichsoni Ganglbauer	Coleoptera: Dermestidae	predator	egg	++
Megatoma pici Kalik	Coleoptera: Dermestidae	predator	egg	++
Julistes floralis Olivier	Coleoptera: Cantharidae	predator	egg	+
Calosoma sycophanta Linnaeus	Coleoptera: Carabidae	predator	larvae	+++
Carabus coriaceus Linnaeus	Coleoptera: Carabidae	predator	larvae	+
Carabus cancellatus Linnaeus	Coleoptera: Carabidae	predator	larvae	+
Carabus cavernosus Frivaldsky	Coleoptera: Carabidae	predator	larvae	+
Carabus intricatus Linnaeus	Coleoptera: Carabidae	predator	larvae	++
Carabus scabriusculus bulgarus Lapouge	Coleoptera: Carabidae	predator	larvae	+
Anastatus japonicus Ashmead	Hymenoptera: Eupelmidae	parasite	egg	++
Oencyrtus kuwanae (Howard)	Hymenoptera: Encyrtidae	parasite	egg	+++
Apanteles sp.	Hymenoptera: Braconidae	parasite	larvae	++
Cotesia melanoscelus Ratzeburg,	Hymenoptera: Braconidae	parasite	larvae	++
Glyptapanteles liparidis Bouché	Hymenoptera: Braconidae	parasite	larvae	++
Blepharipa pratensis (Meigen)	Diptera: Tachinidae	parasite	larvae	++
Exorista larvarum (Linnaeus)	Diptera: Tachinidae	parasite	larvae	+
Compsilura concinnata (Meigen)	Diptera: Tachinidae	parasite	larvae	+
Theronia atalantae (Poda)	Hymenoptera: Ichneumonidae	parasite	pupae	+
Lymantrichneumon disparis (Poda)	Hymenoptera: Ichneumonidae	parasite	pupae	+
Brachimeria intermedia (Nees)	Hymenoptera: Chalcididae	parasite	pupae	+
*Ld*NPV	baculovirus	pathogen	larvae	+++

Legend:
+ poorly represented species
++ represented species
+++ highly represented species

There were six parasitic species of the gypsy moth larvae, two parasitic species of the gypsy moth eggs, and three parasitic species of the gypsy moth pupae. Only one pathogenic species (*Ld*NPV) has been identified so far, but there are indications that two more species are present. Since the microscope survey of the sampled material has not been completed yet, the possible positive results will be published in the future.

Regarding the density of some predator species, *Allotrombium fuliginosum* (Hermann) and *Calosoma sycophanta* Linnaeus were most abundant ones. At least one imago *A. fuliginosum* was reported in almost all egg masses in autumn. *Calosoma sycophanta*, which regularly occurs during the outbreak of the gypsy moth, was found more frequently than other predator species, and it reduced the population size of the gypsy moth both in the larval and imago instars.

Picture 1. *Allotrombium fuliginosum* (Hermann)



Picture 2. *Calosoma sycophanta* Linnaeus

Table 2. *The laboratory analysis of the gypsy moth egg masses collected in the autumn 2010 and 2011 (the size of the sample plot for each Management Unit: 10 plots x 10 egg masses)*

Management Unit	N %	Average number eggs in egg mass							
		Fertilized				Unfertilized		Total	
		Vital		Parasited					
		2010	2011	2010	2011	2010	2011	2010	2011
Lipovica	N	478.2	368.7	59.2	33.0	3.0	1.1	540.4	402.8
	%	88.5	91.5	11.0	8.2	0.5	0.3	100	100
Košutnjačke šume	N	566.5	291.3	39.0	99.6	2.7	1.6	608.2	392.5
	%	93.2	74.2	6.4	25.4	0.4	0.4	100	100
Kosmaj	N	511.7	392.4	75.5	84.9	6.6	2.5	593.8	479.8
	%	86.2	81.8	12.7	17.7	1.1	0.5	100	100
Avala	N	342.8	503.7	107.8	148.0	3.3	7.5	453.9	659.2
	%	75.5	76.4	23.8	22.5	0.7	1.1	100	100

Average parasitism rate of eggs in egg masses at the study localities ranged from 6.4 to 25.4% (Table 2). The greatest positive change in the activity of the parasites occurred in the Management Unit Košutnjačke šume, from 6.4% in 2010 to 25.4 % in the following year. Given the fact that it refers to only one gypsy moth instars, out of four with their peculiar parasitic species, it can be concluded that such a high parasitism rate can considerably contribute to the ending of the gypsy moth outbreak in this area in 2012.

The dynamics of the emergence of the imago parasites was studied in the special experiment which is described in a great detail in the previous chapter. Regarding the species of egg parasites, in 2010 *Anastatus japonicus* Ashmead (syn. *A. disparis* Ruschka) accounted for 31%, *Oencyrtus kuwanae* (Howard) – 69%. Almost identical condition was reported in 2011 (*Anastatus japonicus* – 30%, *Oencyrtus kuwanae* – 70%). The average parasitism rate should not be taken as the final one, because under these laboratory conditions it is impossible to study all the effects of a range of parasites and predators to which the the egg masses are exposed in the field.

At the selected sites the cocoons of the parasitic species from the families *Braconidae* and *Tachinidae* (Table 2) were regularly found in spring. The determination of them was conducted after they were grown in the laboratory conditions and after the emergence of the imagos. Other species were considerably less frequent and were found individually.

Picture 3. *Gypsy moth larvae killed by LdNPV*

Lymantrya dispar NPV caused the death of about 20% of L_4 gypsy moth instar at one site in the Forest Administration Lipovica (Management Unit Košutnjačke šume). In addition, a large number of the larvae brought from the field and subsequently grown in the laboratory conditions were infested by this pathogenic species.

4. CONCLUSION

In the autumn 2010, the regular monitoring of the gypsy moth population level in some forests in the Forest Administrations Lipovica (Management Units Lipovica, Kosmaj, Košutnjačke šume) and Avala (Management Unit Avala), which belong to the Forest Estate Belgrade (Public Enterprise Srbijašume), was conducted. The gypsy moth occupied an area of 4,066.74 hectares.The largest area were subject to the moderate infestation (2,066.68 hectares or 50.8%), followed by

the area subject to the severe infestation (984.80 hectares or 24.2%), the area subject to the light infestation (922.37 hectares or 22.7%) and finally by the area subject to the very severe infestation (92.89 hectares or 2.3%).

In autumn 2011 the gypsy moth egg masses covered an area of 1,418.95 hectares. The largest area was subject to the light infestation (912.67 hectares or 64.3%), followed by the area under the moderate infestation (291.66 hectares or 20.55%), by the area under the very severe infestation (120.24 hectares or 8.5%) and finally by the area subject to the very severe infestation (94.38 hectares or 6.65%). At some sites the number of oviposited egg masses per unit of area (ha) amounted to several thousand ones.

On the infested areas the increased density of gypsy moth natural enemies (parasites, predators, pathogens) was reported. The activity of 24 natural enemies of this insect - twelve predators, eleven parasites and one pathogen - was reported.

Allotrombium fuliginosum and *Calosoma sycophanta* were the most abundant and active predators, whereas *Oencyrtus kuwanae* and *Anastatus japonicus* were the most abundant and active parasites. Also, the presence of one pathogen, *Lymatrya dispar* NPV, was reported.

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Mara TABAKOVIĆ-TOŠIĆ

Summary

The regular monitoring of the population size of the gypsy moth in the Forest Administrations Lipovica (Management Unit Lipovica, Kosmaj, Košutnjačke šume) and Avala (Management Unit Avala), which belong to the Forest Estate Belgrade (Public Enterprise for Forest Management Srbijašume), was conducted in the autumn 2010. The gypsy moth was reported in the broadleaf forests and it occupied an area of 4,066.74 ha. The greatest area was subject to the moderate infestation 2,066.68 hectares or 50.8%), followed by the area subject to the severe infestation (984.80 hectares or 24.2%), by the area subject to the light infestation (922.37 hectares or 22.7%), and, finally, by the area subject to the very severe infestation (92.89 hectares or 2.3%).

In the autumn 2011 the gypsy moth egg masses covered an area of 1,418.95 hectares. The greatest area was subject to the light infestation (912.67 hectares or 64.3%), followed by the area subject to the moderate infestation (291.66 hectares or 20.55%), by the area subject to the very severe infestation (120.24 or 8.5%), and, finally, by the area subject to the severe infestation (94.38 hectares or 6.65%). At some sites several hundred egg masses per a hectare were found.

In the infested area the increased activity of the natural enemies of the gypsy moth (parasites, predators, pathogens) was reported. The activity of 24 species –twelve predators (*Allotrombium fuliginosum, Carabus latus, Dermestes sp., Dermestes erichsoni, Megatoma pici, Julistes floralis, Calosoma sycophanta, Carabus coriaceus, Carabus cancellatus, Carabus intricatus, Carabus cavernosus, Carabus scabriusculus bulgarus*), eleven parasites (*Anastatus japonicas, Oencyrtus kuwanae, Apanteles* sp., *Cotesia melanoscelus, Glyptapanteles liparidis, Blepharipa pratensis, Exorista larvarum, Compsilura concinnata, Theronia atalantae, Lymantrichneumon disparis, Brachimeria intermedia)* and one pathogen (*Lymatrya dispar NPV)* - was reported. The gypsy moth eggs and larvae were infested by the same number of predators (6 species). Six parasitic species of gypsy moth larvae, two parasitic species of gypsy moth eggs and three parasitic species of gypsy moth pupae were reported.

Allotrombium fuliginosum and *Calosoma sycophanta* were the most abundant and active predators, whereas *Oencyrtus kuwanae* and *Anastatus japonicus* were the most abundant and active parasites. Also, the presence of one pathogen, *Lymatrya dispar* NPV, was reported.

PREDATORI, PARASITI I PATOGENI GUBARA U ŠUMAMA BEOGRADSKOG PODRUČJA U PERIODU 2010-2011. GODINE

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Summary

Redovna kontrola populacionog nivoa gubara u području šumskih uprava Lipovica (gazdinske jedinice Lipovica, Kosmaj, Košutnjačke šume) i Avala (Gazdinska jedinica Avala), a koje pripadaju Šumskom gazdinstvu Beograd (Javno preduzeće za gazdovanje šumama Srbijašume) obavljena je u jesen 2010. godine. Gubar je konstatovan u lišćarskim šumama na 4066,74 ha. Najveće površine su bile pod srednjim intenzitetom napada (2066.68 ha ili 50,8%), zatim pod jakim (984.80 ha ili 24,2%), slabim (922.37 ha ili 22,7%) i na kraju pod veoma jakim (92.89 ha ili 2,3%).

U jesen 2011. Godine jajna legla gubara su otkrivena na 1418,95 hektara. Najveće površine su bile pod slabim intenzitetom napada (912.67 ha ili 64,3%), zatim pod srednjim (291.66 ha ili 20.55%), vrlo jakim (120.24 ili 8,5%) i na kraju pod jakim (94.38 ili 6,65%). Na nekim lokalitetima bilo je prosečno po nekoliko hiljada jajnih legala na jednom hektaru.

U napadnutom području uočena je pojačana aktivnost prirodnih neprijatelja gubara (parazita, predatora, patogena). Registrovana je aktivnost 24 vrste, i to dvanaest predatora (*Allotrombium fuliginosum, Carabus latus, Dermestes sp., Dermestes erichsoni, Megatoma pici, Julistes floralis, Calosoma sycophanta, Carabus coriaceus, Carabus cancellatus, Carabus intricatus, Carabus cavernosus, Carabus scabriusculus bulgarus*), jedanaest parasita (*Anastatus japonicas, Oencyrtus kuwanae, Apanteles* sp., *Cotesia melanoscelus, Glyptapanteles liparidis, Blepharipa pratensis, Exorista larvarum, Compsilura concinnata, Theronia atalantae, Lymantrichneumon disparis, Brachimeria intermedia)* i jedan pathogen (*Lymatrya dispar NPV)*. Stadijumi jajeta i larve gubara bili su na udaru jednakog broja (po 6 vrsta) predatora. Parasitskih vrsta larvi gubara je bilo 6, jaja 2, a lutki 3.

Od svih nađenih vrsta, najveću brojnost i aktivnost su imali predatori *Allotrombium fuliginosum* i *Calosoma sycophanta*, paraziti *Oencyrtus kuwanae* i *Anastatus japonicus*, kao i jedini pathogen *Lymatrya dispar* NPV.

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GYPSY MOTH OUTBREAKS IN FOREST COMPLEXES OF THE BELGRADE REGION IN THE PERIOD 1996-2011

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Abstract: *The paper presents the results of investigation of a gypsy moth population density level in the forest area of the Belgrade region, in the period 1996-2011. The characteristics of three over-proliferations were analysed, two of which had a character of an outbreak (2003-2005. and 2009-2011.)*

Key terms: gypsy moth, outbreak, forests, Belgrade region

1. INTRODUCTION

Gypsy moth (*Lymantria dispar* L.), insect in the order *Lepidoptera*, is one of the major pests of broadleaf forests and orchards. It is characterised by its high reproductive capacity, a considerable ecological plasticity and polyphagia. Periodically, it occurs in large numbers (over-proliferation or outbreak). Although present in all four continents (North Africa, Asia, Europe, North America), the most damage has been inflicted in the forests of the Balkan Peninsula, where all

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environmental conditions for its development are favourable (Tabaković-Tošić, 2002).

In the region of Belgrade, where forest complexes cover 32,444 hectares, out of which 16,808 ha or 51.8% is in state, and 15,636 or 48.2% in private ownership, timber volume amounts to 2,649,340 m^3, gypsy moth is an autochthonous species and it often occurs in outbreaks. It was considered earlier that gypsy moth outbreaks occur every 8 to 10 years, however, the events in last 50 years disproved that assumption (Mihajlović *et al*., 1998).

Damage caused by gypsy moth is twofold: both direct – defoliation or a loss of leaf mass, and indirect, manifested through the effects of defoliation. Defoliations caused by feeding of caterpillars lead to reduction of increment, absence of fruit bearing, physiological weakening and drying of trees, as well as the creation of favourable conditions for attacks of phytopathogenic micro-organisms, fungi and xylophagous insects, disruption of spatial aesthetics and other. The reference data indicate that a volume increment is reduced by 40-70% in course of one total defoliation, depending on a type of tree and forest, whereas during a partial defoliation it is reduced by 20-25%.

2. INVESTIGATION AREA

The region of Belgrade, the area in which gypsy moth over-proliferation has been investigated, is situated at the contact - transition point between two natural-geographic units of Serbia, Panonnian Plane in the north, and the hilly-mountain Balkan Peninsula in the south. It is located 45° north of Equator and 20.5° east of Greenwich. It covers the surface area of 3,250 km^2. The Belgrade urban agglomeration, with its one million and six hundred thousand inhabitants, is located in this area. Rivers Danube and Sava divide the region into the north, lowland, morphologically homogenous part (alluvial plains and terraces of 80-100 m altitude) and the south, morphologically heterogeneous part (fluvio-denuded plateaux of 100-200 m altitude); foothills of 200-500 m altitude and horsts of the mountains Avala, of 511 m altitude, and Kosmaj, of 628 m altitude). The climate is moderate continental and, according to Köppen classification, the *Cfb* climate dominates in the region. The average annual air temperature is 11.9ºC. January is the coldest (the average temperature is 1.1ºC), and July the warmest month (the average temperature is 21.7ºC). The mean annual maximum temperature is 16.6ºC, and the minimum temperature is 7.9ºC. The number of days with temperature above 30°C, so-called tropical days, is 31 on average, and the number of summer days with temperature above 25°C is 95 per year. The average annual insolation is approximately 2,000 hours. The highest insolation, about 10 hours per day, is in July and August, and the highest cloudiness is in December and January, when sun shines on average 2-2.3 hours per day. The mean annual relative air humidity is 69%. The average amount of precipitation is approximately 685 mm (maximum in June, 90.4 mm; minimum in October, 40.3 mm). The average annual number of snowfall days is 28. The region is characterised by air silences (183‰) and south-east wind (‘*košava*’) (145‰), which most commonly occurs in the cold half of a year, with the speed of 40 to 70 km/h (Hydro-meteorological Institute of Serbia).

This area is a natural habitat for deciduous tree species (*Quercus cerris* L., *Quercus petraea* (Matt.) Lieblein, *Quercus frainetto* Tenore, *Fagus moesiaca* (Domin, Maly) Czeczott., *Carpinus betulus* L., *Fraxinus excelsior* L., *Fraxinus ornus* L. and other), whereas coniferous trees are introduced sporadically and in small areas.

3. MATERIAL AND METHOD

3.1. Gypsy moth population control

Gypsy moth population control measures were administered in all deciduous forests every year, (during an outbreak period in coniferous forests as well), regardless of their ownership category (state or private), and in accordance with the Instructions supplied by the officials responsible for Report-diagnostic forecast in the domain of plant protection – forest protection. The gypsy moth population control in forests was carried out by means of a permanent (25x25 m) and a temporary (10x10 m) sample plot method, as well as a route method and a method of traps using gypsy moth female sex-attractant for capturing males (pheromone traps).

The determination of the attack intensity and the spatial definition of the attack area are of critical importance, as those determinants present the key factors for selection of a control method and timing: in the egg stadium (mechanical or chemical, from the period of the autumn leaf dropping until the beginning of summer foliation), or in the larva stadium (aerial spraying, conducted at the end of April or in the beginning of May).

Permanent sample plots were subject to control every year, whereas temporary sample plots were controlled only when an over-proliferation threat seemed apparent. The route method and pheromone trap method were applied as additional measures during a gypsy moth latency (low population density) period, whereas they were invariably used during the outbreak period (Tabaković-Tošić, 2002).

3.2. Quantitative and qualitative analysis of gypsy moth egg masses

A detailed quantitative and qualitative analysis of sampled egg masses was conducted at the laboratory of the Institute of Forestry and, depending on the analysed parameter, the ocular method or the method of binocular magnifying glass examination was applied. Additionally, the dynamics of flying out of gypsy moth egg parasitoides imagoes from previously analysed masses was monitored in the laboratory conditions in winter period.

100 randomly sampled, previously cleaned eggs from each egg mass were placed in specially prepared test tubes (with distilled water at the bottom and a cotton wool layer in the middle, intended to prevent a total immersion of eggs). The test tubes with sampled gypsy moth eggs were held in a climate chamber. During the experiment, the air temperature and the light regime had been constant (the temperature 19°C, the light regime – 10 hours night, 14 hours day). The recording of flying out of parasites was conducted daily until it ceased.

4. RESULTS AND DISCUSSION

The occurrence of an outbreak, from the one hand, depends on a gypsy moth physiological constitution, and from the other, on impact of external factors – type and quality of food, meteorological conditions and biotic factors (disease, natural enemies and competitor species) (Janković, 1958; Marović *et al.*, 1998; Mihajlović *et al.*, 1998; Tanasković, 2005).

In the latency period, gypsy moth is a regular member of a forest biocenosis. However, occasionally (when the absence of activity of one or more environmental resistance factors occurs), the pest responds quickly by over-proliferation, i.e. enters into an outbreak phase. The course of an outbreak has four phases: pre-outbreak, eruption, culmination and regression, followed by a period of latency – a regular population density.

The most important qualitative and quantitative parameters indicating a gypsy moth population level increase in one area, are the following: females lay eggs in open places (in the latency period eggs are usually hidden); pronounced gregariousness (grouping instinct); caterpillars feed during the daytime (in the latency period they feed at night); a sexual index value increases, resulting in male predominance at the end of a culmination phase; an increase of caterpillar polyphagy; egg masses contain from 800 to over 1,000 eggs (in the latency period 300-600); the number of egg masses per surface unit significantly increases (Vasić, 1981).

In the course of those investigations, during the process of establishing the number of gypsy moth egg masses per surface unit (1 hectare), particular attention was paid to inclusion of all forests complexes. This aspect was of major importance for the areas in which occurrence of a particularly intense attack was observed (over 500 egg masses per hectare), as the amount of damage manifested through leaf- mass injury, to be caused by hatched larvae, is not the same under the attack of 501 and, for instance, 50,000 egg masses per hectare (Mihajlović *et al*, 2004, Tabaković-Tošić, 2004).

Table 1. *Outspread of gypsy moth in the forests of Belgrade region in the period 1991-2011 (number of oviposited egg masses at the end of summer period)*

YEAR	ATTACK INTENSITY AND ATTACKED AREA								TOTAL
	Low intensity 1-10 egg masses/ha		Medium intensity 11-100 egg masses/ha		High intensity 101-500 egg masses/ha		Severe intensity over 500 egg masses/ha		
	ha	%	ha	%	ha	%	ha	%	
1996.	746,00	100	0	0	0	0	0	0	**746,00**
1997.	998,0	100	0	0	0	0	0	0	**998,0**
1998-2002. – gypsy moth latency period									
2003.	10,00	0,3	349,75	8,9	1729,82	44,2	1824,62	46,6	**3914,19**
2004.	2,00	0,03	473,00	7,6	417,00	6,7	5354,00	85,7	**6246,00**
2005.	2343,11		46,00		22,00		26,00		**2437,11**
2006-2008. – gypsy moth latency period									
2009.	825.53	22,1	2023,74	54,1	865,19	23,2	21,20	0,6	**3735.66**
2010.	922,37	22,7	2066,68	50,8	984,80	24,2	92,89	2,3	**4066.74**
2011.	959,67	65,5	291,66	19,9	94,38	6,4	120,24	8,2	**1465,95**

As can be seen from the data in the Table 1, the population level increase in the investigation area, observed in the period 1996-1997, did not assume a character of an outbreak. The attack intensity is within the category of mild, whereas the attacked area was relatively small and limited to the forests in the Management unit Avala.

The mechanical and chemical control measures, undertaken in the egg stadium, most probably caused the sudden interruption of over-proliferation, prevented spreading of attacked area and restored gypsy moth population density to a normal level, at which it does not inflict economic and ecological damage to forest tree species.

The gypsy moth latency period in this area lasted for five years, and it was followed by a repeated occurrence of over-proliferation (2003), which would assume all characteristics of an outbreak in the following years. Mechanical and chemical suppression measures undertaken in the egg stadium and administered in autumn of 2003 and winter of 2004, did not produce satisfactory results, due to an enormous number of egg masses, laid high in stems and crowns. In the summer period of 2004, air-suppression in the larva stadium was conducted, by means of a biological preparation D-stop (active ingredient: spores and crystals *Bacillus thuringiensis* ssp. *kurstaki*), which also proved ineffective. A partial or total defoliation occurred in the entire area. On the account of an enormous number of voracious larvae and lack of food, a large number of caterpillars died, but nevertheless, a sufficient number of them remained, continuing their development. In autumn of 2004, newly-laid gypsy moth egg masses were found in the area of 6,246 ha.

Following the partial elimination of egg masses, performed in the autumn-winter period in spring of 2005, a repeated air-suppression was conducted in the larva stadium, but this time a third generation chemical insecticide Dimilin SC 48 (active ingredient diflubenzurone) was selected. The performed suppression was effective and, in autumn of 2005, it resulted in a low number of laid egg masses (approximately 10 per hectare), on a nearly three times smaller area. The suppression in the summer period resulted in a termination of the outbreak period and commencement of the latency period in following year. It should be pointed out that the above-mentioned preparations are highly selective and ecologically safe, and applied in ultra low volumes (ULV) (Tabaković-Tošić i Jovanović, 2007).

The third gypsy moth over-proliferation cycle during the investigation period also had every characteristic of an outbreak, with the exception that this time the attacked area was far smaller. The regression phase occurred in autumn 2011, and it was a result of the successful gypsy moth suppression in the egg stadium and the increased activity of gypsy moth natural enemies (parasites and predators).

Picture 1. *August 2004. – laying of egg masses at the Management unit Lipovica*
(author: Gordana Jančić)

Picture 2. *June 2004. – total defoliation at the Management unit Kosmaj*
(author: Mara Tabaković-Tošić)

Picture 3. *August 2004. – laying of egg masses at the Management unit Kosmaj*
(author: Gordana Jančić)

The analysis of gypsy moth egg masses, collected in the area of the Management unit Beograd (Table 2), had been conducted at the laboratory of the Institute of Forestry every year during the investigation period. The average number of eggs in an egg mass ranged from 108.7 (2005) to 739.6 (2003). The egg mass with the largest number of eggs (1449) was submitted to the Institute in 2003 from the department 24b – MU Guberevačke šume. The percentage share of vital eggs in the total number of eggs ranged, on average, from 58.8 in 2005 to 90.5 in 2009.

The average egg parasiticity ranged from 3.7 in 1996 to 40.8% in 2005. The above-stated parasiticity values should not be considered final, as they concern laboratory conditions, which prevent the activity of a number of parasites and predators, to which egg masses are exposed in nature.

Table 2. *Laboratory analysis of gypsy moth egg masses sampled from representative trial plots in the area of FMU Beograd*

Year	Number of egg masses	Average number of eggs in an egg mass						
		Fertilised				Unfertilised		Total
		Vital		Parasitised				
		N	%	N	%	N	%	N
1996	37	397.2	88.5	16.4	3.7	35.2	7.8	448.8
1997-2002 gypsy moth latency period								
2003	297	590.7	79.8	144.0	19.5	4.9	0.7	739.6
2004	154	325.8	74.0	111.8	25.4	2.7	0.6	440.3
2005	38	63.9	58.8	44.4	40.8	0.4	0.4	108.7
2006-2008 gypsy moth latency period								
2009	60	457,1	90.5	44,2	8.7	4,0	0.8	505.3
2010	100	474.8	85.8	70.4	13.5	3.9	0.7	549.1
2011	100	389.0	81.0	91.4	18.4	3.2	0.6	483.6

The results of the analysed quantitative and qualitative parameters of gypsy moth egg masses confirm the above-stated assertion that the increase of gypsy moth population density above normal values in the forest area of Belgrade region in the period 1996-2011 occurred three times, whereas only two population increases had a character of an outbreak.

The dynamics of flying out of parasite imagoes from the previously analysed egg masses was monitored in special trials. Only two egg parasites species *Anastatus japonicus* Ashmead (syn. *A. disparis* Ruschka) and *Oencyrtus kuwanae* (Howard) were present every year. Their percentage ratio was relatively consistent in every year - 30:70%, with clear domination of *Oencyrtus kuwanae.*

5. CONCLUSIONS

After a thirty-year long interval of latency, the increase of the gypsy moth population density above the normal level occurred three times in the forest area of Belgrade region in the period 1996-2011, whereas two population increases (2003-2005 and 2009-2011) had a character of an outbreak.

The control measures undertaken in egg and larva stadia, although adequately prepared and timely applied, did not always produce satisfactory results (2003–2005). In the period between 1996 and 1997, a suppression conducted in the egg stadium was effective, since the intensity of the attack was mild in the entire area and egg masses were laid in places accessible for their elimination.

In the period 2009-2011, a regressive phase occurred as a result of a successful gypsy moth suppression in the egg stadium, as well as the increased activities of gypsy moth natural enemies (parasites and predators).

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OVER-PROLIFERATION OF GYPSY MOTH IN FOREST COMPLEXES OF THE BELGRADE REGION IN THE PERIOD 1996-2011

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Katarina MLADENOVIĆ, Zlatan RADULOVIĆ, Snežana RAJKOVIĆ

Summary

Following a thirty-year long interval of latency, an increase of the gypsy moth population density above the normal level occurred three times in the investigation area in the period 1996-2011, whereas two population increases (2003-2005 and 2009-2011) had a character of an outbreak.

The increase of gypsy moth population level in 1996-1997 did not assume character of an outbreak. The intensity of the attack was within the category of mild, whereas the attacked area was relatively small and limited to forests of Management unit Avala.

The mechanical and chemical control measures, undertaken in the egg stadium, most probably caused the sudden interruption of over-proliferation, prevented spreading of attacked area and restored gypsy moth population to a normal level, at which it does not inflict economic and ecological damage to forest tree species. A gypsy moth latency period in this area lasted for five years, and it was followed by a repeated occurrence of over-proliferation (2003.), which would assume all characteristics of an outbreak in following years. Mechanical and chemical suppression of gypsy moth in egg stadium, conducted in autumn of 2003 and winter of 2004 did not produce satisfactory results, due to an enormous

number of egg masses, laid high in stems and crowns. In the summer period of 2004, the air-suppression conducted in the larva stadium, by means of a biological preparation D-stop (active ingredient: spores and crystals *Bacillus thuringiensis* ssp. *kurstaki*), also proved ineffective. A partial or total defoliation occurred in the entire area. On the account of an enormous number of voracious larvae and lack of food, a large number of caterpillars died, but nevertheless, a sufficient number remained, continuing their development. In autumn of 2004, newly-laid gypsy moth egg masses were found in the area of 6,246 ha.

Following the partial elimination of egg masses, performed in the autumn-winter period, a repeated air-suppression in the larva stadium was conducted in spring of 2005, but this time a third generation chemical insecticide Dimilin SC 48 (active ingredient diflubenzurone) was selected. The performed suppression was effective and in autumn of 2005 it resulted in a low number of laid egg masses (approximately 10 per hectare), on a nearly three times smaller area. The suppression in summer period led to termination of the outbreak period and commencement of the latency period in following year.

The third gypsy moth over-proliferation cycle in the investigation period also had every characteristic of an outbreak, with the addition of the fact that this time attacked area was far smaller. The regression phase occurred in autumn 2011, and it was a result of a successful suppression of gypsy moth in the egg stadium and the increased activity of gypsy moth natural enemies (parasites and predators).

PRENAMNOŽENJA GUBARA U ŠUMSKIM KOMPLEKSIMA BEOGRADSKOG REGIONA U PERIODU OD 1996-2011. GODINE

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Rezime

U istraživanom području, nakon tridesetogodišnje latence, u periodu od 1996-2011. godine tri puta je došlo do povećanja populacionih nivoa gubara iznad normalne vrednosti, a dva (2003-2005. i 2009-2011. godina) su imala gradogeni karakter.

Povećanje populacionog nivoa gubara u 1996-1997. godini nije poprimilo karakter gradacije. Intenzitet napada je bio u kategoriji slabog, a napadnuta površina je bila relativno mala i ograničena samo na šume u Gazdinskoj jedinici Avala. Preduzete mehaničke i hemijske mere suzbijanja u stadijumu jajeta su najverovatnije uzrokovale nagli prekid prenamnoženja, sprečile širenje površine pod napadom i vratile populacioni nivo gubara na normalnu vrednost, kada ne pričinjava ekonoske i ekološke štete šumskim vrstama drveća.

Period latence gubara u ovom području je trajao pet godina, nakon čega ponovo nastupa njegovo prenamnoženje (2003. godina), a koje će u narednim godinama poprimiti sve osobine gradacije. Mehaničke i hemijske mere suzbijanja gubara u stadijumu jajeta, preduzete u jesen 2003. i zimu 2004. godine nisu dale zadovoljavajuće rezultate jer se radilo o enormnom broju legala položenih visoko na deblima i u krošnjama. U prolećnom periodu 2004. godine izvršeno je aviosuzbijanje u stadijumu larve biološkim preparatom D-Stop (aktivna materija: spore i kristali Bacillus thuringiensis ssp. kurstaki), koje je takođe bilo neefikasno. Na celokupnoj površini došlo je delimičnog ili totalnog golobrsta. Usled enormnog broja proždrvljivih larvi i nedostatka hrane, veliki broj gusenica je uginulo, ali je ostao dovoljan broj koji je nastavio razviće. U jesen 2004. godine novopoloženih jajnih legala gubara je bilo na ukupnoj površini od 6246 ha.

Nakon delimičnog uklanjna jajnih legala, preduzetog u periodu jesen-zima, u proleće 2005. godine ponovo je preduzeto aviosuzbijanje u stadijumu larve, ali ovaj put je odabran hemijski insekticid treće generacije Dimilin SC 48 (aktivna materija

diflubenzuron). Suzbijanje je bilo efikasno, pa je u jesen 2005. godine gubar je položio mali broj jajnih legla (do 10 legala/ha) na skoro 3 puta manjoj površini. Njihovo suzbijanje u jesenjem periodu je rezultiralo završetkom gradacije i nastupanjem latence u narednoj godini.

Treće prenamnoženje gubara u istraživačkom periodu takođe ima sve osobine gradacije, s tim što je ovaj put napadnuta površina znatno manja. Retrogradaciona faza je nastupila u jesen 2011. godine, a posledica je uspešnog suzbijanja gubara u stadijumu jajeta i povećane aktivnosti prirodnih neprijatelja gubara (parazita i predatora).

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SUSTAINABLE FORESTRY **ODRŽIVO ŠUMARSTVO**
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SIMULTANEUS ATTACK OF *LYMANTRIA DISPAR* L. AND *MICROSPHAERA ALPHITOIDES* GRIFF. ET MAUBL. ON *QUERCUS* SPECIES (*Q. CERRIS, Q. FARNETTO* AND *Q. PETRAEA*) IN CERTAIN PARTS OF SERBIA FROM 2004 TO 2006

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Abstract: *This paper presents research conducted in three regions in the Republic of Serbia – around Kragujevac, Pozarevac and Vrnjacka Banja – as there are large zonally situtated areas populated by oak clusters (the most common oak species in these regions are Quercus farnetto, Q. cerris and Q. petraea). At permanently established sample plots examinations were conducted to assess chlorosis, defoliation and damages caused by the gypsy moth and powdery mildew instigators.*

The aim of this paper was to perform preliminary examinations and determine whether there is any connenction between the magnitude of the mildew infections and that of the gypsy moth attacks on Hungarian oak, Turkey oak and Sessile oak trees in the territory of Serbia and whether there are differences in attacks among the three oak species. The largest number of defoliated Sessile oak trees with severe chlorosis were recorded during the year 2005, which was followed by the strongest attacks of the powdery mildew and gypsy moth on the same species.

Key words: Turkey oak, Hungarian oak, Sessile oak, Gypsy moth, Powdery mildew

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SIMULTANI NAPAD *LYMANTRIA DISPAR* L. I *MICROSPHAERA ALPHITOIDES* GRIFF. ET MAUBL. NA *QUERCUS* VRSTAMA (*Q. CERRIS, Q. FARNETTO* I *Q. PETRAEA*) U PERIODU OD 2004. DO 2006. GODINE U NEKIM DELOVIMA SRBIJE

Izvod: *Ispitivanja u ovom radu su vršena na 3 područja u Republici Srbiji - Kragujevac, Požarevac i Vrnjačka Banja, na kojima se zonalno nalaze veće površine pod hrastovim sastojinama (najčešće vrste hrastova na ovim područjima su Quercus farnetto, Q. cerris i Q. petraea). Pregledi su rađeni na stalnim bioindikacijskim tačkama, na kojima je vršena ocena hloroze, sušenja i evidentirana oštećenja od gubara i prouzrokovaća pepelnice. Cilj ovog rada je bio da se izvrše preliminarna ispitivanja i utvrdi da li postoji veza između intenziteta zaraze pepelnicom i jačine napada gubara i na sladunu, ceru i kitnjaku na području Srbije i da li postoji razlika u napadu na ove tri vrste hrastova. Najviše suvih stabala kitnjaka i stabala sa jakom hlorozom bilo je tokom 2005. godine, što je bilo praćeno i najjačim napadom pepelnice i gubara na ovoj vrsti.*

Ključne reči: cer, sladun, kitnjak, gubar, pepelnica

1. INTRODUCTION

Serbia is considered a medium forested country. According to the latest data by the National Forest Inventory for the year 2009, 29.1% of the total land area of Serbia is under forests.

The total forested land area in Serbia amounts to 2,252,400 ha, with oak forest area of 720,800 ha. Out of these,Turkey oak forests (*Quercus cerris* L.) cover 345,200 ha and Sessile oak forests (*Quercus petraea* /Mattuschka/ Liebl.) cover 173,200 ha, whereas Hungarian oak (*Quercus farnetto* Ten.), English oak (*Quercus robur* L.) and Downy oak trees (*Quercus pubescens* Willd.) populate 159,600 ha, 32,400 ha and 10,400 ha respectively (the National Forest Inventory of the Republic of Serbia, 2009).

There are a dozen oak species in Serbia, of which the above said ones are considered the most important forest trees (Gajic, Tesic, 1992).

As the basis of various national and international policies, sustainable forest management is based on the information on the key factors affecting the health of forests. Such information is collected through extensive, long-term and intensified monitoring of the forest condition conducted within *ICP Forests* (*the International Co-Operative Programme on Assessment and Monitoring Air Pollution Effects on Forests)* and *the Convention on Long-Range Transboundary Air Pollution (CLRTAP)* of the EU. Their foundations and guidelines were defined by the working group of the European Forestry Commission (EFC) and the International Food and Agriculture Organisation (FAO). The foundations of the current ICP manual as the method for harmonised continuous forest condition monitoring were laid by the United Nations – European Forestry Commission (Freiburg, 1984).

Sustainable forest management includes regular monitoring of the occurance and dissemination of severe diseases and pests, which is particularly significant for forest protection in practice.

Large-scale drying of oak forests is partly a result of the presence of powdery mildew caused by the pathogen fungus *Microsphaera alphitoides* Griff. et Maubl. (1910), which particularly affects new, young foliage susceptible to infection. Oak powdery mildew presents a serious problem for seedlings in nurseries as well as for naturally and artificially introduced young plants. In adult trees, it reduces height growth and hinders natural forest restoration. The infections occur from the beginning of May up to the end of the vegetation period.

Pathogens causing powdery mildew are obligate parasites which belong to the order *Erysiphales*. Their presence has been noticed in over 1,300 deciduous plants in 28 countries all over the world. Powdery mildew pathogens occur in 256 species of trees and bushes (Nef and Perrin, 1999). Being epiphyte, they develop on the leaf surface, enter through the epidermis of the host cells and take the nutrients from the host plant by means of haustoria with specialised structure.

Mildews occur mostly in forest trees, where they are most apparent. They are distributed all over the world, especially in the USA and Europe. Occasionally they occur in beech, alder, birch, sycamore, sweet chestnut, maple, willows, poplars and other tree species. More than 30 species of the *Quercus* genus are susceptible to mildew instigators. Conifers are resistant to this pathogen (Karadzic, 2010).

A more intensive research of the gypsy moth began in Serbia in the 1920s becuase at the time it was considered, alongside the oak powdery mildew (*Microsphaera alphitoides* Griff. et Maubl.), to be the major factor leading to the deterioration of oak forests.

Conditionally speaking, gypsy moth *(Lymantria dispar L., Lepidoptera, Lymantridae)* is one of the major pests attacking deciduous forests; it is characterised by a great reproductive power and significant ecological plasticity and polyphagia. Gypsy moth is an indigenous species with optimal conditions for reproduction. It feeds on the leaves of over 500 tree and bush species and is best developed on the species of the *Quercus* genus (Lance, 1983 according to Milanovic, 2010). Gypsy moth caterpillar larvae feed on the leaves of almost all deciduous tree species, forest bushes, shrubs and weeds, all fruiters and green mass of many farming and vegetable crops. Its vitality and adaptability allow for periods of excessive propagation – large-scale gradations. During the 20th century gypsy moth caused immense damages to the economy and various other areas of life. As many as 17 instances of excessive gypsy moth propagation have been recorded up to date.

During these gradations of the gypsy moth (*Lymantria dispar* L.), which last between 3 and 5 years, the first to suffer is oak foliage devoured by the caterpillars. Soon afterwards, oak trees leaf again and the new foliage is attacked by powdery mildew. Following the successive mildew instigators' attacks over several years, oak trees become physiologically weak and vulnerable to the attacks of honey fungus (*Armillaria mellea*), which causes root rot (Karadzic, Milijasevic, 2005).

Damages caused by the gypsy moth (except defoliation) may be indirect, in the form of collateral consequences. Defoliation resulting from larvae food intake lead to the loss in height growth, failure in fruit bearing, physiological weakening and drying of the trees as well as creation of favourable circumstances for attcks by

various pathogenic microorganisms, fungi and xylophagous insects, ruining the aesthetics of the forested area, etc. (Tabakovic-Tosic, 2005). Although it feeds on a large number of plant species, gypsy moth exhibits preference toward species of the *Quercus* genus. In the reference works cited, the most preferred species are English oak and Turkey oak. Recent research suggests that Turkey oak displays more favourable features for the development of the gypsy moth than the other oak species. Out of all significant oak species in Serbia, Hungarian oak remains insufficiently researched in relation to the gypsy moth attacks (Milanovic, 2010).

The aim of this paper was to perform preliminary research and determine whether there is any connenction between the magnitude of the mildew infections and the magnitude of the gypsy moth attacks on Hungarian oak, Turkey oak and Sessile oak trees in the territory of Serbia and whether there are differences in attacks among the three oak species.

2. MATERIALS AND METHODS

The Republic of Serbia is involved in the ICP Forests (*the International Co-Operative Programme on Assessment and Monitoring Air Pollution Effects on Forests)* through its Nacional Focal Centre (NFC). Monitoring of the Level 1 forest condition has been performed in Serbia since 2003, during the vegetation periods, at 131 sample plots established within either 16-kilometre or 4-kilometre grid. 68 of these sample plots are situated in oak forests.

Within a sample plot, a quadrat is established, whose central point is permanently marked with a metal stake. The trees for the crown condition assessment are selected systematically as clusters of trees around the 4 loci, which are at a 25-metre distance in 4 cardinal directions from the centre marked with a stake. In this way the nearest 6 trees in each direction are selected (24 in total) and defined as samples for assessment. Samples include all tree species on condition their height is over 60 cm.

Every year, during the vegetation period, the selected trees are observed for the assessment of chlorosis and defoliation and damages are recorded and classified according to the types (entomological, phytopathological and mechanic) and species of instigators. In addition, the exact tree part where damage is observed is recorded (foliage, branches, bark, part of the trunk, base, root, etc.). Chlorosis (decolourisation) is measured by indices ranging from 0 to 3, and branch drying (defoliation) is measured by indices ranging from 0 to 4 (Table 1).

Table 1. *Methods of assessing chlorosis and defoliation at sample plots in Serbia*

Foliage chlorosis (decolourisation)		Branch drying (defoliation)	
Indices	Symptoms for foliage chlorosis indexing	Indices	Symptoms for branch drying indexing
0	Change in foliage colour 0 to10%	0	Branch drying 0 to10%
1	Change in foliage colour 11 to 25%	1	Branch drying 11 to 25%
2	Change in foliage colour 26 to 60%	2	Branch drying 26 to 60%
3	Change in foliage colour over 61%	3	Branch drying over 61%
		4	Completely dried up trunk – 100%

In order to obtain relevant and objective assessment of the health condition of the trees, examination is performed in mid-vegetation period, approximately at the same time (this is particularly important for deciduous species, due to autumn foliage drying, which may affect defoliation and decolourisation evaluation and render a false assessment of the crown condition).

Research presented in this paper was conducted in three geographically separated regions in the Republic of Serbia – around Kragujevac, Pozarevac and Vrnjacka Banja – as there are large zonally situtated areas populated by oak clusters (the most common oak species in these regions are *Quercus farnetto*, *Q. cerris* and *Q. petraea*).

Examinations were performed at permanently established sample plots numbered 18, 20, 21 (in the territory of Kragujevac), 26, 27 and 29 (in the territory of Pozarevac) and 60 and 61 (in the territory of Vrnjacka Banja).

The gypsy moth attacks in the above said regions during the 3-year period were monitored by counting hatches and expressed by means of the following scale:

weak attack (1-10 hatches per hectare),
medium attack (11-100 hatches per hectare),
strong attack (101-500 hatches per hectare),
very strong attack (over 500 hatches per hectare).

The attacks of powdery oak mildew instigators on oaks in the above said regions in Serbia from 2004 to 2006 are expressed in percentages of the trees affected relative to the total number of trees at a sample plot.

3. RESULTS AND DISCUSSION

Table 2 presents magnitude of the gypsy moth and powdery mildew attacks on Hungarian oak, Turkey oak and Sessile oak trees in Serbia (in the territories of Kragujevac, Vrnjacka Banja and Pozarevac) from 2004 to 2006.

Table 2. *Magnitude of the gypsy moth and powdery mildew attacks on Hungarian oak, Turkey oak and Sessile oak trees in Serbia from 2004 to 2006*

Oak species	Sample plot No.	Occurence of mildewand gypsy moth in oak trees						
		Region examined	2004		2005		2006	
			mildew	gypsy moth	mildew	gypsy moth	mildew	gypsy moth
Q. farnetto	18	Kragujevac	20	-	20	strong	8	medium
Q. cerris	20		-	-	-	weak	21	weak
Q. farnetto	20		40	-	50	weak	50	weak
Q. cerris	21		-	weak	-	-	-	-
Q. farnetto	21		-	-	-	-	-	-
Q. cerris	60	Vrnjacka Banja	-	-	-	-	-	-
Q. farnetto	60		15	strong	5	weak	2	-
Q. petraea	61		5	weak	-	-	-	-
Q. cerris	26	Pozarevac	2	-	-	-	-	-
Q. farnetto	26		40	very strong	30	very strong	30	strong
Q. petraea	27		-	-	9	weak	13	weak
Q. cerris	29		5	medium	-	weak	-	-
Q. farnetto	29		15	medium	8	weak	5	-

The above table shows that medium, strong and very strong attacks of the gypsy moth were recorded only on Hungarian oak trees, whereas other oak species (Sessile and Turkey oaks) suffered either weak gypsy moth attacks or none at all.

The greater magnitude attacks of powdery mildew instigators were also recorded only on Hungarian oak trees, whereas Sessile and Turkey oaks suffered either weak mildew attacks or none at all.

A very strong gypsy moth attack on Hungarian oak in the territory of Pozarevac took place during the years 2004 and 2005. It was subsequently followed by a most intensive mildew attack (30 to 40%). Similarly, a strong gypsy moth attack on the same oak species in the territory of Kragujevac in 2005 was followed by a mildew attack of 20% magnitude. Only during 2004, in the territories of Vrnjacka Banja and Pozarevac, was there a strong gypsy moth attack followed by a lower magnitude of the mildew infection (15%).

It is also evident from the data in the table above that, during the whole assessment period, mildew infections at almost all locations monitored were proportional to the gypsy moth attacks in magnitude, which applies to all the examined oak species. In other words, when a change occurs and a very strong gypsy moth attack following a large percentage of trees with mildew infection turns into a strong attack, or a strong attack turns into a medium one etc., the infection with this pathogen fungus also subsides. This was the case in Požarevac, when a medium gypsy moth attack on Hungarian oak trees from 2004 turned into a weak attack in 2005 and the magnitude of mildew infection dropped from 15% in 2004 to 8% during 2005. At the same location, a transition from a weak gypsy moth attack in 2005 to a complete absence of the gypsy moth in 2006 was related to the subsidence of the mildew infection from 8% in 2005 to only 5% during the year 2006.

Moreover, a severe mildew infection (40% in the territory of Kragujevac in 2004) with no gypsy attack coinciding increased to 50% in 2005, followed by a weak gypsy moth attack, which remained the same in magnitude the next year, as well as mildew infection.

The impact of the gypsy moth caterpillars on defoliation in oak forests often results in the losses in height growth of up to 30% or even 40% (Klepac, 1966). Financial losses, which may be very high, can thus be easily calculated. Besides, many experts consider reduction in the forest ecological stability an even graver negative effect. On the other hand, successive mildew infections over the course of several years will additionally reduce the height growth of the trees and make them physiologically weak and susceptible to the attacks of other diseases and pests.

In his work, Karadzic (2006) states that, in respect to the most common foliage diseases, no significant differences in susceptibility have been observed among Sessile oak, Hungarian oak and Turkey oak species.When these species are compared by susceptibility to parasitic fungi, the most susceptible is Sessile oak, Hungarian oak comes second and Turkey oak ends up third as the most resistant. In natural clusters of trees, all three species are vulnerable to the attacks of parasitic fungi that occur on both foliage and bark, whereas in urban areas the trees exhibit more vulnerability to the attacks of wood-rotting fungi.

The results of the preliminary examinations conducted and presented in this paper suggest that no direct connection can be established between the gypsy moth attack magnitude and that of the mildew infection, i.e. a strong gypsy moth attack is not always followed by a severe mildew infection the next year. This is, among other things, due to the fact that the magnitude of the infection with this pathogen fungus primarily depends on the climate factors at a certain geographical area during the vegetation period (first of all, relative air humidity and temperature).

Table 3 summarises the health condition of the oak trees at sample plots at all the locations monitored and their mildew infections during the 3-year period.

Table 3. *Health condition of oak trees at sample plots in Serbia and mildew and gypsy moth*

Oak species	Year	Chlorosis (%)				Defoliation (%)					Trees infected with mildew (%)	Gypsy moth attack magnitude
		0	1	2	3	0	1	2	3	4		
Q. cerris	2004	84.7	12.4	3.0	0.0	56.9	31.4	11.6	0.0	0.0	1.5	very weak
	2005	88.1	8.1	3.0	0.7	44.4	38.9	16.7	0.0	0.0	2.0	weak
	2006	88.5	9.6	1.7	0.2	59.8	30.8	9.2	0.0	0.2	2.9	weak
Q. farnetto	2004	79.5	11.4	6.4	2.7	45.5	32.4	19.3	2.7	0.0	0.7	strong
	2005	75.5	14.6	8.9	0.5	34.4	39.1	25.7	0.7	0.0	2.7	strong
	2006	72.8	20.8	6.4	0.0	51.9	27.5	20.6	0.0	0.0	12.6	medium
Q. petraea	2004	52.1	30.7	14.6	2.6	38.5	41.1	19.8	0.5	0.0	9.9	-
	2005	56.0	22.5	14.1	7.3	25.1	42.9	30.4	1.6	0.0	16.2	very weak
	2006	68.6	20.4	9.4	1.6	34.0	38.2	27.2	0.5	0.0	37.2	weak

It is evident from the summarised results in Table 3 that in Turkey oak powdery mildew attacks were very weak during the whole assessment period – from 1.5 to 2.9%, only 2.1% on average. The largest number of Turkey oak trees with powdery mildew infection were recorded during the year 2006 (2.9%). The gypsy moth attacks on Turkey oak were also recorded, yet they were weak during the whole assessment period. With regard to chlorosis, the largest numbers of trees with high chlorosis indices were recorded in 2005, whereas the year 2006 was the least favourable for Turkey oak with regard to defoliation, followed by a more intensive mildew infection.

The powdery mildew attacks on Hungarian oak were also rather weak during the whole assessment period – from 0.7 to 12.6%, or 5.3% on average. The strongest mildew attack on Hungarian oak was recorded in 2006 (12.6%). However, the gypsy moth attacks were strong (within the first two years of the assessment period) to medium (during 2006). In terms of chlorosis and defoliation, the year 2004 was the least favourable for Hungarian oak with the largest numbers of dried trees and those with high chlorosis indices.

During the assessment period, the powdery mildew attacks on the examined Sessile oak trees amounted from 9.9 to 37.2%, i.e. 21.1% on average. A weak mildew attack was recorded in 2004 (9.9%). A medium mildew attack occurred in 2005 and encompassed 22.1% of the Sessile oak trees, whereas a mildew strong attack (16.2%) was recorded in 2006. The gypsy moth attacks were either very weak or they did not occur at all. The largest numbers of dried Sessile

oak trees and those with severe chlorosis were recorded during 2005, which conditions were followed by the strongest attacks of both powdery mildew and gypsy moth.

4. CONCLUSION

The largest numbers of dried Sessile oak trees and those with severe chlorosis were recorded during 2005, which conditions were followed by the strongest attacks of both powdery mildew and gypsy moth.

At locations monitored in Serbia, the strongest powdery mildew infection was recorded on Sessile oak trees, while medium, strong and very strong gypsy moth attacks were recorded only on Hungarian oak trees (during 2004 and 2005). As for the other oak species (Sessile oak and Turkey oak), the gypsy moth attacks were either rather weak or there were none at all. The magnitude of powdery mildew infections varied greatly on different locations due to weather conditions.

No direct connection could be established between the gypsy moth attack magnitude and that of the mildew infection, which is, among other things, due to the fact that the magnitude of the infection with this pathogen fungus primarily depends on the climate factors at a certain geographical area during the vegetation period (first of all, relative air humidity and temperature).

In the future, research of this kind ought to be extended to other areas. For the purpose of timely preparation and organisation of protective measures, regular monitoring of pests and forecasts of pest and disease development for each acoming year are of great importance to practical forest stewardship and should be utilised by forest staff.

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Rezime

Ispitivanja u ovom radu su vršena na 3 područja u Republici Srbiji - Kragujevac, Požarevac i Vrnjačka Banja, na kojima se zonalno nalaze veće površine pod hrastovim sastojinama (najčešće vrste hrastova na ovim područjima su Quercus farnetto, Q. cerris i Q. petraea). Pregledi su rađeni na stalnim bioindikacijskim tačkama, na kojima je vršena ocena hloroze, sušenja i evidentirana oštećenja od gubara i prouzrokovaća pepelnice. Cilj ovog rada je bio da se izvrše preliminarna ispitivanja i utvrdi da li postoji veza između intenziteta zaraze pepelnicom i jačine napada gubara i na sladunu, ceru i kitnjaku na području Srbije i da li postoji razlika u napadu na ove tri vrste hrastova. Gubar (Lymantria dispar L., Lepidoptera, Lymantridae) je jedna od najvećih štetočina lišćarskih šuma, a odlikuje se velikom reproduktivnom moći, znatnom ekološkom plastičnošću i polifagnošću. Gubar je autohtona vrsta sa optimalnim uslovima za razmnožavanje, hrani se lišćem preko 500 vrsta drveća i žbunja, a najbolje se razvija na vrstama iz roda Quercus. Tokom gradacija gubara koje traju 3 do 5 godina, prvo lišće hrasta strada od golobrsta gusenica. Ubrzo posle toga, hrast ponovo prolista i to drugo lišće napada pepelnica. Pepelnica hrasta (Microsphaera alphitoides Griff. et Maubl.) je ozbiljan problem na sadnicama u rasadnicima i na prirodnom i veštački unesenom podmlatku. Na odraslim stablima umanjuje prirast i otežava prirodno obnavljanje šuma. Infekcije se ostvaruju od početka maja meseca pa do kraja vegetacionog perioda. Najviše suvih stabala kitnjaka i stabala sa jakom hlorozom bilo je tokom 2005. godine, što je bilo praćeno i najjačim napadom pepelnice i gubara na ovoj vrsti.

SIMULTANEUS ATTACK OF *LYMANTRIA DISPAR* L. AND *MICROSPHAERA ALPHITOIDES* GRIFF. ET MAUBL. ON *QUERCUS* SPECIES (*Q. CERRIS, Q. FARNETTO* AND *Q. PETRAEA*) IN CERTAIN PARTS OF SERBIA FROM 2004 TO 2006

Miroslava MARKOVIC, Snezana RAJKOVIC, Katarina MLADENOVIC

Summary

This paper presents research conducted in three regions in the Republic of Serbia – around Kragujevac, Pozarevac and Vrnjacka Banja – as there are large zonally situtated areas populated by oak clusters (the most common oak species in these regions are Quercus farnetto, Q. cerris and Q. petraea). At permanently established sampling plots examinations were conducted to assess chlorosis, defoliation and damages caused by the gypsy moth and powdery mildew instigators. The aim of this paper was to perform preliminary examinations and determine whether there is any connenction between the magnitude of the mildew infections and that of the gypsy moth attacks on Hungarian oak, Turkey oak and Sessile oak trees in the territory of Serbia and whether there are differences in attacks among the three oak species. Gypsy moth (Lymantria dispar L., Lepidoptera, Lymantridae) is one of the major pests attacking deciduous forests; it is characterised by a great reproductive power and significant ecological plasticity and polyphagia. Gypsy moth is an indigenous species with optimal conditions for reproduction. It feeds on the leaves of over 500 tree and bush species and is best developed on the species of the Quercus genus. During the gradations of the gypsy moth, which last between 3 and 5 years, the first to suffer is oak foliage devoured by the caterpillars. Soon afterwards, oak trees leaf again and the new foliage is attacked by powdery mildew. Oak powdery mildew (Microsphaera alphitoides Griff. et Maubl.) presents a serious problem for seedlings in nurseries as well as for naturally and artificially introduced young plants. In adult trees, it reduces height growth and hinders natural forest restoration. The infections occur from the beginning of May up to the end of the vegetation period. The largest number of defoliated Sessile oak trees with severe chlorosis were recorded during the year 2005, which was followed by the strongest attacks of the powdery mildew and gypsy moth on the same species.

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SPIDER MITES AND PREDATORY MITES (ACARI: *TETRANYCHIDAE, PHYTOSEIIDAE*) ON OAK TREES IN THE CITY OF BELGRADE AND ITS VICINITY

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Abstract: *This paper presents preliminary research of diversity of fam. Tetranychidae and fam. Phytoseiidae on different oak species in the city of Belgrade and its vicinity in the period from 2010 to 2011. The study covers six different tree species from genus Quercus, four indigenous and two introduced species. The presence of two species of mite from Tetranychidae family, and three species from Phytoseiidae family has been verified so far.*

Key words: Tetranychidae, Phytoseiidae, *Quercus*

PAUČINARI I PREDATORSKE GRINJE (ACARI: TETRANYCHIDAE, PHYTOSEIIDAE) NA HRASTOVIMA ŠIREG PODRUČJA BEOGRADA

Sažetak: *U rada su izneta prelaminarna istraživanja diverziteta vrsta fam. Tetranychidae i fam. Phytoseiidae na različitim vrstama hrasta u Beogradu i njegovoj široj okolini u periodu 2010-2011. godine. Pregledom je obuhvaćeno šest različitih biljnih vrsta iz roda Quercus od čega su četiri autohtone a dve alohtone. Do sada je utvrđeno prisustvo dve vrste grinja iz fam. Tetranychidae i tri vrste iz fam. Phytoseidae.*

Ključne reči: Tetranychidae, Phytoseiidae, *Quercus*

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1. INTRODUCTION

Problems with mites as pests emerged in mid-20th century as a result of changes in environmental conditions, particularly apparent in urban areas due to the huge impact of the human factor. In urban conditions, due to unstable soil moisture, increased air pollution and temperature, plants become physiologically weakened and more susceptible to development of phytophagous mite, while in natural conditions plants rarely suffer severe damage since the numbers of mites are controlled by their natural enemies.

In Serbia, the studies of spider mites (Acari: Tetranychidae) and their predators (Acari: Phytoseiidae) have so far been mainly focused on agricultural ecosystems since the diversity of these mite species is less apparent on forest trees. A number of papers discuss occurrence of spider and predatory mites on forest plant species (Tomašević, 1964; Kropczynska and Petanović, 1987; Petanović and Stojnić, 1995; Stojnić and Petanović, 1994; Stojnić, 1993; Stojnić et al., 2002; Mladenović at al., 2010a, 2010b).

Oaks typically inhabit temperate region of the northern hemisphere. The *Quercus* genus includes around 450 tree and shrub species but only about ten of those 450 are present in our region. Oaks are one of the most important groups of forest plants in our country.

2. MATERIALS AND METHODS

Oak tree samples were collected during the vegetation period in the years 2010 and 2011, in autochthonous plant associations and in urban areas of Belgrade.

Belgrade is situated within the southern rim of the Pannonian basin and the northern border of the Balkan Peninsula. The northern part of the city area is located within the Pannonian plain, and the southern part lies on the rolling hills of Central Serbia. Mountains Avala (511 m) and Kosmaj (628 m) stand out in the relief of Šumadija region. The terrain gradually declines from south to north and is patched with river valleys. Belgrade hills (Banovo, Lekino, Topčidersko, Julino, Petlovo etc.) are located to the south of the Sava and Danube rivers, and alluvial planes and loess plateaus stretch to the north of the Sava and Danube. The city's average altitude is 132 m, with the lowest elevation in Grocka (71 m) and the highest elevation on Mt. Kosmaj. Belgrade has a temperate continental climate. Average annual temperatures vary from year to year due to the human factor impact and global warming (Faculty of Geography, Belgrade, 2011).

Samples were collected from six oak species: *Quercus robur* L., *Q. petraea* Liebl., *Q. frainetto* Ten., *Q. cerris* L., *Q. borealis* Michx. f., *Q.trojana* Webb.

Each sample contained 50 leaves. The samples were collected during the vegetation period. Separation of Tetranychidae and Phytoseiidae was carried out in laboratory by exposing the leaves to ethyl-acetate for 20 minutes, after which the leaves were shaken off and mites were recognized by means of a stereomicroscope. Isolated mite organisms were placed in solution of ethyl alcohol and lactic acid (Evans & Browing, 1955). After illumination, permanent preparations were made using Hoyer's medium (Baker & Wharton, 1964).

The appropriate keys were used to determine Tetranychidae (Prichard and Baker, 1955; Mitrofanov at al., 1987; Rota, 1961-62; Manson, 1967; Reeves, 1963) and Phytoseiidae (Begljarov, 1981; Karg, 1993). Permanent preparations were kept in storage at the Department of Entomology and Agricultural Zoology of the Faculty for Agriculture, University of Belgrade.

3. RESULTS AND DISCUSSION

Examination of the plant material showed the presence of two species of spider mites fam. Tetranychidae on two studied oak species: *Q. robur* and *Q. cerris*. Predatory mite species from Phytoseiidae family were found on all six studied oak species: *Q. robur, Q. petraea, Q. frainetto, Q. cerris, Q. borealis* and *Q. trojana*. Table 1 presents the Tetranychidae species found on oak tree species. Table 2 presents the Phytoseiidae species found on oak tree species.

3.1. Tetranychidae family

Table 1. *Species from Tetranychidae family found on Q. robur and Q. cerris*

Oak Species	Tetranychidae Species	Location
Quercus robur	*Schizotetranychus garmani*	Ada Ciganlija
	Oligonychus brevipodus	Ada Ciganlija, Banovo Brdo Park, Banjica Forest, Pionirski Park
Quercus cerris	*Oligonychus brevipodus*	Košutnjak Park Forest

Schizotetranychus garmani Pritchard & Baker, 1955

Typical distribution location of this species is in the USA and its typical host is *Salix sp.* It is also found worldwide on eight hosts: *Acer sp., Quercus robur*, *Populus tremula*; *Salix caprea*; *Salix humilis*; *Salix petiolaris*; *Salix sp.*; *Salix tristis*.

Distribution of this species encompasses Nearctic: USA; Palaearctic: Iran, Poland, Russia and Switzerland.

In Serbia it was first found on *Q. robur, Salix alba, Acer negundo* and *Corylus avellana* (Stojnić, 1993). During this research it was also found on *Q. robur*.

Oligonychus brevipodus Targioni Tozzetti, 1878

sin. *Oligonychus quercinus* Berlese, 1886

This species has not been sufficiently studied. Its typical distribution location is in Italy, while the typical host is *Quercus ilex*. It is also found worldwide on *Quercus ilex*; *Quercus pubescens*; *Quercus sp.*

Distribution of this species includes the Australian region: Australia, New Zealand, Tasmania; Palaearctic**:** France, Italy, Holland and the United Kingdom.

In Serbia it was first found on *Q. robur* and *Q. cerris* (Stojnić, 1993). During this research, the finding was confirmed both on *Q. robur* and *Q. cerris*.

3.2. Phytoseiidae Family

Table 2. *Species from Phytoseiidae family found on Q. robur, Q. cerris, Q. frainetto, Q. petraea, Q. trojana and Q. borealis*

Oak Species	Phytoseiidae Species	Location
Quercus robur	*Euseius finlandicus*	Košutnjak Park Forest, Ada Ciganlija, Rit, Progarska Ada, Bojčin Forest, Barajevo-Šiljakovac, Banjica Forest, Kalimegdan Park, Lazarevac-REIK
	Kampimodromus aberans	Banjica Forest
Quercus cerris	*Euseius finlandicus*	Lipovica –Bivolje Swamps, Košutnjak Park Forest, Miljakovac Forest, Sremački Rit, Bojčin Forest
Quercus frainetto	*Euseius finlandicus*	Lipovica – Bivolje Swamps, Topčider Park, Košutnjak Park Forest, Sremački Rit, Lazarevac-REIK
	Amblyseius andersoni	Lazarevac-REIK
	Kampimodromus aberans	Lazarevac-REIK
Quercus petraea	*Euseius finlandicus*	Miljakovac Forest
Quercus trojana	*Euseius finlandicus*	Faculty of Forestry Arboretum
Quercus borealis	*Euseius finlandicus*	Savski Venac-Emergency Center

Euseius finlandicus Oudemans, 1915

This species is a distinct cosmopolite, distributed across Europe, Asia, Africa, North and South America. It is observed in Serbia on numerous hosts (Radivojević and Petanović, 1984; Kropczynska and Petanović, 1987; Stojnić, 1993; Stojnić and Petanović, 1994; Stojnić, 2001; Mladenović at al, 2010b). It can be assumed that this species is dominant in Phytoseiidae habitats. It occurs on many plant species. During this study it was identified on all six oak species: *Q. robur, Q. petraea, Q. frainetto, Q. cerris, Q. borealis* and *Q. trojana*.

Amblyseius (Amblyseius) andersoni Chant, 1957

This species is present in most of Europe, Algeria, Canada, USA and former Soviet Republics. It is found in Serbia as well (Radivojević and Petanović, 1984; Kropczynska and Petanović, 1987; Mladenović at al, 2010b). It is found on numerous woody and herbaceous plants. During this research its presence was confirmed on *Q. frainetto.*

Kampimodromus aberrans Oudemans, 1930

This species is present in most of Europe, Algeria, Canada, USA and former Soviet Republics. It is found in Serbia as well (Radivojević and Petanović, 1984; Kropczynska and Petanović, 1987; Stojnić, 1993; Stojnić and Petanović 1994; Mladenović at al, 2010b). It is found on numerous woody and herbaceous plants. During this research its presence was confirmed on two oak species *Q. robur* and *Q. frainetto.*

4. CONCLUSIONS

This paper presents preliminary research of mite species diversity from fam. Tetranychidae and fam. Phytoseiidae on different oak species in the city of Belgrade and its vicinity.

The study covered six oak species: *Quercus robur* L., *Q. petraea* Liebl., *Q. frainetto* Ten., *Q. cerris* L., *Q. borealis* Michx. f., *Q. trojana* Webb., four species of which are indigenous (Sessile oak, English oak, Turkey oak and Hungarian oak) and two of which are introduced species (Macedonian oak and red oak).

The study confirmed the presence of two species of spider mites fam. Tetranychidae on English oak and Turkey oak, and three species of predatory mite fam. Phytoseiidae on all six examined oak species.

Tetranychidae are present on oak trees in the inner city central area, while Phytoseiidae were mostly found in natural plant associations in the vicinity of Belgrade.

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SOIL EXAMINATION FOR THE PURPOSE OF FORECASTING OCCURRENCE OF ENTOMOPATHOGENIC AND BENEFICIAL MICROORGANISMS

Vesna GOLUBOVIĆ ĆURGUZ[1], Zoran MILETIĆ[2]

Abstract: *In two sample plots, located at the site of Hungairan Oak and Turkey Oak forest (Quercetum frainetto cerris) and at the site of montane beech forest (Fagetum montanum), in which a mass natural perishing of gypsy moth larvae occurred in spring of 2011, the principal characteristics of soil – a natural development environment for certain stadia of possible entomopathogenic and other microorganisms, and a potential cause for the collapse, were analysed. Physical and chemical properties, as well as the abundance of principal physiological groups of soil microorganisms, were examined. The existence of similarity in soil physical properties was revealed at both sites, whereas the differences between chemical properties were far more significantly pronounced. The differences in chemical properties of the soil and the organic layer resulted in manifestation of differences with respect to abundance and relations among principal physiological groups of soil microorganisms.*

Key words: Soil physical properties, soil chemical properties, soil microorganism abundance

PREGLED ZEMLJIŠTA U FUNKCIJI PROGNOZE POJAVE ENTOMOPATOGENIH I KORISNIH MIKROORGANIZAMA

Izvod: *Na dva ogledna polja na staništu sladuna i cera (Quercetum frainetto cerris) i staništu brdske bukove šume (Fagetum montanum), gde je konstatovan masovan pomor gubara, a da nije bilo tretiranja nikakvim hemijskim i biološkim preparatima*

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analizirano je zemljište. Ispitane su fiziče i hemijske osobine kao i brojnost osnovnih fizioloških grupa zemljišnih mikroorganizama. Konstatovano je da postoji slinost u fizičkim svojstvima zemljišta na oba lokaliteta, a da su razlike u hemijskim svojstvima značajnije izražene. Razlike u hemijskim svojstvima zemljišta i organske prostirke su rezultirale ispoljavanjem razlika u brojnosti i odnosima osnovnih fizioloških grupa zemljišnih mikroorganizama.

Ključne reči: Fizička svojstva zemljišta, hemijska osobine zemljišta, brojnost zemljišnih mikroorganizama.

1. INTRODUCTION

A large number of beneficial entomopathogenic microorganisms spend one period of their development cycle in soil. Soil properties (soil solution reaction, nature of organic matter, presence of mineral plant assimilatives, humidity, aeration and oxidisability of pedochemical environment, as well as thermal conditions), to a large extent determine the species of soil microorganism that inhabit the soil, as well as their activity. Allelopathic relations of symbiosis and antagonism are established within a microorganism community that inhabits one pedochemical environment. That is performed through creation of matters by means of which microorganisms act upon each other, such as antibiotics, fungistatics, etc. The survival of entomopathogenic and other beneficial microorganisms, which spend only a part of their development cycle in soil, depends on such relations established within a soil microorganism community, as well as on physical and chemical properties of the environment in which they are active.

2. WORK METHODS

Sample plots were established at two sites in which a mass perishing of gypsy moth was observed. The first sample plot was established in the Hungarian Oak and Turkey Oak forest in the area of Barajevo, while the other was set up in a montane beech forest at Kosmaj. Pedological profiles were created in sample plots, the type of soil was determined and the samples, according to pedogenetic horizons, were taken for laboratory analysis.

The analysed soil properties are the following:

- Active and substitution acidity (pH u H_2O i pH u KCl), - potentiometrically ,
- Hidrolytic acidity (Y1) and the sum of adsorbed base cations (S), by Kappenn's method (Živković 1966). Based on those values, the unsaturation of adsorptive complex (T-S), total capacity of adsorption (T) and the degree of adsorptive complex saturation by base cations (V) were calculated, according to the following formulae:

$$T\text{-}S = 0.65 \cdot Y1 \quad [\text{ekv. mmol}/100\text{ g soil}]$$

$$T = S + (T\text{-}S) \quad [\text{ekv. mmol}/100\text{ g soil}]$$

$$V = \frac{S}{T} \cdot 100 \quad [\%]$$

- The total humus content was determined by wet combustion in the potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4) compound, by Tjurin method (Škorić, Racz 1966).
- The total nitrogen content, by Kjeldahl method (Džamić 1966)
- The content of plant accessible forms of phosphorus and potassium, using AL-method by Egner-Richm (Džamić et al 1996); whereby phosphorus was determined by a colorimetric method and potassium by a flame-photometric method.
- Soil particle size composition was determined by a sedimentation method with the application of Na- pyrophosphate as a peptisation agent. Removal of organic matter, carbonates and gypsum was not performed during the process (Racz 1971). Based on the soil textural composition, a textural class was determined, according to a Ferre's triangle.

For the purpose of examination of the abundance of soil microorganisms, samples of the horizon organic layer and the humus-accumulative horizon were taken. The determination of soil microorganism abundance was performed on samples in natural wetness condition. Nutrient media were sown by soil suspension 0.1 ccm in 10^{-3} dilution. The sowing was repeated three times, and the number of microorganisms was calculated per 1g of absolutely dry soil. Four different media were used: Čapek's agar (3 gr. $N_a NO_3$, 1 gr. KH_2PO_4, 0.5 gr. KCl, 0.5 gr. $MgSO_4$, 0.01 gr. $FeSO_4$, 20.0 gr. agar, 3.0 gr. sucrose, distilled water up to 1000 ml), MPA (meso-peptonic agar- 41.3 gr. nutrient agar, distilled water up to 1000 ml), Erzbi's agar (0.2 gr. KH_2PO_4,. 0.2 gr. $MgSO_4$, 0.2 gr. NaCl, 0.1 gr. K_2SO_4, 5.0 gr. $CaCO_3$, 20.0 gr. agar, 20.0 gr. malt sugar (glucose), distilled water up to 1000 ml) and synthetic agar with sucrose (0.5 gr. KH_2PO_4, 0.5 gr. $MgCO_3$, 0.50 gr. NaCl, 1,0 gr. KNO_3, 0.01 gr. $FeSO_4$, $CaCO_3$ in excess, 20,0 gr. agar, 25 gr. sucrose, distilled water up to 1000 ml). The media were sterilised in an autoclave at the temperature of 120°C, pressure of 1.5 at, in duration of 20 minutes. Following the autoclaving, the media were poured in petri dishes. After sowing, all petri dishes were placed in a thermostat at the temperature of 22±1°C. The determination of the total number of fungi, bacteria and actinomyces, developed on nutrient media, was performed after 5 and 10 days. The obtained measurement data were presented in graphs and tables, according to their site of origin.

The following physiological groups were determined:

- The number of ammonifying microorganisms on meso-peptonic agar;
- The number of oligonitrofilic microorganisms on Esbhi's agar;
- The number of actinomyces on synthetic agar;
- The number of fungi on Čapek's agar;
- The total number of microorganisms on soil agar;

3. RESEARCH RESULTS

The soil type in the sample plot 1 is luvisol, which is a soil type typical of oak forests. The physical properties of this soil are characterised by a large depth of solum, which in the analysed profile amounts to 100 cm (Table 1).

Table 1. *Soil -particle size composition and textural class*

Horizon	Depth	Coarse sand	Fine sand	Silt	Clay	Total sand	Total clay	Textural class
	cm	%	%	%	%	%	%	
Ilimerised soil - Luvisol								
A	0-5	3.70	49.90	25.20	21.20	53.60	46.40	Silty loam
E	5-20	0.60	27.30	34.00	38.10	27.90	72.10	Clay loam
Bt	20-100	0.40	26.10	32.00	41.50	26.50	73.50	Clay
Brown loessial soil - ilimerised cambisol								
A	0-2/8	1.00	32.00	42.60	24.40	33.00	67.00	Loam
E	2/8-30	0.90	28.40	44.80	25.90	29.30	70.70	Loam
(B)/Bt	30-100	1.10	28.10	39.00	31.80	29.20	70.80	Clay loam

This is a deep soil of a high capacity for absorption and retention of water. The skeleton is completely absent in the entire depth of solum. The humus-accumulative horizon belongs to a silty loam textural class. It is well water-permeable and aerated. As the soil depth increases, so does the content of clay, while the textural class in the eluvial horizon transforms into clay loam, and in the illuvial horizon it changes into clay. Such profile differentiation, based on textural composition, causes blocking of gravitational water runoff into the deeper layers of soil.

The chemical properties of the analysed luvisol are characterised by moderately acid reaction of the humus-accumulative horizon. As the depth of solum increases, so does the pH value and in the eluvial horizon active acidity of soil solution is in transition between moderately acid and highly acid. In the illuvial horizon the acidity slightly decreases. The adsorptive complex is characterised by a high total adsorption capacity, particularly in the humus-accumulative horizon. Such high total adsorption capacity in the humus horizon is a result of a high content of humus, while in the deeper horizons it is a result of a high content of clay. The sum of adsorbed base cations is highest in the humus-accumulative horizon, which is a result of a release of bases by mineralisation of organic matter. In the eluvial horizon, the sum of basis abruptly decreases and then again increases in the illuvial horizon. The degree of the adsorptive complex base cations saturation follows a similar pattern. According to the content of total humus in the humus-accumulative horizon, the soil belongs to a type with a high content of humus. Still, the thickness of the humus horizon is very low. The content of total nitrogen is high, while the carbon nitrogen ratio in the humus horizon is very broad, which indicates a quite high content of non-decomposed organic matter. As the solum depth abruptly decreases, so does the content of humus and nitrogen, while the C/N ratio is becoming narrower. According to the limit value for AL-method, the content of plant accessible phosphorus forms is within the limits of well supplied. However, it is quite sufficient for the needs of forest tree species. The humus horizon is well supplied with plant accessible potassium forms, while eluvial and illuvial horizons are average supplied.

Table 2. *Soil chemical properties*

Hori-zon	Depth	pH		Adsorptive complex					Total			Accessible	
				T	S	T-S	V	Y1	humus	N		P_2O_5	K_2O
	cm	H_2O	KCl	ekv.m.mol/100g			%	cm^3	%	%	C/N	mg/100g	
Ilimerised soil - Luvisol													
A	0-5	5.96	5.38	109.40	58.01	51.39	53.03	79.06	20.92	0.96	12.58	7.36	31.61
E	5-20	4.46	3.39	41.02	11.78	29.24	28.71	44.98	1.18	0.21	5.73	5.39	14.39
Bt	20-100	4.79	3.54	36.08	16.14	19.94	44.74	30.67	0.91	0.18	5.15	6.03	14.58
Brown loessial soil - ilimerised cambisol													
A	0-2/8	4.70	3.59	34.79	13.09	21.71	37.61	33.40	2.10	0.20	10.54	0.00	7.63
(E)	2/8-30	4.88	3.52	28.61	11.78	16.83	41.16	25.90	0.84	0.28	3.03	0.00	4.61
Bt(B)	30-100	5.06	3.60	27.67	15.27	12.40	55.17	19.08	0.53	0.19	2.81	0.00	5.44

At the sample plot at Kosmaj, in a montane beech forest, a brown loessed soil was identified. The solum depth is 100cm. According to the textural composition, the humus-accumulative and cambic horizon belong to a loam class, while the illuvial horizon is composed of clay loam. Although signs of ilimerisation are present in the soil profile, the clay transition index is less than 1.5, which classifies this soil as cambic (Škorić et al 1985). The soil is weakly skeletal, well-structured and well-aerated. The water-absorption and retention capacity is high.

`The humus-accumulative and eluvial horizons are characterised by a very high acidity of soil solution, whereas the acidity of illuvial horizon is high. The sum of adsorbed base catones is quite low. According to the degree of adsorptive complex base catones saturation, the humus-accumulative and elluvial horizons are district, while the illuvial horizon possesses a slightly higher degree of base catones saturation of 50%, which classifies it as eutric. According to the content of total humus in the humus-accumulative horizon, the soil belongs to a class with a low content of humus. The amount of total nitrogen is high in relation to such a low humus content, which results in a narrow carbone nitrogen ratio. The narrow C/N ratio indicates the intensity of organic matter decomposition processes and the occurrence of rapid transition of plant assimilatives from organic to mineral and plant accessible forms. The quantity of plant accessible phosphorus forms is extremely low and it is below the limit for an AL-method detection, in the entire depth of soil solum. Additionally, the supply of plant accessible potassium forms is very weak in the entire depth of solum.

In the organic layer of beech forest, the abundance of ammonifying microorganisms is nearly equal to the total number of microorganisms on soil agar (Table 3). The equal number of mineralogenic and ammonifying microorganisms indicates that the processes of organic matter decomposition occur in the organic layer, with a part of decompositon inter-products entering into mutual synthesis by creating humus matter, and a part of them is decomposed to final products, whereby plant assimilatives are released in easily soluble and plant accessible forms. In the humus-accumulative horizon of the identical profile, mineralogenic organisms, which use plant assimilatives in the same form as higher plants,

significantly prevail over ammonifying microorganisms. This is a result of spreading of soluble plant assimilatives from the organic layout into the soil surface layers. Oligonitrophile microorganisms are weakly represented, both in the organic layer and in the humus-accumulative horizon. Actinomyces are not identified in the organic layer, i.e., fungi are dominant in dehumidification processes. That indicates that the decomposition of hard-degradable matters, such as lignin or humus, is not performed to the final products and that the decomposition products have an acid reaction. Decomposition processes of hard-degradable matters take place more intensely in the humus-accumulative horizon, where actinomyces, capable of decomposing humus matters, appear in more significant numbers. Decomposition of hard-degradable organic compounds is performed already in the organic layer, where more significant abundance of actinomyces was observed.

Table 3. *Abundance of soil microorganism principal groups (1000 units/1gr dry soil)*

Horizon	Soil agar	MPA	Erzbi's agar	Synthetic agar		Čapek's agar	
	Total number of microorganisms	Ammonifiers	Oligonitrophiles	Actinomyces	Fungi	Actinomyces	Fungi
OP 1 Oak forest							
O lfh	57,761	57,760	17,205	-	31,952	-	3,686
A	151,920	40,902	9,089	5,194	19,477	5,843	25,320
OP 2 Montane beech forest							
O lfh	11,464	93,078	25,280	4,596	29,877	-	16,087
A	71,666	28,779	63,201	-	12,415	-	10,722

In the organic layer horizon of the sample plot at Kosmaj in a montane beech forest, the number of ammonifying microorganisms significantly prevails over the total number of microorganisms on soil agar. That means that a large amount of mineral forms of plant assimilatives are not released in processes of decomposition of organic matter in the organic layer. In the humus-accumulative horizon, the total number of microorganisms on soil agar significantly prevails over the ammonifying microorganisms. This is a result of a higher presence of soil mineral component in surface layers of soil. In comparison to the first sample plot, the total number of microorganisms on soil agar is significantly lower in the beech forest, both in the organic layer and in the humus horizon. That indicates a lower soil fertility in the second sample plot and a lower amount of plant accessible forms of nitrogen, phosphorous and potassium. Fungi prevail in the humus horizon, while actinomyces are not identified either on a synthetic or Čapek's agar. This is a result of a significantly lower humus content in comparison to the first sample plot.

4. DISCUSSION

The rhizosphere is the narrow region of soil that is directly influenced by root and it presents a dynamic system with a specific physical, chemical and biological characteristics. The biological component of this region consists of plant roots and rhizospheral microorganisms. In addition to root secretions, the microbe population in rhizosphere is influenced by soil parameters (soil type, pH, structure,

content of nutrients). Root age also influences composition and diversity of microbe populations. During the period of intensive root growth, bacterial populations are dominant, whereas mature root provides better conditions for development of fungi and actinomyces (Raičević i sar., 2010). The activity of soil microbe communities contributes, in a long-term, to stability and sustainability of ecosystem.

Numerous and diverse microbe populations play the role in a large number of processes, primarily in the processes of organic matter transformation, creation of plant assimilatives, maintaining a soil structure, degradation of pollutants, but also in biological control of plant and animal pathogens. Great abundance of microbe populations and their large diversity enable them a full participation in those processes.

Populations dominant in the soil are those participating in the transformation of easily degradable organic compound, monosaccharides, organic acids, amino acids and, under a large presence of these compounds, dominant fungi genera are *Mucor, Pythium, Penicillium*, while the dominant bacteria genus is *Pseudomonas*. In the second phase, dominant species are of the genera *Trichoderma, Fusarium, Chaetomium*, and bacteria *Bacillus* spp., which participate in cellulose and hemicellulose decomposition processes. The third phase is far slower, the transformation of hard-degradable organic matters, lignin and polyphenol takes place in this phase and it is dominated by fungi, primarily basidiomycete, but also cellulolytic fungi *Fusarium* i *Trichoderma*.

Large variances in the diversity of microbe populations occur as a response to edaphic conditions, with excessive humidity stimulating growth of anaerobic bacteria. The increased acidity favours the growth of certain microbe populations, and in current conditions, fungi are generally dominant.

5. CONCLUSION

Based on the conducted investigations, it can be concluded that there are certain similarities, but also differences, in the soil characteristics at the sites in which a mass perishing of gypsy moth occurred, with no treatment by bio-pesticides and chemo-pesticides.

Both investigated soils are characterised by a great depth of solum, high capacity for water absorption and retention, good aeration and favourable oxidising conditions of surface layers. A profile differentiation according to textural composition is evident in both investigated soils.

The chemical properties of soils differ significantly. The acidity of soil solution is particularly pronounced in both sites, but the total content of humus and nitrogen is significantly higher in the oak forest in comparison to beech forest. The soil in the oak stand has a higher total adsorption capacity and the higher sum of adsorbed base catones. Moreover, it is better supplied with accessible forms of phosphorous and potassium.

The differences in chemical characteristics of the soil, along with the differences in characteristics of beech and oak litter, resulted in differences in the abundance ratio of certain physiological groups of soil microorganisms, both in the organic layer horizon and in the humus-accumulative horizon.

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SOIL EXAMINATION FOR THE PURPOSE OF FORECASTING OCCURRENCE OF ENTOMOPATHOGENIC AND BENEFICIAL MICROORGANISMS

Vesna GOLUBOVIĆ ĆURGUZ, Zoran MILETIĆ

Summary

In two sample plots, located at the site of Hungairan Oak and Turkey Oak forest (Quercetum frainetto cerris) and at the site of montane beech forest (Fagetum montanum), in which a mass natural perishing of gypsy moth larvae occurred in spring of 2011, the principal characteristics of soil – a natural development environment for certain stadia of possible entomopathogenic and other microorganisms, and a potential cause for the collapse, were analysed. Physical and chemical properties, as well as the abundance of principal physiological groups of soil microorganisms, were examined.

Both investigated soils are characterised by a great depth of solum, high capacity for water absorption and retention, good aeration and favourable oxidising conditions of surface layers. A profile differentiation according to textural composition is evident in both investigated soils

The chemical properties of soils differ significantly. The acidity of soil solution is particularly pronounced in both sites, but the total content of humus and nitrogen is significantly higher in the oak forest in comparison to beech forest. The soil in the oak

stand has a higher total adsorption capacity and the higher sum of adsorbed base catones. Moreover, it is better supplied with accessible forms of phosphorous and potassium.

The differences in chemical characteristics of the soil, along with the differences in characteristics of beech and oak litter, resulted in differences in the abundance ratio of certain physiological groups of soil microorganisms, both in the organic layer horizon and in the humus-accumulative horizon.

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ASSESSMENT OF THE SYSTEM FOR MANAGING PROTECTED AREAS IN THE REPUBLIC OF SERBIA

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Abstract: *The system of protected areas (PA) in Serbia is a complex structure comprising various actors, rules, authorities and institutions involved in the work of PA. The Law on Nature Protection (2009) is one of the main pillars of nature protection in Serbia. This law defines various types of management in protected areas as well as forms of their protection. The law further defines some of the basic principles of protection, both from the aspect of nature protection and from the aspect of its implementation and improvement, measures of control and implementation of its principles as well as the institutions involved in its work. In order to enable studying of the system of protected areas from the perspective of management, the open system theory will be used. The concept of `responsible management `, which has not been adequately applied in our country so far, is analyzed within the framework of this theory.*

Key words: protected area system, interactive responsible management, organization

ПРОЦЕНА СИСТЕМА ЗА УПРАВЉАЊА ЗАШТИЋЕНИХ ПОДРУЧЈА У РЕПУБЛИЦИ СРБИЈИ

Извод: Систем заштићених подручја (ЗП) у Србији представља комплексну структуру различитих актора, правила, надлежности и институција укључених у рад ЗП. Закон о заштити природе из 2009. године представља један од основних стубова заштите природе у Србији. Овај закон дефинише различите облике управљања у заштићеним подручјима као и облике заштите. Такође закон дефинише

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једне од основних начела заштите, како са аспекта заштите природе тако и са аспекта његовог коришћења, унапређења, мера за контролу и спровођење његових начела и институција које су укључене у њен рад. Како би се овај систем заштићених подручја могао посматрати са ниво његовог управљања, теорија отвореног система ће бити коришћена. У оквиру ове теорије обрађен је и концепт „одговорног управљања“ који до сада код нас нема адекватни примену.

Кључне речи: систем заштићених подручја, интерактивно одговорно управљање, организација

1. INTRODUCTION

Protection of natural resources, which implies protection of certain areas, has a long tradition both in the Republic of Serbia and in Europe, The United States of America (USA) and other countries worldwide. The concept of nature protection originated from the need of aristocracy to have their own area of privacy and a place for hunting. A lot of forests in Europe enjoyed that kind of protection in the past century only because they were used as hunting areas (Martinic, 2007). The first advocates of the nature protection concept were from the USA. The National Park Yellowstone, established in 1872, introduced a new type of PA, the purpose of which was primarily in the field of education, conservation and commercialization of this kind of service. One of the oldest protected areas in the Republic of Serbia is Obedska Bara, which has been protected since 1874. Today it has the strictest form of protection (1st degree protection regime) that can be applied. There was a significant expansion of protected areas during the twentieth century. One of the first laws on nature protection in the Republic of Serbia was passed in 1960. It proclaimed Fruska Gora a national park, while the law from 1977 clearly defined the boundaries of this National Park (Djordjevic, 2009). One of the main purposes of the park was related to recreation because the areas around the national park had the same purpose. If we look at the concept of area protection from the perspective of forbidding excessive felling and utilization of an area, then it dates back to the fourteenth century, since Article 123 of Tzar Dushan`s Code forbids the Saxon miners to cut trees in the forests around the mine and obliges them to replant the deforested areas.

According to the Law on Nature Protection[2] (2009), protected areas are defined as areas which have distinguished geological, biological, ecosystem and/or landscape diversity and as such they can be declared as protected areas of general interest. On the other hand, the International Union for Conservation of Nature(IUCN) defines a protected area as `a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values`.

The Law on Nature Protection distinguishes three categories of protected natural goods. They are protected landscapes, protected species and mobile

[2] Law on Nature Protection (Official Gazette of the Republic of Serbia, No 36/09 and 88/2010)

protected natural documents. Different types of protected areas belong to these three categories, for example:

strict natural reserve,

a) special natural reserve,
b) national park,
c) natural monument,
d) protected habitat,
e) landscape of exceptional characteristics,
f) natural park.

Protected areas cover 520.092 ha, which is 5.89 % of the total area of the Republic of Serbia. There are actually different sources that provide different estimates of this coverage and according to them it ranges from 5.8 to 6.6 %. The coverage of 5.89% is obtained from a comprehensive data base established for these purposes. It contains information of The Institute for Nature Conservation, Public Enterprise Srbijasume (Serbianforests) and Public Enterprise Vojvodinasume (Vojvodinaforests), citations from literature and from various strategies adapted at both national and regional levels, as well as data obtained from secondary sources. We used data on protected area coverage from several different sources in order to obtain the most representative information and to enable the use of one reliable source of information.

Apart from the above stated categories of protected areas, this research deals with organizations or managers of these protected areas. These managers can be roughly classified into four categories. The overview of the managers is shown in Table 1.

Table 1. *Types of protected areas management categories*

Management categories			
Types of state management	**Types of private management**	**Types of non-governmental management**	**Other types of management**
Public enterprises	Limited Liability Companies	Various types of non-governmental organizations	Churches and monasteries
Local Self-Management Units	Joint-stock companies	Individuals	National companies (in the process of reorganization)
Tourist Organizations	Hotels		
Military Institutions			

2. THEORETICAL FRAMEWORK

The interactive theory of `responsible management` uses the ` rational open system` model (Jentoft 2007; Richard 1992, Scott *et al*. 2003; Jentoft *et al*, 2007. This model describes a management system as a complex, diverse network of political coalitions with more or less numerous and influential interest groups, which are partly inside and partly outside the system. Goals cannot be achieved immediately prior to events or for the sake of all people. Their achievement is always affected by certain interest groups and their agendas as well as by the interaction between the groups. The model operates on the assumption that a pressure group is formed with the purpose of protecting its interests and benefiting

the group, while its demands from the system depend on the relationship between the input and output values. Consequently, responsible management refers more to the question of who exerts greater influence in the process of decision-making than to the question of jurisdiction application. It means that the system is essentially unstable and dynamic. In such a situation, management would be the result of ongoing socio-political processes in which one side could outweigh the other at some point, depending on the negotiating skills of interest groups, individuals or coalitions. However, certain inertia can be expected from institutionalized frameworks, which show a tendency to stick to their initial agreements by taking a firm line and coping with the pressure (Stinchcombe 1995).

Interactive theory of responsible management further defines the relationship between the managing system and the system that ought to be managed. In order to make the relationship between these two systems mutually acceptable, they need to be structurally adjusted. They also need to be compatible. In the management of protected areas, this relates not only to the existing natural mechanisms, but also to the intentions, plans and institutionalized framework of the stakeholders involved in the process. According to the theory of responsible management, the stakeholders are legislative bodies, agencies that participate in the planning process and public organizations that act either independently or together. It is certainly a difficult task to find the right position for each institution, since the whole system of nature protection, which has to be taken into consideration, is extensive. The measures have to be effective and efficient but at the same time ethically correct and socially acceptable. Last but not least, everything has to be fitted into a specific framework, because the system cannot function in social, cultural and political vacuum. There are also some general characteristics of the managed system that affect the managing system (Jentoft 2007).

The term `responsible management` has gained growing importance in recent years and the concept has been widely applied in many different forms of investigation. Responsible management is defined as an interaction between institutions, processes and traditions that determine the process of power exertion, the process of decision-making in the field of public and private interest and the participation of citizens and interest groups in the process of decision-making (Graham *et al*, 2003).

The concept of responsible management is today widely used to explain different relationships, rules and processes in the management of natural resources. Therefore, there is a wide and diverse range of literature that addresses this problem. Various principles of responsible management have been defined. However, the following three main concepts will be used (PROFOR 2011) for the purposes of evaluating the protected area management:

1. Legislative and institutionalized framework
2. Planning and decision-making
3. Implementation and enforcement of laws

3. RESEARCH METHOD

The applied research method is deductive because it is based on the interactive theory of responsible management. Deductive reasoning is the basic

method of scientific research. It is defined as an analytical and specialized methodological procedure, in which the existing scientific knowledge is used to acquire new knowledge (Milijević 2007). In order to divide the subject of the investigation into its structural components, we will apply the analytical method. According to Milijević (2007), these components are functions of connection and relationships that refer to a specific place and time. Partial analysis will be applied since only one part of the protected area system will be investigated (we won't take all protected areas into consideration). The analysis will include a content analysis, a structure analysis and partially a comparative analysis (Milijevic 2007). The content analysis reveals the scientific contents of the documents, which are the subject matter of the investigation, while the structure analysis deals with the components that constitute the subject matter. The comparative analysis will reveal certain similarities and differences in the management of various types of protected areas. According to Neuman (2006), the method of investigation can be either descriptive or exploratory. A descriptive method provides a picture of the current management of the protected area system, together with all historical facts that have led to it, while an exploratory method deals with possible trends of protected area management.

The sources of data in this investigation can be divided into two categories. The first category includes the statements of the stakeholders, in this case the statements of protected area managers and interest groups, while the second one consists of documents that have been previously compiled. Milijevic (2007) classifies these documents into four groups: a.) action documents (plans and programs); b.) registers (all kind of files and registers); c.) normative documents (regulations and procedures) and d.) business documents (contracts, protocols, etc.). It follows that there are numerous different sources of data. Analyzing the above listed documents together with interviewing has been selected as the method and technique of data collection. Interview is a method which enables collection of data in the form of either oral or written statements of the respondents. The interviews will be individual and the type will be combined. The data will be collected directly in the form of oral answers (Milijevic, 2007). For this purpose, a questionnaire with open and closed ended questions will be prepared (Neuman, 2006). This form of interviewing will be used for the collection of qualitative data from the protected area employees. Apart from the questionnaire, the type of directive interview will be used for collecting data from the interest groups that are involved in the work of the protected areas. Directive interview has a very precisely and wisely elaborated tool and procedure for each specific case (Milijevic, 2007).

4. RESULTS AND DISCUSSION

According to the current legislation, protected area managers can be different legal entities, from state enterprises and different types of private enterprises to non-governmental organizations and religious institutions. The state enterprises with the largest share in the management are public enterprises, tourist organizations, local self-management units and military institutions. Private enterprises with the largest share in the management of protected areas are limited

liability companies and joint-stock companies. Non-governmental organizations are a new type of management and they are increasingly popular in the field of protected areas. Apart from the managers who are directly involved in the work of the protected areas, The Law on Nature Protection designates entities of protection at national, provincial and local levels.

At the national level, the relevant ministries as well as The Institute for Nature Conservation play a very important role in the work of protected areas. Ministry of Environment, Mining and Spatial Planning, together with The Institute for Nature Conservation are the top national organizations. The Ministry is in charge of the activities in the field of protection and sustainable use of natural resources, inspection, nature conservation, environmental protection and other activities defined by law. It is further responsible for the preservation and improvement of the protected areas, monitoring and sustainable use of biodiversity and landscapes. Apart from this Ministry, certain responsibilities are within The Ministry of Agriculture, Trade, Forestry and Water Management or its Directorate for Forests. These two ministries play the most important role in the management of protected areas at the national level. The Institute for Nature Conservation, established in 1948, is a governmental institution, which conducts activities in the field of conservation and enhancement of the natural heritage of The Republic of Serbia. The Institute is engaged in the professional activities of conservation of natural resources. It carries out field studies and scientific research of natural resources with the aim of putting new areas under protection.

The second level of governmental organizations includes institutions at the level of the autonomous province. The Law on establishing the jurisdiction of AP Vojvodina[3] was passed in 2009 and it allowed these institutions to take over some responsibilities. Consequently, certain functions were transferred to the Provincial Secretariat for Environmental Protection and Sustainable Development. The Secretariat carries out activities on the territory of the province in the field of environmental control, monitoring, placing natural resources under protection, making management plans and programs, supervising the use and protection of the natural resources and goods. Local self-management units also belong to the second level of governmental organizations.

Local self-management units include municipalities and towns. They share responsibilities in the field of spatial planning, environmental control and development, i.e. the responsibilities that are not within the institution at the national level. Strategic assessment of plans and programs, environmental impact assessment and integrated permissions are also among their responsibilities. However, this is not the case with all local self-management units. Only some of them have The Secretariat for Environmental Protection and Inspection Services (Grujicic, 2009). Another Institute for Nature Conservation was established at the provincial level. It carries out activities on the territory of Vojvodina and its range of activities is similar to the range of activities The Institute for Nature Conservation of Serbia has at the national level.

Apart from these three protection entities, non-governmental organizations also take interest in the management of protected areas. It is interesting that non-

[3] The Law on establishing the jurisdiction of AP Vojvodina, (Official Gazette of RS, No 99/09)

governmental organizations are involved in the management not only as direct managers, but as interest groups at local and regional levels too.

Interview will be used in two protected area case studies. The snowball method will be applied in order to reach all stakeholders who take interest in the management of the protected areas. The interview comprises seven open ended questions (assessment of legislation, effectiveness and efficiency of management, interest groups, transparency, responsibilities and management capacities) and a number of sub-questions that will steer the conversation into the desired direction.

Questionnaires with open and closed ended questions will be used in the above mentioned 11 categories of the management types. The questions will be classified into three groups: a.) legislative and institutionalized framework; b.) planning and decision-making; c.) implementation and enforcement. The legislative and institutionalized framework includes different sets of laws (legislation), institutions and instruments for protected area management. This component comprises an assessment of the current legislation, its consistency, clarity and effectiveness. Its institutionalized part refers to the assessment of the importance and responsibilities of the institutions involved in the process. The components of this part are the input values of the system of PA management and they constitute the managing system that has previously been defined. In order to make a valid assessment of the `managing system` and the interaction between the two systems, two concepts will be used. The first concept refers to the process of planning and decision-making that is assessed through the degree of transparency, responsibility and involvement in PA management. The purpose of this component of responsible management is to explain the participation of the most important organization in the management of protected areas, namely the organizations that directly manage the protected areas – managers, as well as the non-governmental organizations at national, provincial and local levels. By applying different instruments of PA management, we evaluate the way they are put in practice or the way the legislative and institutionalized framework is implemented.

Questionnaires and interviews will be used as methods of investigation. Questionnaires will be used to collect data about the management from the people employed in the organizations that manage protected areas. On the other hand, interviews will be used to examine the opinions of protection entities and interest groups about the current jurisdiction, authorities and involved institutions. A combination of different research methods will provide a clear picture of the management methods both from the point of view of the protection entities and interest groups and from the point of view of individuals or organizations that manage the areas.

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ПРОЦЕНА СИСТЕМА ЗА УПРАВЉАЊА ЗАШТИЋЕНИХ ПОДРУЧЈА У РЕПУБЛИЦИ СРБИЈИ

Илија ЂОРЂЕВИЋ,Радован НЕВЕНИЋ, Зоран ПОДУШКА, Рената ГАГИЋ, Горан ЧЕШЉАР, Светлана БИЛИБАЈКИЋ, Томислав СТЕФАНОВИЋ

Резиме

Укупна површина заштићених подручја у Републици Србији је негде око 521.000 ha или 5.89 процената од укупне површине. Управљање са овим заштићеним подручјима обављају организације које по својој структури могу бити владине тј

државне, не владине и организације којима управљају различити облици приватног предузетништва.

Проблем управљања са заштићеним подручјима ће се посматрати кроз три перспективе. Ове три перспективе представљају основ интерактивне теорије одговорног управљања. Прва перспектива је „управљачки систем“ тј систем који дефинише начине којим се управља са заштићеним подручјима. Друга перспектива је „систем којим се управља“, одређеним заштићено подручјем, и трећа перспектива је интеракција управљања која се дешава између ова два система.

ASSESSMENT OF THE SYSTEM FOR MANAGING PROTECTED AREAS IN THE REPUBLIC OF SERBIA

Ilija DJORDJEVIĆ, Radovan NEVENIĆ, Zoran PODUŠKA, Renata GAGIĆ, Goran ČEŠLJAR, Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ

Summary

The total area of the protected areas in the Republic of Serbia is about 521.000 ha or 5.89% of the whole territory. These protected areas are managed by organizations which can be either governmental (state), non-governmental or different types of private enterprises.

The management of protected areas will be studied from three different perspectives. These three perspectives are the basis of the interactive theory of responsible management. The first perspective is `the managing system` or the system that defines the types of PA management. The second perspective is `the managed system` of the specific protected area. The third perspective is the interaction between these two systems.

Reviewer: Ph.D. Snežana Rajković

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IMPACT OF INNOVATIVENESS ON NEW TECHNOLOGY IMPLEMENTATION IN FORESTRY COMPANIES

Zoran PODUŠKA[1], Svetlana BILIBAJKIĆ, Renata GAGIĆ-SERDAR, Goran ČEŠLJAR, Ilija ĐORĐEVIĆ, Tomislav STEFANOVIĆ, Radovan NEVENIĆ

Abstract: *This paper presents examples of improvement in operations of the companies within the forestry sector achieved through implementation of new technologies. The improvements in operations are viewed by means of the concepts of innovation and innovativeness. Innovation is understood as a process of improving the existing products and technological and organizational procedures in a company. Innovativeness refers to the company's inclination to adopt and manage changes.*

The research was conducted in public forestry companies, privately owned wood processing companies and NGOs in charge of protected public property stewardship. The data were collected by means of interviews and from other available sources.

The results of the research thoroughly describe the adoption of new or improved products, technological procedures and services. State Forest enterprises mostly improve services such as education on forests and recreation and forestry based tourism. A significant progress has been made in nursery production, through technology and knowhow transfer. Privately owned wood processing companies are introducing new products such as briquettes and pellets. The processes of collecting, purchasing and processing non-wood products are the slowest in modernization.

Key words: innovation, innovativeness, new technologies, forestry companies

УТИЦАЈ ИНОВАТИВНОСТИ НА ПРИМЕНУ НОВИХ ТЕХНОЛОГИЈА У ШУМАРСКИМ ПРЕДУЗЕЋИМА

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Translation: Galina Perišić

Извод: *У раду су приказани примери унапређења досадашњег пословања предузећа у шумарском сектору применом нових технологија. Унапређење пословања посматрано је кроз концепт иновација и иновативности. Иновацијом се подразумева процес унапређења постојећих производа и технолошких и организационих поступака у предузећа. Иновативност је склоност предузећа ка прихватању и управљању променама.*

Истраживање је обављено у јавним шумарским предузећима, приватним предузећима за прераду дрвета и невладиним организацијама која управљају заштићеним природним добрима. Подаци су прикупљани путем интервјуа и из других доступних извора података.

Резултати истраживања таксативно приказују примену нових или унапређених производа, технолошких поступака и услуга. Јавна шумарска предузећа углавном унапређују услуге као што су рекреација и едукација у шуми и излетнички туризам. Велики напредак начињен је у расадничкој производњи, кроз трансфер технологија и знања. Приватна предузећа за прераду дрвета уводе нове производе као што су брикети и пелети. Најспорије се модернизује сакупљање, откуп и прерада недрвних шумских производа.

Кључне речи: иновације, иновативност, нове технологије, шумарска предузећа

1. INTRODUCTION

As an industry, forestry has all the characteristics of a traditional branch of economy. It is traditional for it depends upon wood as a basic and most common product and often neglects other forest functions which can provide a basis for new products and services. Another important feature of forestry is its territoriality of both production and supply since they are both carried out in forests. The territoriality trait is associated with products as well as services, which are executed and offered at a given location at the same time (Ranković, 2008). From the viewpoint of innovation, traditional industries are slow in introduction of new technologies while the markets are slow in changing conditions (von Tunzelmann, 2005). Unlike the traditional ones, modern industries which depend on advanced technologies, particularly information and communication technologies. For the purpose of forestry advancement, it is necessary to adopt and implement new technologies, introduce new products, improve business organization and modernize relevant institutions by harmonizing legislation and work procedures. The aforesaid improvements correspond to the concepts of innovation and innovativeness supported by the Organization for Economic Co-operation and Development of the European Commission (OECD 2005) and the Ministry of Education and Science of the Republic of Serbia (2005).

In its broadest sense, innovation means successful implementation and exploitation of new ideas and technologies. Successful conversion of new ideas into commercial success in the market comprises a process of creating innovation. Such a process may be a feature of a company, industry or a country on the whole. This paper deals with the possible commercial implementation of new ideas and technological procedures in the forestry sector in Serbia.

Innovation is a specific phenomenon which is nowadays the subject of more and more scientific literature, yet there is no complete theory formulated about it up to date. The theory that defines the innovation process is still in progress.

Conceptually, innovation is understood as:

- news or novelty,
- innovation process or activity.

Understood as novelty, innovation contains a change which, in its character and manifestation, may be a replacement, addition or restoration within the existing status.

In Serbia, innovation is determined by the Law on innovative activity *("Official Gazette of RS," No. 110/05*). Pursuant to this law, innovation refers to a new product, process, technology or service with unique properties, achieved through application of one's own or other party's scientific research and its results, findings and discoveries, using one's own concept, idea or method for its creation, and placing it into the market at an adequate value.

According to Wagner and Hansen (2005), the term innovation may be used to denote a significant number of a company's activities, such as development of new products, improvement and enhancement of the existing range of products, improvements to the production processes and business operations and introduction and adoption of new production processes and business operations. All the aforesaid suggests that the innovations in businesses have different forms, although the emphasis is always on the products, so that improving the existing products and introducing new ones are still considered to be the most common definition of innovation.

Within forestry sector innovations and innovativeness are becoming crucial to the advancement of the business operations of companies, development of business companies and development of entrepreneurship in general. Development of business companies contributes to the overall development of forestry sector and decrease in poverty, particularly through development of rural areas.

In forestry, innovations are defined as discontinuous changes of products or production processes of a company planned in advance (Rametsteiner *et al*., 2005). This definition encompasses radical or gradual changes within a forestry company, novel to the company itself or to the market. These changes refer to the adoption of the existing innovations as well as those recently created within the given company (Weiss 2011).

For the purpose of the research of innovation and innovativeness in the forestry sector in Serbia, innovation is understood as novelty containing a change which, in its character and manifestation, may be a replacement, addition or restoration within the existing status. Innovativeness refers to the company's inclination to create and adopt changes and its receptiveness to change and successful change management (Stošić 2007).

In contemporary reference works, there are two major innovation categories (Table 1):

- product innovations and
- production process innovations:

Table 1. *Innovation categories*

Product innovations		Production process innovations	
tangible goods	**services**	**technological**	**organizational**

Source*:* Rametsteiner *et al.*, 2005

Product innovations are changes in what a company offers. They are defined as changes of company's tangible goods or services. Production process innovations are changes of the manner in which what the company produces or has at disposal is created or offered. Production process innovations may be technological and organizational. An innovation may occur through introduction of novelty into the already existing products or processes, changing the way they are perceived.

Since the subject matter of this research is innovation in the forestry sector based on the concept that views the innovation as a process of implementing ideas that create value, it is necessary to recognize where it is possible to adopt and implement one's own or other party's knowledge, skills and ideas through one's own concept or method in order to improve the business operations of a company.

2. METHODS

The research of the process of improving the business operations of forestry companies was carried out from 2004 to 2011. During this period, it was necessary to define successful and less successful attempts of improving business of forestry companies. That is why information on the following aspects needed to be collected:

- innovation process (idea, development, implementation);
- participants and their roles;
- the impact of innovation on the production organization;
- the role and strategy of the state;
- stimulating and limiting factors;
- expected and unexpected results.

For the purpose of primary and secondary data collection, a methodological approach was defined in relation to the subject matter. Primary data were collected by means of the case study method. A case study is specific, descriptive and reaches the depth of the problem. This scientific research method provides a subjective view of the problem, based on the collected information and individual interviews.

Expert and scientific reference works as well as relevant web pages were used as sources of secondary data. The collected data were processed by means of qualitative analysis, whereas the reference works data were analyzed using specific scientific methods (Mihajlović D., 2004):

- analysis-synthesis method,
- abstraction and concretization methods,
- generalization and specialization methods,
- classification methods,
- induction and deduction methods.

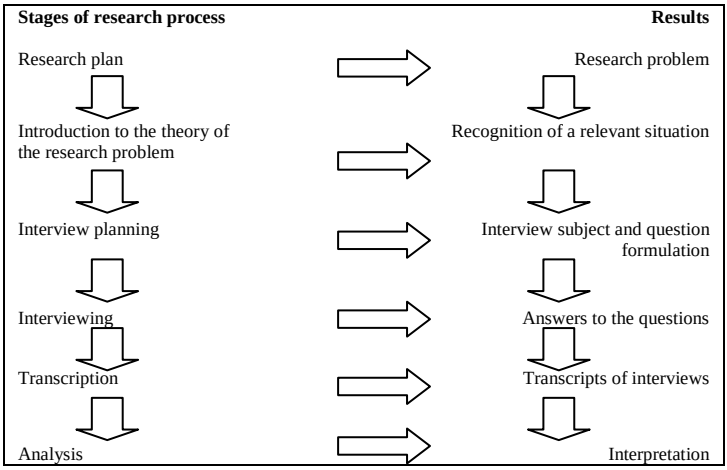
Collecting, processing and interpreting the data included the following stages:

1 Material identification – finding reference works on innovation and entrepreneurship,
2 Material analysis based on the criteria relevant for the research and
3 Data interpretation.

Picture 1 shows stages of the research process. The stages were thoroughly planned and each has a corresponding result. In the initial phases of the research, a plan of research was made to define the subject matter. The subject matter determined the collection of reference works. The result obtained in this stage was the recognition of the relevant situation in the forestry of Serbia. This was followed by planning the interviews, which resulted in designing a questionnaire as an instrument for primary data collection.

As a research instrument, interview is conducted personally. The questions are focused on the subject matter which is defined prior to the interview, and the respondents are informed on the subject matter and the time, venue and the duration of the interview are arranged well in advance. The questions asked aim at disclosing facts and personal opinions of the respondents on the subject matter.

Picture 1. *Stages of the research process*

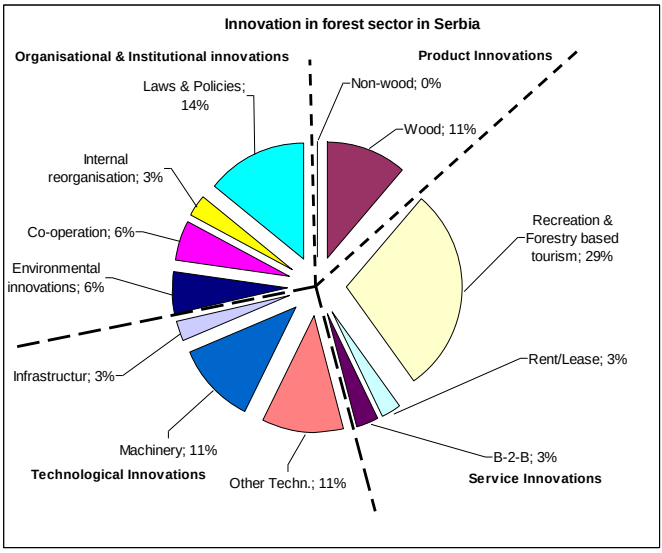


Source:Newman, L., 2006

3. RESULTS

Improvements to the business operations were identified in the public companies in charge of state-owned forest and national park stewardship, privately owned wood processing companies and NGOs in charge of protected property stewardship. Improvements to the forestry products and services were also defined as well as technological, organizational and institutional advancements. Improvements to the business operations in practice up to date are shown in Graph 1.

Graph 1. *Innovation in the forestry sector in Serbia*



Source: Author

Graph 1 presents innovative improvements in the forestry sector in Serbia. The most common improvements were achieved through innovative services, such as recreation and forestry-based tourism. Recreation is a value-added service mostly in protected forests and in devastated habitats as well (Cvejić M., 2008.). The examples of adapting the forest and forest land to a recreational tourism function are:

- Recreation in *Zabran Forest* near Obrenovac;
- Eco-tourism and ethno-tourism in *Golija Nature Park*;
- Educational and tourist trekking in the protected public property of *Obed Swamp,"Obed Tower"*;
- *Ada Ciganlija* Adventure Park;
- Educational trekking in *Bagremara Special Nature Reserve* near Bačka Palanka;
- Eco-tourism and ethno-tourism in *Zasavica Special Nature Reserve*;
- Cycling lanes and eco-tourism in *Djerdap National Park*;
- Hiking trails and eco-tourism in *Djerdap National Park*;
- Bird watching and eco-tourism *Djerdap National Park.*

New technologies:

- A harvester in Vojvodinašume State Enterprise;
- A video surveillance system in Deliblato Sand Reserve;
- New road construction technology in Vojvodinašume State Enterprise;
- A surveillance system in Fruška Gora National Park;
- Implementation of the GIS in the state companies Srbijašume and Vojvodinašume*;*
- New technologies for seed processing in seed product plants in Morović, Požega and Pirot.

New wood products include pellets and briquettes. The production was started in several privately owned companies since 2006. The following companies are successful in pellet and briquette production and marketing: *Bioenergy Point* in Boljevac, a member of the East Point Group from Belgrade with a pellet plant in Doljevac, Zelena Drina and O_3 in Bajina Bašta and Bio Brik in Titel.

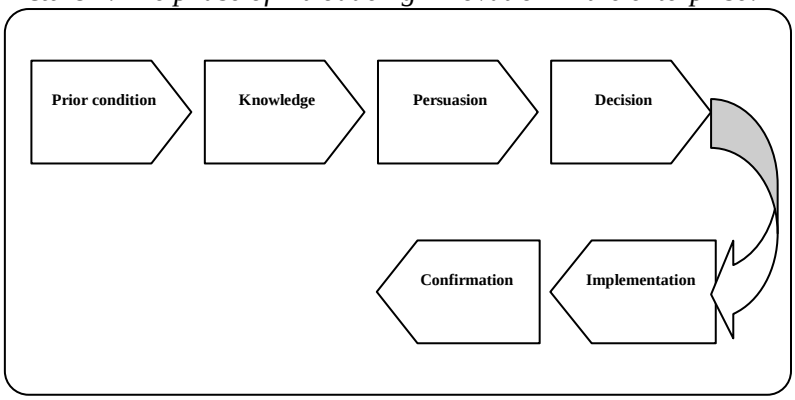
Organizational and institutional improvements in the forestry sector resulted *form* harmonizing a set of laws regulating the area of forestry. Harmonizing the laws and introducing new procedures such as certification decrease the conflict between forestry and nature preservation (Nevenić R., *et.al*. 2008; Nevenić R., *et.al*. 2009). The attempts to advance business operations by means of restructuring public companies have not yet been implemented and therefore exemplify unsuccessful effort toimprove the organization of business operations in Srbijašume State Enterprise. A new way of land usage was introduced through a land lease agreement between Vojvodinašume State Enterprise and Beška Farming Cooperative.

In addition to a detailed list of new products and technological procedures, which were more or less successfully implemented, a process of innovation adoption within a company was established. The process of improving the existing status consists of several stages. Those stages are:

- Prior condition;
- Knowledge;
- Persuasion;
- Decision;
- Implementation;
- Confirmation.

Picture 2 illustrates the stages which correspond to Roger's (Roger, M.E., 1983) phases of innovation diffusion within a business system.

Picture 2. *The phase of introducing innovation in the enterprise*.



Source: Roger, M.E., 1983.

All the observed companies shared the stages of the process of business decision making. They all had the same starting point, the original status, existing prior to improvement introduction. In this stage, the management seeks an opportunity to improve the status by scanning and searching the environment. Employees with their potentials of ideas and knowledge comprise a key factor to

the business success for ideas of improvement originate with the employees. The management needs to have a vision of positive changes and an affinity for introducing changes. It is necessary to convince a broad circle of decision makers that the future innovation will increase the value (of products, services, interpersonal relationships, environment etc). This is the phase of selecting the most promising options. The decision to introduce innovation is a process of expressing readiness to implement novelty and it depends on the company's management. Implementation involves introduction of innovation, from an idea to market implementation. During this phase experience from the preceding successes and failures are analyzed in order to obtain acquisition of new knowledge for improved management of the whole process. Acknowledgement of innovation justifiability is the final stage in the innovation introduction process, where it is acknowledged that the introduced innovation contributes to value increase.

As improving business operations is a dynamic process mostly influenced by company's management decision making, it is vital that the strategy of the company improvement be planned in advance. The strategy of the company improvement depends on human resources, business organization and the business environment of the company.

4. DISCUSSION

The most common innovations in business operations of the companies observed refer to new services on offer, particularly tourism and recreation services. New services in forestry are offered by public companies Srbijašume and Vojvodinašume and national parks Fruška Gora, Tara and Djerdap. New products are offered by privately owned wood processing companies. Some of the companies offer new products such as briquettes and pellets. Advancement in the nursery production has been achieved through application of new technologies in seed processing and preparation for planting.

Based on the analysis of the collected data on improvements in business operations of forestry companies, it may be concluded that innovativeness exists in public, private and non-government sectors. Business decision making in companies is aimed at profit maximization (Sabadi R. 1992), and the business improvement process depends on the company's management decision. This business decision making is an essential part of the process of adoption and market commercialization of new ideas.

In order to initiate improvement in business operations, it is necessary to stimulate employees to develop new ideas and actions. The employees are stimulated to think and behave innovatively by means of professional trainings, education, visits to expert meetings and exhibitions. Financial stimulation of the employees has not yet been observed, i.e. a system of rewarding the employees whose ideas become commercially profitable has not yet been established.

Innovation is not only the path to better business operations, but it also leads to better social relationships, wealthier companies and a wealthier society. Introduction of profitable or cost-effective innovation means a better life for each and every individual. Innovation is the driver of economic growth,

competitiveness, new job creation, particularly in rural areas, and positive changes to the environment and sustainable development.

State institutions' support and stimulation are essential to the development of innovative activities in business companies (Weiss, Rametsteiner, 2005). Most common problems in carrying out innovation projects in order to improve business operations of forestry companies stated during the research include lack of funds, poor technological equipment and computer literacy of the employees, long planning periods and organizational rigidity of the companies due to a centralized system of decision making, which is usually remote from the site of new product or service creation.

5. CONCLUSIONS

Analysis of the research results led to the following conclusions:

- New services such as forest-based tourism and recreation are most frequently improved services in forestry.
- The public sector has a greater and more varied range of new services on offer as well as technological improvements that affect the production process.
- Privately owned wood processing companies develop new products such as pellets and briquettes.
- Non-wood forest product production is by far the most traditional as there is not one example of improvement in collecting, purchasing or processing forest fruits and herbs.
- Large public forestry companies adopt and implement new procedures and standards such as requests for certification of forests on large areas.
- Improvement in business operations of forestry companies are becoming necessary because: they improve the quality of the existing products; create new products and services and enter new markets; reduce labour costs; increase the production volume; allow faster compliance with standards and regulation; reduce negative effects on the environment; reduce material and energy consumption.
- Factors hindering the improvement of forestry companies include: high prices and high risks; lack of information on markets; lack of qualified staff; organizational rigidity of the companies; partial non-compliance with the standards and regulations; lack of information on market demands; lack of information on technologies.

Research of improvement in business operations of forestry companies is a complex process which relies on numerous theories and research methods. For the purpose of result generalization, it is necessary to examine the ways and possibilities to improve public companies as the major factor of the forestry sector in Serbia. In addition to public companies, less successful privately owned companies also need to be analyzed in order to stimulate entrepreneurship. For further research of the process of improving public forestry companies' business operations, cost-benefit analysis ought to be conducted when implementing new technology. Possibilities for additional profit contribution to public companies from sales of non-wood products and services also need to be analyzed.

Development of new products and services such as forest-based tourism and recreation is in accordance with multifunctional character of forests and leads to production diversification and greater competitiveness of forestry companies. Forest-based tourism and recreation comprise the most common examples of business improvement and have a significant role in forestry. Therefore they need to be defined, researched and placed into a context of possible additional profit of forestry companies.

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