International Scientific Conference

FORESTS IN THE FUTURE

Sustainable Use, Risks and Challenges

INVITATION PAPERS

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FORESTS IN THE FU-TURE Sustainable Use, Risks and Challenges

photo M. Veselinović, Jastrebac mountain

4^{th}-5^{th} October 2012, Belgrade, Republic of Serbia

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POSITIONING FOREST RESEARCH IN THE FUTURE – THE CONTRIBUTION OF IUFRO

Alexandar BUCK[1]

In 1992, the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, established the concept of "sustainability" as a global norm for utilizing natural resources, including forests. Sustainability requires the reconciliation of environmental, social and economic demands on forests through appropriate management practices and policy frameworks. The role of the scientific community is to provide state-of-the-art information about the most effective approaches to forest management and policy.

Twenty years after UNCED, the context for sustainable forest management and forest research has changed profoundly. An increasingly comprehensive set of international goals and priorities has emerged to steer forest use and conservation, accompanied by a diverse array of institutions, policies and mechanism. Many of these institutions, policies and mechanisms focus on broader sustainability issues, with forests being only part of their agenda. Against this background, it is important for the forest science community to demonstrate the contribution of its research to addressing these broader sustainability issues. As a member of the Collaborative Partnership on Forests (CPF), an arrangement among 14 leading international organizations with substantial programmers on forests, IUFRO plays a key role in promoting global cooperation in forest-related research and in disseminating scientific knowledge to stakeholders and decision-makers. IUFRO brings together about 650 member organizations with about 15,000 researchers in more than 120 countries, including in Southeast Europe. The IUFRO Strategy 2010-2014 with the theme "Reading the pulse of forest science for the benefit of forests and people" sets out six thematic areas that are meant to guide the science collaboration within the nine disciplinary Divisions of IUFRO and to provide entry points for collaboration with researchers from various other scientific disciplines in currently nine interdisciplinary Task Forces. The six themes are: forests for people; forests and climate change; forest bio-energy; forest biodiversity conservation and environmental services; forest and water interactions; and resources for the future. Each of these six themes constitutes a key aspect of sustainability. The presentation will provide information about how IUFRO addresses the above mentioned broader sustainability issues and associated risks and challenges through its global network of forest research and education institutions and scientists. Broader research for sustainability is also reflected in the on-going preparations for a new IUFRO Strategy 2015-2019.

[1] International Union of Forest Research Organizations (IUFRO)

THE FUTURE OF WILDLIFE MANAGEMENT. PROMISE AND LIMITATIONS OF FORESIGHT PROCESSES

Ulrich SCHRAML[1]

Already today the management of wildlife is a conflict ridden issue. Different actors pursuing different interests take part in the debates on the use and the protection of species. Due to the increasing influence of European and international legislation the situation grows more complex as the negotiations take place on different political levels. Human-wildlife-conflicts are to be found on all levels from local to international. This complexity is fuelled by the uncertain development of the species´ habitats. Climate change as well, as the change caused by anthropogenic land use, are constantly modifying the natural environment and the possibilities of its use. Actors who bear responsibility for wildlife should be prepared for this moment of uncertainty. Foresight processes might be an important tool to meet these challenges.

This presentation is going to illustrate the potential of foresight processes and to explain their field of application by looking at different ways of land use, especially in the field of forestry and nature protection. With respect to this, two questions are to the fore: 1) How can these processes contribute to being prepared for an uncertain future of wildlife and its use? 2) Which impacts does the common reflection on this future have on the actors and therefore on the human-wildlife-conflict? On this basis recommendations for the use of foresight instruments in the field of game management are drafted.

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FORESTS IN THE FUTURE

Sustainable Use, Risks and Challenges

INVITATION PAPERS

ESTIMATES OF BIOMASS AND CARBON STOCK IN BEECH HIGH FORESTS IN SERBIA

Miloš KOPRIVICA[1], Bratislav MATOVIĆ[2], Milivoj VUČKOVIĆ[3], Branko STAJIĆ[3], Vlado ČOKEŠA[1]

Abstract: *With the aim of resolving complex problems of mankind, energy crisis, and climate changes, scientists worldwide have recognized the importance of studying biomass as well as carbon stock and cycling in forest ecosystems. There haven't been any significant investigations of this kind in Serbia (Koprivica et al. 2010, Koprivica and Matović 2011, Koprivica et al. 2011). The sample taken for the purposes of this investigation consists of eleven pure beech high stands selected in six forest areas or nine management units. They are all uneven-aged stands that have been managed mostly by applying selection and group selection management systems for several decades. The stands have a specific structural form and they used to be virgin forests at the beginning of the twentieth century. Their site class is I/II-III/IV, the altitude ranges from 400 to 1380 m. One stand is classified as submontane (Fagenion moesiacae submontanum B. Jov. 1976), and the other ten as montane (Fagenion moesiacae montanum B. Jov. 1976) beech forests. Systematic sampling was used for the purposes of determining dry biomass of aboveground and belowground living trees. Deadwood was studied as well, but the results will be presented in a separate paper. Circular sample plots of 500 m^2 in size arranged in a grid of 100 x 100 m were used as sample elements in the stands. A set of 242 sample plots was established. The measurements included diameter at breast height and height of all living trees on the sample plots. Total tree biomass and carbon stock were calculated by applying regression equations (Wutzler et al. 2008, Joosten et al. 2004). Both simple and stratified sampling were used for estimating the average and total biomass and carbon stock. The average dry biomass of the stands above and below ground was estimated at 296.40 t ha^{-1}, and the average carbon stock at 146.41 tC ha^{-1}. The aboveground biomass participates with 85.7% and the belowground with 14.3%. It can be concluded that regarding their site production potential and projected optimal compositions, beech high stands in Serbia have biomass and carbon stock lower than expected, which is primarily due to inadequate implementation of management systems.*

Key words: biomass, carbon, beech forests, stand, volume, living tree, sample

INTRODUCTION

With the aim of resolving complex problems of mankind, energy crisis, and climate changes, scientists worldwide have recognized the importance of studying biomass as well as carbon stock and cycling in forest ecosystems. The earliest investigations performed within set experiments by Boysen-Jensen (1932), Meller (1946) and Burger (1950) were related to studying the effects of thinning on the biomass production of economically important tree species (according to Matić 1980). Then during the sixties of the twentieth century, investigations and discoveries on tree and stand

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biomass greatly improved, primarily due to the development of modern timber industry (production of pulp, fiberboard, etc) and the energy crisis which challenged the whole humankind to change their attitude towards energy utilization. It was then that the joint biological programme of forestry experts - International Biological Programme - was created (Duvignenaud 1971, according to Lukić and Kružić 1996).

The most commonly researched issues refer to the effects of climate changes and management systems on development and stability of forest ecosystems and to contribution of forest ecosystems to mitigating the adverse effects of climate changes on the living environment, through capturing carbon from the atmosphere and storing it in living and deadwood, organic layer and soil (Cannell 1995, Lebaube *et al*. 2000, Joosten *et al*. 2004, Mund 2004, Mund and Schulze 2006, Liski *et al*. 2006).

Furthermore, numerous papers have studied different ways of determining, measuring and using tree and stand biomass (Cannell 1982, Kauppi *et al*. 1992, Nabours *et al*. 2003, Raupach *et al*. 2005, Widlowski *et al*. 2003, Thurig and Schelhas 2000, Linder and Karjalainen 2007, Somogyi *et al*. 2007). Among other things, regression equations for estimating biomass of different tree species in different regions were investigated. These investigations resulted in generalized allometric volume and biomass equations for spruce (*Picea abies L*), Scots pine (*Pinus sylvestris L*), birch (*Bettula spp*.), beech (*Fagus spp*.) and oak (*Quercus spp*.) in Europe (Muukkonen 2007). A large number of studies are devoted to European beech (*Fagus sylvatica L),* the results of which were used to generate general equations for estimating biomass of beech in Central Europe (Wutzler *et al*. 2008). Similar beech investigations were conducted in Greece (Zianis and Mencuccini 2003), The Czech Republic (Cienciala *et al*. 2006), the Netherlands (Bartelink 1997) and other countries. Apart from regression equations for the biomass of beech trees, regression equations for estimating the carbon stored in this biomass were studied as well (Joosten *et al*. 2004).

There haven't been any significant investigations of biomass and carbon stock of Serbian forest ecosystems. The facts on biomass and carbon stock published in international (global) reports on forest resources have been most commonly based on unreliable data of conducted forest inventories and on general biomass expansion factors for converting stand volume to tree biomass, proposed by the Intergovernmental Panel on Climate Change (IPCC 2003). The first research papers on biomass and carbon stock of uneven-aged beech stands in Serbia have been recently published (Koprivica *et al*. 2010, Koprivica and Matović 2011, Koprivica *et al*. 2011).

The aim of this research is to obtain comprehensive and accurate estimates of biomass and carbon stock in the living wood of uneven-aged beech high stands in Serbia, as well as new and up-to-date parameters necessary for more successful sustainable forest management and biodiversity conservation. Unfortunately, this research doesn't comprise biomass and carbon stock in deadwood, organic layer and soil – in other words carbon in the organic layer and the organic carbon in the soil.

MATERIAL AND METHOD

The investigated beech stands have a specific structural form. They used to be virgin forests at the beginning of the twentieth century and then by implementing negligent selection cuttings they have been converted into economic (production) type of forests. The sample consists of eleven pure uneven-aged beech high stands. One stand is classified as submontane (*Fagenion moesiacae submontanum* B. Jov. 1976), and the other ten as montane (*Fagenion moesiacae montanum* B. Jov. 1976) beech forests. Parent rock consists of different rock types (sandstone, limestone, gneiss, andezite, rafter, granites, granodiorites, schists) and different soil types (dystric ranker, dystric cambisol, calcomelanosol, calcocambisol, luvisol, pseudogley, brunipodzol), 20-120 cm deep. The climate is temperate continental, continental and mountain.

The stand area is 9.8-32.4 ha, site class I/II-III/IV, altitude 400-1380 m, average slope $11\text{-}27^0$, prevailing aspect is north-west, degree of canopy closure 69-94%. Beech participates with 94-100% in the volume. The stand quadratic mean diameter ranges from 30 to 42 cm, while Lorey`s mean height amounts to 22-34 m. The number of trees is 214-482 per ha, basal area 21-33 m^2 ha^{-1}, volume 290-522 m^3 ha^{-1} and volume increment 5.0-10.5 m^3 ha^{-1}. The quality and assortment structure of the investigated beech stands is unfavourable. The percentage of the least favourable silvicultural class (the third class) in the stand wood volume (growing stock) is about 55%, while the percentage of the least favourable technical classes (the third and the fourth) is about 35%. The logs participate with about 40% (Koprivica *et al*. 2010).

Simple systematic sampling was applied for the purposes of collecting and processing stand data. Circular sample plots of 500 m^2 in size were arranged in a grid of 100 x 100 m. In total 242 sample plots were established in the following stand arrangement: 20 (27a), 29 (122a), 16 (8a), 10 (8b), 23 (44a), 33 (116a), 23 (33a), 18 (42a), 10 (42b), 32 (31a) and 28 (46a). The measurements included diameters and heights of all living trees with dbh exceeding 5.0 cm. Furthermore, a secondary circular sample of 7.065 m^2 in size was established in each primary sample plot of 500 m^2. These secondary sample areas were used for measuring diameters and heights of smaller trees (h >1.3 m and d < 5.0 cm).

Lorenz index (Lee *et al*. 1999) was obtained on the basis of the basal area of all trees measured on all 500 m^2 sample plots.

The age of trees was determined on the circular plots of 500 m^2, arranged in a grid of 200 x 200. The trees were bored at breast height using Pressler borer. In order to determine the age of the trees, 10 years were added to the number of years calculated on the obtained increment core to the center of the stem.

Regression equations for European beech (Wutzler *et al*. 2008) were used to determine the total dry biomass of aboveground living trees as well as the biomass of roots. The amount of carbon in the total aboveground tree biomass was determined using the regression equation for European beech (Joosten *et al*. 2004), while the root carbon was calculated by multiplying its biomass by a 0.5 coefficient (IPCC 2003).

The field data were processed in the laboratory of the Institute of Forestry in Belgrade. Dendrometric data processing was carried out in EXCEL and statistical data processing in STATGRAPHICS, version 5.0.

RESULTS AND DISCUSSION

The values of beech stand estimation elements

The average values of the number of trees, basal area, volume and volume increment of the beech stands per hectare at the time of measurements are presented in Table 1.

The average values of the estimation elements of all beech stands together at the time of measuring are the following: number of trees 298 trees ha^{-1}, basal area 27.0 m^2 ha^{-1}, volume 383.9 m^3 ha^{-1} and volume increment 8.3 m^3 ha^{-1}.

Table1. Average values of beech stand estimation elements per hectare

Element	S t a n d									
	27a	122a	8a	8b	44a	116a	33a	42a	42b	31a	46a
N	259	214	352	482	294	314	274	321	308	301	298
G	23.1	29.0	30.8	29.5	31.0	22.2	33.4	31.7	31.5	21.5	23.2
V	353.7	503.6	385.2	361.0	502.0	289.9	522.4	379.6	333.2	290.8	316.0
I_v	8.0	10.5	8.9	6.7	9.2	8.0	8.6	6.6	5.0	6.4	10.1

Diameter and age structure of the beech stands

Diameter structure and age structure of the beech stands are presented in Tables 2 and 4.

Diameter structure: The stands are most commonly characterized by irregular declining distribution of trees per diameter classes, typical of heterogeneous uneven-aged stands. The trees of different diameters are spatially intermingled, either individually or in small groups. The trees with diameters above 80 cm are present in most of the stands, while in some stands trees attain diameters of even 100 cm.

Table 2: Diameter structure of beech stands (in %)

Stand	Diameter class (cm)									
	< 20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	> 90	Suma
27a	36.3	20.5	18.1	10.8	9.3	4.2	0.8	-	-	100
122a	25.2	15.8	15.5	16.8	11.6	11.3	3.2	0.6	-	100
8a	13.1	30.9	34.7	16.0	5.3	-	-	-	-	100
8b	39.4	29.5	17.4	9.5	4.2	-	-	-	-	100

Stand	Diameter class (cm)									
	< 20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	> 90	Suma
27a	36.3	20.5	18.1	10.8	9.3	4.2	0.8	-	-	100
122a	25.2	15.8	15.5	16.8	11.6	11.3	3.2	0.6	-	100
8a	13.1	30.9	34.7	16.0	5.3	-	-	-	-	100
8b	39.4	29.5	17.4	9.5	4.2	-	-	-	-	100
44a	37.6	20.4	12.2	10.9	7.7	6.2	4.4	0.6	-	100
116a	43.8	20.5	18.3	10.8	4.1	1.7	0.6	0.2	-	100
33a	28.3	20.0	17.1	10.5	12.7	7.3	2.5	1.3	0.3	100
42a	19.7	24.2	26.3	16.6	9.7	3.1	0.4	-	-	100
42b	29.9	24.0	11.7	17.5	11.0	4.6	1.3	-	-	100
31a	41.9	22.0	15.6	15.4	2.7	2.1	0.3	-	-	100
46a	45.9	19.6	12.2	10.0	8.4	2.7	1.2	-	-	100

Heterogeneity of the stands was confirmed by Lorenz index (Table 3), since its values ranged between 0.53 and 0.66 in ten stands. Only stand 8a had the value of Lorenz index below 0.5 (0.42). Seven investigated stands had Lorenz index above 0.60, which is a feature of stands with distinct structural heterogeneity. Lorenz index was above 0.50 in about 80% of the established sample plots, which also points to significant spatial heterogeneity of the stands.

Table 3: Values of Lorenz index (L) per sample plots (SP) and stands

Stand	27a	122a	8a	8b	44a	116a	33a	42a	42b	31a	46a
Minimum	0.35	0.26	0.34	0.51	0.54	0.45	0.38	0.35	0.44	0.21	0.46
Maximum	0.74	0.74	0.54	0.72	0.75	0.75	0.73	0.73	0.75	0.74	0.75
Average	0.61	0.57	0.42	0.61	0.66	0.62	0.60	0.53	0.61	0.54	0.65
Number SP	20	29	16	10	23	33	23	18	10	32	28
L< 0,5	4	8	13	0	0	2	4	8	1	10	3
L> 0,5	16	21	3	10	23	31	19	10	9	22	25

Age structure: These are characteristically uneven-aged beech stands, with specific age structure. Regarding the age, trees are spatially intermingled, either individually or in small groups. There is a significant percentage of trees over 200 years of age, with some trees reaching 250 to 300 years. These are also the first results of researching the age structure of beech high stands in Serbia. Previous studies dealt only with diameter stand structure, which often led to erroneous conclusions about the structural form of the beech stands of generative origin and to wrong choice or inadequate implementation of management measures.

Ellenberg (1996) states that old-growth broadleaved forests in Europe are usually not even-aged, which corresponds to the results of our research.

Table 4: Age structure of the beech stands (in %)

Stand	Age class (year)								
	< 40	40-80	80-120	120-160	160-200	200-240	240-280	> 280	Total
27a	1.9	20.4	9.3	11.1	35.2	20.4	1.9	-	100
122a	1.8	8.8	26.3	22.8	17.5	17.5	3.5	1.8	100
8a	-	2.2	43.5	34.8	15.2	4.3	-	-	100
8b	-	28.1	28.1	5.3	5.3	14.0	10.5	8.8	100
44a	-	14.5	20.0	21.8	10.9	16.4	3.6	12.7	100
116a	14.3	22.0	40.7	17.6	2.2	-	-	3.3	100
33a	0.8	22.3	50.8	9.2	11.5	3.1	1.5	0.8	100
42a	-	9.9	35.8	44.4	5.0	4.9	-	-	100
42b	-	4.7	30.2	23.3	14.0	16.2	9.3	2.3	100
31a	4.6	9.3	4.6	33.8	46.2	1.5	-	-	100
46a	1.6	48.4	23.4	12.5	6.3	4.7	1.6	1.5	100

Biomass and carbon stock of the beech stands

Biomass and carbon stock of the beech stands are presented in Table 5.

Stand biomass: The average biomass of aboveground living wood of all stands together amounts to 254.06 t ha^{-1}, and belowground 42.34 t ha^{-1}, which makes 296.40 t ha^{-1} in total. The ratio between aboveground and belowground living biomass is 85.7% : 14.3%. Stand 31a has the lowest biomass of aboveground and belowground living wood (228.65 t ha^{-1}), and stand 33a the highest (393.18 t ha^{-1}). The management of the former stand included high intensity cuttings and its volume was 290.8 m^3 ha^{-1}, while the latter one had lower intensity cuttings and its volume was 522.4 m^3 ha^{-1}.

Analysis of variance was used to test the statistical significance of the difference between the average values of the aboveground living wood biomass per hectare in the stands and it proved to be significant ($F_0 = 8.87$, $p < 0.0001$). Duncan’s test ($p = 0.95$) classified the stands into four homogeneous groups. Out of 55 possible comparisons of the average stand biomass values, 26 or 47% were statistically significant.

In practice, according to the average biomass of the aboveground living wood, the stands can be classified into four groups:

from 150 to 200 t ha^{-1} – stands 31a and 116a

from 200 to 250 t ha^{-1} – stands 46a, 27a, 8b and 42b from 250 to 300 t ha^{-1} – stands 8a and 42a

from 300 to 350 t ha^{-1} – stands 122a, 44a and 33a

Statistically speaking, these groups are strata. Therefore, the assessment of the biomass of beech high stands used not only simple, but also stratified sampling.

Table 5: Average biomass and carbon stock in the living wood of the beech stands

Stand	Sample size	Biomass (t ha^{-1})			Carbon (tC ha^{-1})		
		Above ground	Below ground	Total	Above ground	Below ground	Total
27a	20	225.034	36.053	261.087	110.742	18.026	128.768
122a	29	314.649	48.694	363.343	155.480	24.347	179.827
8a	16	265.903	45.213	311.116	130.387	22.606	152.993
8b	10	243.559	41.879	285.438	119.213	20.940	140.153
44a	23	319.781	51.100	370.881	158.059	25.550	183.609
116a	33	197.053	33.432	230.485	96.913	16.716	113.629
33a	23	337.691	55.487	393.178	167.036	27.744	194.780
42a	18	267.586	48.763	316.359	132.007	24.381	156.388
42b	10	249.002	50.302	299.304	123.637	25.151	148.788
31a	32	196.511	32.145	228.656	96.471	16.072	112.543
46a	28	212.385	35.951	248.336	104.671	17.976	122.647
All stands	242	254.057	42.340	296.397	125.239	21.170	146.409

Table 6 presents the statistical parameters of the variability (coefficient of variation) and the assessment accuracy (relative standard error, p = 95%) of the biomass per stands and for all beech stands together.

Table 6: Coefficient of variation and relative standard error of the stand biomass

Stand	Sample size	Coefficient of variation (%)			Relative error (%)		
		Above ground	Below ground	Total	Above ground	Below ground	Total
27a	20	45.5	42.3	45.0	21.29	19.80	21.06
122a	29	36.0	34.4	35.7	13.69	13.08	13.57
8a	16	28.2	24.8	27.7	15.02	13.21	14.76
8b	10	18.3	19.4	18.3	13.09	13.88	13.09
44a	23	32.4	32.7	32.4	14.01	14.14	14.01
116a	33	38.5	35.6	38.1	13.68	12.65	13.54
33a	23	29.8	29.9	29.8	12.89	12.93	12.89

Stand	Sample size	Coefficient of variation (%)			Relative error (%)		
		Above ground	Below ground	Total	Above ground	Below ground	Total
27a	20	45.5	42.3	45.0	21.29	19.80	21.06
122a	29	36.0	34.4	35.7	13.69	13.08	13.57
8a	16	28.2	24.8	27.7	15.02	13.21	14.76
8b	10	18.3	19.4	18.3	13.09	13.88	13.09
44a	23	32.4	32.7	32.4	14.01	14.14	14.01
116a	33	38.5	35.6	38.1	13.68	12.65	13.54
33a	23	29.8	29.9	29.8	12.89	12.93	12.89
42a	18	22.8	22.1	22.6	11.34	10.99	11.24
42b	10	23.6	22.1	23.3	16.88	15.81	16.66
31a	32	33.0	34.8	33.1	11.91	12.56	11.95
46a	28	37.2	34.9	36.8	14.42	13.53	14.27
All stands	242	38.9	37.0	38.5	4.95	4.71	4.90

The error of the average biomass of aboveground living wood per hectare in the beech stands, determined by applying simple sampling and with 95% of probability, is +/- 11.34-21.29%, while the error of the average biomass of belowground living wood amounts to +/-10.99-19.80%. For all beech stands together, the error of the average biomass of aboveground living wood per hectare is +/- 4.95%, while the error of the average biomass of the belowground living wood per hectare amounts to +/- 4.71%, which makes the error of the total living biomass +/- 4.90%.

The presented data show that the living wood biomass was precisely determined using a sample of 242 sample plots, so the obtained results have a high degree of reliability.

It is interesting that the average wood volume per hectare determined by using simple sampling at a stand level is also approximately the same and amounts to +/- 11.59-22.79%, or for all stands together +/- 5.42%.

By applying stratified sampling in the estimation of aboveground living wood biomass, the error of the average biomass is +/- 4.26%, with 95% of probability. This error is 1.162 times smaller (4.95/4.26), so in order to obtain the same error by applying simple sampling, the sample should comprise 327 sample plots (242 x 1.162^2). The sample would have 86 sample plots more and it would be 35% larger.

Stand carbon stock: In all stands together, the average carbon stock in the living wood above ground is 125.24 tC ha^{-1}, and below ground 21.17 tC ha^{-1}, or 146.41 tC ha^{-1} in total. The ratio between the carbon in the biomass above and below ground is 85.5% : 14.5%. Like in the case of biomass, stand 31a again had the smallest amount of carbon above and below ground (112.54 tC ha^{-1}) and stand 33a the largest (194.78

tC ha^{-1}). This is directly the result of the almost functional relationship between the dry biomass of beech wood and the amount of carbon in that biomass (Koprivica and Matović 2011).

Due to a strong relationship between biomass and carbon, the coefficients of variation and the relative standard errors of assessment are practically the same as for biomass in all cases. Thus, the analysis of variance would provide the same result on the difference between the average values of carbon per hectare in the beech stands.

Mund and Schulze (2006) studied the influence of management on carbon stock in beech stands in Germany. They found that the total amount of carbon in the biomass of living and dead wood, organic layer and soil (to the rock layer) increased with the decrease in the intensity of management: for regeneration cutting 246 tC ha^{-1}, for selection cutting 266 tC ha^{-1} and for unmanaged – natural forests 352 tC ha^{-1}. The carbon in the biomass of living and dead wood amounted to about 65% of the total carbon in the forest ecosystems (ground vegetation was not included), or approximately 64% for regeneration cutting, 67% for selection cutting and 70% for natural forests. The carbon in deadwood was below 1% for regeneration and selection cutting and 2% for natural forests.

Since selection cutting is the method applied in the investigated beech stands in Serbia, the carbon stock in the biomass of living wood should be 175.6 tC ha^{-1} (266 x 0.66) on average. However, the determined carbon stock amounts to 146.4 tC ha^{-1} which is 16.63% less. Furthermore, successive removal of trees from beech forests by regeneration or selection cutting proved to reduce the amount of carbon stored in the tree biomass by about 30% in comparison to unmanaged forests (Mund and Schulze 2006).

Estimates of volume, biomass and carbon stock in beech high stands

There are around 350 000 ha of beech high forests in Serbia (Stojanović *et al*. 2005). Although the sample used in this investigation is small in size, wood volume above ground can be expected to be 135 million cubic meters, its dry biomass around 89 million tons and carbon stock around 44 million tons. The error of the volume estimated by applying simple sampling with 95% of probability is +/- 5.42%, while the error of the estimated biomass and carbon stock amounts to +/- 4.95%. If we apply stratified sampling, biomass and carbon stock are estimated with a smaller error, +/- 4.26%.

About 15 million tons of the estimated biomass below ground and about 7 million tons of carbon stock in this biomass should be added to the estimated aboveground biomass and carbon stock. Finally, the total dry biomass of beech high stands in Serbia above and below ground is around 104 million tons and the carbon stock in that biomass is 51 million tons. The sample error for the total biomass and carbon stock is +/- 4.90%.

Regression equations for estimating biomass and carbon of beech stands

There is a strong statistical relationship between volume, biomass and carbon of trees or stands, which means that biomass and carbon can be easily estimated on the basis of previously determined volume. Since in practice, we usually have volume figures, they can be easily, but imprecisely converted (using the general wood density and general biomass expansion factors), into dry biomass and then the amount of carbon in that biomass can be determined, by multiplying biomass by a 0.5 coefficient.

In this investigation, biomass and carbon stock of living beech trees on the sample plots in the stands is determined directly and precisely using regression equations (Wutzler *et al*. 2008, Joosten *et al*. 2004). For each sample plot, volume (V), biomass (B) and carbon (C) of aboveground wood are determined and the obtained values are then extrapolated per hectare. Furthermore, the biomass of tree roots (Br) is determined as well.

Based on these data, regreesion equations, easily applicable in practice, are obtained:

$$B = 13.4405 + 0.657982V – 0.0000679913V^2 \quad (1)$$

$S_e = 15.722$ t ha^{-1} $R^2 = 97.487\%$

$$C = 6.68714 + 0.322229V – 0.0000291779V^2 \quad (2)$$

$S_e = 7.788$ tC ha^{-1} $R^2 = 97.491\%$

$$C = 0.235619 + 0.488106B + 0.0000134137B^2 \quad (3)$$

$S_e = 0.753$ tC ha^{-1} $R^2 = 99.976\%$

$$Br=-0.429475 + 0.182227B – 0.000047499B^2 \quad (4)$$

$S_e = 3.431$ tC ha^{-1} $R^2 = 95.233\%$

In these regression equations (1-4) biomass and carbon are expressed in t ha^{-1} and volume in m^3 ha^{-1}. Coefficients of regression are in all equations statistically significant ($p < 0.001$).

CONCLUSION

Due to serious energy crisis and climate changes, studying biomass and carbon stock in forest ecosystems has become one of the main tasks of the contemporary science in the world. There has been little progress in Serbia in this field, both in methodological and in practical sense, which gives special significance to the results of this research.

Beech stands in Serbia are most commonly characterized by irregular declining distribution of trees per diameter classes, typical of heterogeneous uneven-aged stands. There are trees with diameters of up to 80 cm in most of the stands, while trees in some stands reach 100 cm in diameter.

Heterogeneity of the stands is confirmed by Lorenz index since its values are between 0.53 and 0.66. Regarding the age structure, the stands are typically uneven-aged. The trees are spatially intermingled either individually or in groups. There are trees above 200 years of age in all stands, while in several stands some trees are as old as 300 to 400 years.

In all stands together, the average biomass of living wood above ground is 254.06 t ha^{-1}, below ground 42.34 t ha^{-1}, or 296.40 t ha^{-1} in total. The ratio of the living biomass is 85.7% : 14.3%. Stand 31a has the lowest biomass of the living wood above and below ground (228.65 t ha^{-1}) and stand 33a the largest (393.18 t ha^{-1}). The former had a higher intensity of cutting applied during the management and its volume is 290.8 m^3 ha^{-1} and the latter had a lower intensity cutting and its volume is 522.4 m^3 ha^{-1}.

The error of the average biomass of aboveground living wood per hectare in the investigated beech stands, determined by applying simple sampling and with 95% of probability, is +/- 11.34-21.29%, while the error of the average biomass of belowground living wood amounts to +/- 10.99-19.80%. For all beech stands together, the error of the average biomass of aboveground living wood per hectare is +/- 4.95%, while the error of the average biomass of belowground living wood per hectare amounts to +/- 4.71%, which makes the error of the total living biomass +/- 4.90%. Thus, it can be concluded that the obtained results have a high degree of reliability.

In all stands together, the average carbon stock in the living wood above ground is 125.24 tC ha^{-1}, and below ground 21.17 tC ha^{-1}, or 146.41 tC ha^{-1} in total. The ratio of carbon is 85.5% : 14.5%. Like in the case of biomass, stand 31a again had the smallest amount of carbon stock above and below ground (112.54 tC ha^{-1}) and stand 33a the largest (194.78 tC ha^{-1}).

Wood biomass and carbon stock in that biomass is in uneven-aged beech stands in Serbia smaller by 16.6% in comparison to their optimal state and site potentials and in comparison to well-managed beech stands in Europe. In fact, the problem lies in the volume per hectare in the investigated stands, which is low both in quantity and in quality. Biomass and carbon stock directly depend on size and diameter structure of wood volume. The current state of beech stands in respect to their volume, biomass and carbon stock per hectare is unsatisfactory and it is primarily due to years of inadequate management and frequent changes of beech forest management systems (selection, group selection, shelterwood etc.).

Serbia has about 350 000 ha of beech high forests and in order to obtain an accurate estimate of their volume, biomass and carbon stock we need a sample much bigger than the one used in this investigation. Nevertheless, the total wood volume of these forests is estimated at approximately 135 million cubic meters, its dry biomass at about 89 million tons and carbon stock around 44 million tons. The error of the volume estimated by applying simple sampling with 95% of probability is +/- 5.42%, while the error of the estimated biomass and the carbon stock amounts to +/- 4.95%. If we apply stratified sampling, the biomass and the carbon stock are estimated with a smaller error, +/- 4.26%.

Furthermore, about 15 million tons of the estimated biomass below ground and about 7 million tons of carbon stock in this biomass should be added to the estimated aboveground biomass and carbon stock. It follows that the total biomass of beech high stands in Serbia above and below ground is estimated at around 104 million tons and the carbon stock in that biomass at 51 million tons. The sample error for the total biomass and carbon stock is +/- 4.90%.

Scientific investigations into biomass and carbon of beech stands and stands of other species with different site conditions and different management systems should be continued. At the same time, these investigations should further include the estimates of the carbon stock in deadwood, organic layer and soil in order to obtain information on the total biomass and carbon stored in the forest ecosystems.

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THE ROLE AND IMPORTANCE OF SOME SECONDARY METABOLITES (TERPENES, ALKANES AND FLAVONOIDS) IN TREES

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Abstract: *Unlike the primary metabolites that build plant cell, tissue and organs and are essential for living plant cells, secondary metabolites don't have a primary effect on the survival of the organism, which has not yet been sufficiently clarified. However, it is considered that it was the secondary metabolites contribute to the adaptation of plants to different environmental influences and thus enable the survival of the species. They have a role in the inactivation and storage of harmful products but sometimes assume the role of coenzymes or hormones. Furthermore, they protect the plant against herbivore and pathogens attacks and regulate the relations between plants (allelopathy). Some secondary metabolites are also considered as good chemotaxonomic markers. Terpenes and alkanes are particularly suitable for studying the variability of trees at interpopulation and intrapopulation levels. In our country they have been thorougly investigated only in Serbian spruce, Bosnian pine and Macedonian pine. Flavonoids are increasingly being used in the separation of species and lower taxonomic categories. In our forest trees, more detailed studies were conducted only in English oak.*

Key words: geographic variability, genetic markers, chemotaxonomic markers, detection of hybrids, separation of similar species

INTRODUCTION

Unlike primary metabolites (nucleic acids, proteins and polysaccharides), which form plant cells, tissues and organs and are essential for plant cell life, secondary metabolites (terpenes, alkanes, flavonoids, sesquiterpene lactones, glycosides, limonoides, nonprotein amino acids, lignans, tannins, sugars, phenols, sterols, rubber, suberin, resin acids, etc.) do not exert a primary influence on survival of the organism that produces them, which is still not sufficiently clarified. In a certain phase of its ontogenetic development, or by agency of an external factor, a cell is reduced to a physiological state optimal for activation of genes and synthesis of enzymes, in which a biochemical process, resulting in a synthesis of various metabolites, commences. It is considered that precisely secondary metabolites contributed to plant species adaptation to various ecological impacts and that it is precisely they which largely ensured the survival of the species. Secondary metabolites perform an important role in functioning of a plant organism; they represent inactivated forms and harmful product depots, form integral parts of some enzyme systems (co-enzymes), possess

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hormone activity, perform an important role in protection of plants against herbivore, regulate the relations of the plant in which they are formed with other plants (allelophatic role), etc. (Kovačević 2002).

Certain secondary metabolites are also considered good chemotaxonomic markers, at the level of genus, species and lower systemic categories (population, ecotype, race, variety, sub-species, form, cultivar, genotype, clone), less frequently at the level of tribe and family. Terpenes and alkanes, chemotaxonomic importance of which had been noted long ago, are particularly suitable for investigation of variability of plant species at inter-population and intra-population level, as the procedure for their extraction is relatively simple and inexpensive, while the methodology of establishing main chemical components is already well-known (Marin 1995). Flavonoids are increasingly more frequently used in differentiation between plant species and lower taxonomic categories (sub-species, varieties, forms, etc).

TERPENES

Terpenes (terpenoids, isoprenoids or polyisoprenoids) represent a large class of natural compounds, which belong to a large family of lipids (Lajšić & Grujić-Injac 1998), while at the same time constitute the most numerous group of plant secondary metabolites. They are broadly represented in plants and sporadically in animal tissues. According to a general isoprene rule (C_5), numerous terpene classes originate from only few basic structures (precursors), out of which most diverse terpene compounds are created in cyclisation processes, by means of introduction of various functional groups or re-organisation of molecules (Ružička 1953, after Kovačević 2002). In some plants, biosynthesis sites of mono- and sesquiterpenes are separated. For instance, at *Pinus pinaster* monoterpene biosynthesis takes place in epithelial cells and it is closely related to leucoplasts, while sesquiterpene synthesis is related to endoplasmic reticulum (Heinrich et al. 1980 and Bernard-Dagan et al. 1982, after Mimica-Dukić 1995).

Through a series of investigations of biosynthesis in various mentha species and hybrids, conducted by Murray & Hefendehl (Mimica-Dukić 1995), the assumption that a terpene biosynthesis takes place in sequences has been confirmed, as well as that each individual transformation is controlled by a specific gene responsible for biosynthesis of the enzyme that catalyses a given transformation. If the enzyme is not active on account of genetic reasons, the biogenesis will stop in certain point, which will result in accumulation of the last synthesised component.

Although the basic principle is the same, synthesis genetic control in conifers is even more complex, as the manner of terpene inheritance varies from monogenic, with dominant and recessive allele, to polygenic (Hanover, 1966 and Marpeau et al. 1975, after Bojović 1997a,b). By means of a monoterpene analysis of *Pinus monticola* (Hanover 1966a,b,c), it has been established that certain components (α-pinene, β-

pinene, myrcene, δ-3-carene and limonene) are under strict genetic control. An investigation of *P. eliotti* (Squillace & Fisher 1966) also confirmed that certain monoterpines are suitable as genetic markers. Tests based on full progeny confirmed monogenic inheritance of δ-3-carene in *Picea abies* (Esteban et al. 1976) and *Pinus sylvestris* (Hiltunen et al. 1975); β-phellandrene, β-pinene, myrcene, and limonene in *Pinus sylvestris* (Yazdani et al. 1982a,b, 1985; Pohjola et al. 1989); δ-3-carene, myrcene, limonene, longipholene and caryophyllene in *Pinus pinaster* (Baradat et al. 1972; Baradat & Pastuszka 1992; Marpeau et al. 1975, 1983) and limonene, myrcene, β-pinene, and β-phellandrene in *Pinus taeda* (Squillace et al. 1980). The fact that β-pinene is under strict genetic control has been proved in numerous species, while trimodal distribution of this component in Austrian pine suggests monogenic type of inheritance (Bojović et al. 2005). Certain terpene components of Bosnian pine also have trimodal distribution (α-pinene, Nikolić et al. 2007), Macedonian pine (β-pinene, α-copaene, β-elemene, δ-cadinene, α-cadinene, kaur-15-ene, and 13-epidolabradiene, Nikolić et al. 2008) and Serbian spruce (α-cadinol, myrcene, santene, and (*E*)-hex-2-enal, Nikolić et al. 2009). Differentiation of Heldreich pine provenances in Bulgaria into the north and the south, based on a terpene composition, Naydenov et al. (2005a) explicate by a nuclear polygenic control. The intermediary quality of F1 hybrids of some pines in terms of terpene concentration, as compared to parents, confirms their hybrid character (Idžojtić et al. 2005). According to Müller-Starck et al. (1992), pleiotropy of the gene controlling terpene is frequent due to common precursors in biosynthetic pathways. That is the case, for instance, with δ-3-carene and terpinolene in *Pinus maritima* (Baradat et al. 1972). Additionally, it has been established that genes controlling δ-3-carene, myrcene and limonene in *P. maritima,* are linked genes (Marpeau et al. 1983).

Terpenes were known as early as in antiquity and Middle Ages (Stanković 1961). An intensive study of terpene composition in conifers and other species dates from the middle of the last century, emerging with development of techniques for analysis of etheric oils and identification of monoterpenes and sesquiterpenes. It was soon established that the composition and the quality of etheric oils considerably vary and that the variation is contingent upon a plant species, which was subsequently followed by publication of first results of the study of the genera *Pinus* (*P. koraiensis*, *P. peuce*, Iloff & Mirov 1956; many pines, Mirov 1961), *Picea* (*P. rubens*, von Rudloff 1966; *P. glauca*, *P. mariana*, von Rudloff 1967b, etc.) and other conifer genera (von Rudloff 1975). Etheric oils were also studied by Serbian scientist in that period, who published their first research results with respect to Austrian pine and Scots pine, Norway spruce, Douglas fir (Stanković & Karapandžić 1955; Stanković 1961), Serbian spruce, Heldreich pine and Macedonian pine (Karapandžić, 1964, 1966).

Regardless of the undisputed fact that the composition and production of etheric oils and terpene in plants are under strict genetic control, terpenes frequently individually vary in quantity contingent upon a type of tissue (*Picea glauca*, von Rudloff 1972), season changes and plant tissue age (*Pinus ponderosa*, Zavarin et al. 1971a), crown illumination level (*Pinus sylvestris*, Manninen et al. 2002), leaf position in crown

(*Picea abies*, Holubova et al. 2001), numerous ecological factors (*Pinus caribea*, Barnola & Cedeño 2000), a plant raw material processing method (picking, storing) and isolation of etheric oils (Muzika et al. 1990). Based on terpene composition, intra-popular variability of species can be determined, even when there are no morphological differences (npr. kod *Mentha arvensis*, Jančić & Mimica-Dukić 1990, after Jančić 1995).

Application and importance of terpenes in woody species are manifested in the following activities:

1. *in study of geographic variation*: genus *Pinus* (*P. banksiana*, Lapp & von Rudloff 1982; *P. caribaea*, Barnola & Cedeño 2000; *P. cembroides*, Zavarin & Snajberk 1985; *P. edulis*, Zavarin et al. 1989; *P. eliottii*, Kossuth & Muse 1985; *P. flexilis*, Zavarin et al. 1993; *P. heldreichii*, Nikolić et al. 2007, 2011; Bojović et al. 2011; *P. maritima*, Marpeau et al. 1975; *P. nigra*, Gerber et al. 1992; Bojović 1995; *P. peuce*, Nikolić et al. 2008a, 2011; *P. pinaster*, Arrabal et al. 2005; *P. pinea*, De Simón et al. 2001; *P. ponderosa*, Smith et al. 1969; *P. strobus*, von Rudloff 1985; *P. taeda*, Squillace & Wells 1981; *P. sylvestris*, Tobolski & Hanover 1971; 5 Greek pine species, Roussis et al. 1995, 2001; 22 Chinese pine species, Song et al. 1995); genus *Picea* (*P. abies*, Roshchin et al. 1986; *P. glauca*, von Rudloff 1967b, 1972; *P. mariana*, von Rudloff 1967b; *P. omorika*, Nikolić et al. 2009a, 2011; *P. rubens*, von Rudloff 1966; *P. sitchensis*, Hrutfiord et al. 1974; von Rudloff, 1978), several species (von Rudloff 1967a); genus *Abies* (*A. alba*, Zeneli et al. 2001; *A. lasiocarpa*, Zavarin et al. 1970; *A. nephrolepis*, Li et al. 2005), three species of *Abies* from Greece (Roussis et al. 2000); other conifers (*Juniperus communis*, Mastelić et al. 2000; *Pseudotsuga menziessi*, Snajberk & Zavarin 1976; *Sequoia sempervirens*, Hall & Langenheim 1986; *Thuja plicata*, von Rudloff 1962); other species (in flowers and pollen of *Rosa rugosa* and *R. canina*, Dobson et al. 1987); triterpenes in leaves of *Actinidia deliciosa* (Celaño et al. 2006), etc.

2. *as genetic and/or chemosystematic markers*: families (Araucariaceae, Kreidler 2003; Pinaceae and Cupressaceae, von Rudloff 1975); many genera from 4 families (Yatagai & Sato 1986); genus *Pinus* (*P. californiarum*, *P. monophylla*, Zavarin et al. 1990; *P. cembroides*, Zavarin & Snajberk 1985; *P. elliottii*, Squillace 1971; *P. longaeva*, Zavarin et al. 1982; *P. monticola*, Hanover 1966a; *P. maritima*, Bernard-Dagan et al. 1971; *P. nigra*, Arbez et al. 1974; Bojović 1995; *P. pinaster*, Baradat & Marpeau-Bézard 1988; *P. radiata*, Cool & Zavarin 1992; *P. sylvestris*, Tobolski & Hanover 1971; *P. uncinata*, Cantegrel 1984; hibrida *P. brutia* x *P. halepensis*, Gallis 2005 and refs. cited therein; many pine species (Mirov, 1967); genus *Picea* (*P. engelmanii*, *P. pungens*, Schaefer & Hanover 1986; *P. glauca*, Wilkinson et al. 1971; *P. omorika*, Stevanović-Janežić et al. 1994; *P. orientalis*, Uçar et al. 2003; many species, von Rudloff 1966; von Schantz & Juvonen 1966; Sedlakova et al. 2003); genus *Abies* (*A. borisii regis*, *A. cephalonica*, Fady 1990, 1992; *A. balsamea*, *A. fraseri*, Zavarin & Snajberk 1972; *A. lasiocarpa*, Zavarin et al. 1970, 1971b; *A. concolor*, Zavarin et al. 1975); other

conifers (*Cupressus* sp., Zavarin et al. 1971c; *Juniperus* sp., Vasek & Scora 1967; *Pseudotsuga sp.*, von Rudloff 1973; *Sequoia* sp., Hall & Langenheim 1986); *Tsuga* sp., Lagalante & Montgomery 2003), etc.

3. *in the identification of taxa, subspecies, varieties, hybrids, transitional forms, clones*: *Pinus monophylla* (Zavarin et al. 1990), *P. cembroides* (Zavarin & Snajberk 1985), *P. nigra* subsp. *laricio* (Bader et al. 2000), *P. contorta* var. *latifolia* (Pauly & von Rudloff 1971), *Pseudotsuga taxifolia* var. *menziesii*, var. *glauca* (von Rudloff 1973), *Picea omorika* var. *vukomanii* (Nikolić et al. 2008b), *Pinus brutia* x *P. halepensis* (Gallis & Panetsos 1997), hybrids of *P. nigra* and *P. sylvestris*, *P. densiflora* and *P. thunbergiana* (Idžojtić et al. 2005), transitional forms between *P. discolor* and *P. cembroides* (Bailey et al. 1982), between *P. discolor* and *P. johannis* (Zavarin & Snajberk 1986), spontaneous hybrids with *Picea sitchensis* (von Rudloff 1978, after Strauss et al. 1992), hybrids between *P. glauca* and *P. engelmanni* (Schaefer & Hanover 1986), *Juniperus squamata* var. *fargesii* (Adams et al. 1996), etc.

4. *in studies of genetic control of terpene biosynthesis*: genus *Picea* (*P. abies*, Fischbach et al. 2000; 9 species, Martin et al. 2002); genus *Pinus* (*P. maritima*, Gleizes et al. 1984; *P. pinaster*, Heinrich et al. 1980, after Mimica-Dukić 1995; *P. sylvestris*, Fäldt et al. 2001); genus *Abies* (*A. grandis*, Steele et al. 1998); some decidous species: *Quercus ilex* (Fischbach et al. 2000), etc.

5. *in studies of seasonal emissions of terpenes*: *Pinus pinea* (Staudt et al. 2000), *Malus domestica*, *Prunus avium* (Rapparini et al. 2001), etc.

6. *in the regulation of relations between plants and insects or pathogens and resistance of plants to diseases and pests:* genus *Pinus* (*P. caribaea*, Barnola et al. 1997; *P. pinaster*, Kleinhentz et al. 1999; *P. pinea*, Hmamouchi et al. 2001; *P. ponderosa*, Krauze-Baranowska et al. 2002; *P. taeda*, Rockwood 1973; Ochocka et al. 2002 several pines, Fäldt 2000); genus *Picea* (*P. sitchensis*, Brooks et al. 1987, after Hanover 1992; several spruces, Ochocka et al. 2002); other conifers (*Juniperus communis*, Ochocka et al. 1997), etc.

7. *in comparative studies with other markers*: alkanes (*Pinus sylvestris*, Hellström 2003), glycosides (*Juniperus oxycedrus*, Miloš & Radonić 2000; *J. communis*, Mastelić et al. 2000), volatile aglycones (*Pinus heldreichii var. leucodermis*, Marić et al. 2007), isoenzymes (*Abies alba*, Sagnard et al. 2002), microsatellites (*Pinus pinaster*, Ribeiro et al. 2002; *P. heldreichii*, Naydenov et al. 2005a; *P. sylvestris*, Naydenov et al. 2005b), resin acids and total phenols (*Pinus sylvestris*, Nerg et al. 1994), etc.

8. *in phytopharmacy using*: antimicrobial properties (various conifers, Diğrak et al. 1999**),** antioxidant properties (*Pinus mugo*, Grassmann et al. 2003), bronchodilator properties (*Eucaliptus* sp., Juergens et al. 1998), in regulation of circulation (*Ginkgo biloba*, Gold et al. 2002), etc.

9. *in cosmetics as ingredients of*: perfumes (citronelol iz *Chamaecyparis lawsoniana*), repellent fundes (*Azadirachta indica, Eucalyptus maculata, Pinus longifolia,* Ansari et al. 2005 and refs. cited therein), etc.

10. *in other industries* (Dev, 1989**,** after Obst 1998): as resin and rubber compounds (gutta-percha and rubbers from some politerpenes), turpentine, etc.

ALKANES

n-Alkanes are saturated hydrocarbons, also known as ’paraffins’. They are composed only of two elements: carbon and hydrogen, connected by simple bonds. The size of the alkanes is defined by a number of inter-connected C atoms. The most important commercial sources of alkanes are natural gas and naphtha. Additionally, alkanes are tar, asphalt and biogas components. Alkanes with an odd number of C-atoms are one of the most represented components of plant cuticle. Most represented in majority of plants are *n*-C_{29} (*n*-nonacosane) and *n*-C_{31} (*n*-hentriacontane) alkanes, sometimes constituting as much as 90% of the total wax composition (Morice & Shorland 1973; Franich et al. 1978; Jenks et al. 1995; Barnes et al. 1996). Terrestrial plants are characterised by strong domination of odd *n*-alkanes in range C_{25}–C_{35}, while aquatic plants are typified by C_{23} (*n*-tricosane) and C_{25} (*n*-pentocosane) abundance.

Alkane biosynthesis is genetically controlled. Genetic changes result in a decreased production of waxes or reduction of content of some of the components, and they might even lead to a change of wax crystal structure. According to Kunst & Samuels (2003), the beginning of wax biosynthesis is the synthesis of fatty acids, which occurs in epidermal cell plastids, while a further elongation of fatty acid chains (with over 20 C-atoms) occurs in contact with the endoplasmic reticulum membrane. Four enzymes are responsible for synthesis and elongation of fatty acid chains. Reduction and decarboxylation to *n*-alkane C_{29} take place in endoplasmic reticulum zone, which is in contact with a cytoplasmic membrane and connected to a cell wall (Staehelin & Chapman 1987 and Craig & Staehelin 1988, after Kunst & Samuels 2003). According to a different theory, biosynthetic pathway goes from the endoplasmic reticulum, over Golgi apparatus, while decarboxylation takes place in the cytoplasmic membrane (von Wettstein-Knowles 1979 and Bagnat et al. 2000, after Kunst & Samuels 2003). It cannot be concluded with certainty as yet how hydrophobic wax components, through a cell membrane wall, reach cuticule. It is assumed that there is one gene responsible for change of micro-aperture in cell wall, in that manner influencing wax excretion.

Based on an epicuticular wax composition, damage caused by impact of air pollutants can be detected in early stadia (Cape & Percy 1998). On the basis of the n-alkane composition, that is, the carbon atom chain’s mean length, certain micro-climatic conditions can be detected, such as fog, for instance (Percy et al. 1993). By shortening carbon atom chains of *n*-alkanes, plants react to global climatic changes, to increased air humidity, for instance, which can be a cause of deterioration of forest communities

(Oros et al. 1999), while, by means of an increase of the chain's mean length, plants at lower altitudes react to a desiccation threat in summer period, or to a frost threat at higher altitudes (Dodd & Poveda 2003). The elongation of these chains can also indicate an increased population age (Herbin & Robins 1969; Lutz et al. 1990). According to Ensikat et al. (2006), the alkane molecule length determines the wax layer depth. Plant age also influences wax composition by a reduction of the enzyme activity on its biosynthetic pathway, which leads to a change in wax composition, breaking of wax layer or its attenuation and diminishing of wax protective function (Kolattukudy 1970, 1984, Harker & Ferguson 1988, and Hatton et al. 1994, after Mićović 2006).

According to Oros et al. (1999), polar lipids dominate in conifer waxes (over 90%), while nonpolar, particularly *n*-alkanes, are poorly represented (from 0,1% in *Pseudotsuga* sp. to 3,5% in *Tsuga mertensiana* and 4,4% in *Sequoia sempervirens*). There are also conifers with a high content of alkanes (12-22% in Wollemia nobilis, Dragota & Riederer 2007). *n*-Alkane C31, or less frequently C29 or C33 (Maffei et al. 2004), are most commonly dominant in epicuticular waxes of conifer needles, while in some species even C25 or C27 (Oros et al. 1999). The latter are dominant far more frequently in some deciduous tree species. (C27 in hybrids of genera *Salix*, Teece et al. 2008 and genus *Populus*, Cameron et al. 2000). According to Maffei et al. (2004), order Pinales (Coniferales) contains on average 6.18 μg of *n*-alkane per 1g of needle dry matter, orders *Pinus* and *Picea*, correspond to this average according to the amount of alkanes, while some species contain two times (familije Araucariaceae, Cupressaceae, Pinaceae i Taxaceae), event tree times (Cephalotaxaceae) larger amount of n-alkanes than the average (over 20 μg).

Certain angiospermae also have a significant content of n-alkanes on leaf surface, like *Coffea arabica* (22-35%, Stocker & Wanner 1975), *Eucaliptus gunnii* (12,7%, Li et al. 1997), *Fagus sylvatica* (17,9%, Reynhardt & Riederer 1994), and *Salix dasyclados* (25%, Teece et al. 2008) or fruits, like *Prunus avium* (13%, Peschel et al. 2007).

By extending the original taxonomic research of families Cupressaceae and Pinaceae, conducted by Herbin and Robins (1968b), Maffei et al. (2004), based on *n*-alkanes composition in 112 species and cultivars of the Pinales order, differentiated families Cupressaceae, Pinaceae and Taxaceae from families Podocarpaceae, Araucariaceae, Cephalotaxaceae and Sciadopityaceae. A more comprehensive comparative research of alkanes and other wax components was also performed on 28, that is, 16 different species of the genus *Picea* (Corrigan et al. 1978 and Maffei et al. 2004, respectively). A comparative research of 21 species of the genus Pinus (Maffei et al. 2004) was also conducted.

Application and importance of alkanes in woody species are manifested in the following activities:

1. *in chemosystematic studies:* order Pinales (Maffei et al. 2004); families of conifers: Pinaceae (Herbin & Robins 1968b), Cupressaceae (Herbin & Robins 1968b; Dyson & Herbin 1968), Podocarpaceae (Borges del Castillo et al. 1967);

genus *Picea* (Corrigan et al. 1978); different genera: *Allagoptera* sp. (Rodrigues & Salatino 2006), *Anthocleista* sp. (Sonibare et al. 2007), *Clusia* sp. (Medina et al. 2004, 2006), *Eucualiptus* sp. (Herbin & Robins 1968a) and it's subgenus *Symphyomyrtus* (Li et al. 1997; Knight et al. 2004), *Ficus* sp. (Sonibare et al. 2005), *Ludwigia adscendens* (Barik et al. 2004), *Salix* sp. (Cameron et al. 2000), etc.

2. *in the study and detection of plant hybrids and lower systematic categories:* hybrids of genus *Eucaliptus* (Knight et al. 2004), *Corylus avellana* x *C. maxima* (Caramiello et al. 2000), *Populus deltoides* x *P. nigra* (Cameron et al. 2000); species and hybrids of genus *Taxus: T. baccata* (Dempsey et al. 2003; Wen et al. 2006), *T. canadensis, T. celebica, T. cuspidata* (Dempsey et al. 2003); reciprocal hybrids of *Rosa* sp., section *Caninae* (Wissemann et al. 2007), hybrids and clones of *Salix* sp. (Teece et al. 2008), *Taxus* x *hunnewelliana, T.* x *media* (Dempsey et al. 2003); varieties: *Juniperus communis* var. *saxatilis,* var. *montana* (Dodd & Poveda 2003), Picea *omorika* var. *vukomanii* (Nikolić et al. 2009b), *Pinus heldreichii* var. *pančići* (Nikolić et al. 2010), many varieties in *Rosa* sp. (Jenks et al. 2001), etc.

3. *in styding the chemical composition of leaf cuticular waxes*: genus *Picea* (*P. abies*, Günthardt-Goerg 1985; P. engelmannii, Mardarowicz et al. 2005; *P. mariana*, Beri & Lemon 1970; *P. obovata*, Chernenko et al. 1993; *P. pungens*, von Rudloff 1959; *P. sitchensis*, Prügel & Lognay 1996); genus *Pinus* (*P. cembra*, Günthardt-Goerg 1985, 1986; *P. heldreichii*, Nikolić et al. 2012; *P. sylvestris*, Günthardt 1984; Günthardt-Goerg 1986); genus *Abies* (*A. alba*, Güth & Frenzel 1989; *A. balsamea*, Beri & Lemon 1970); genera: *Cupressus* (*C. dupreziana*, *C. sempervirens*, Piovetti et al. 1981), *Juniperus scropulorum* (Tulloch & Bergter 1981), *Araucaria araucana* (Rafii & Dodd 1998), *Wollemia nobilis* (Dragota & Riederer 2007); species of decidous and evergreen woody trees (*Carpinus betulus*, *Corylus avellana*, *Fraxinus excelsior*, *F. ornus, Sorbus aucuparia*, Piasentier et al. 2000; *Crataegus monogyna*, Wollrab 1969; *Eycaliptus gunnii*, Wirthensohn et al. 1999; *Fagus sylvatica*, Reynhardt & Riederer 1994; *Ginkgo biloba*, *Magnolia grandiflora*, *Liriodendron tulipifera*, Gülz et al. 1992b; *Juglans regia*, Prasad & Gülz 1990; *Malus sylvestris*, Hellmann & Stoesser 1992; *M. pumila*, Holloway 1973; *Prunus laurocerasus*, Jetter et al. 2000; *Quercus robur*, Prasad et al. 1990), etc.

4. *in the study of the connection between chemical composition and microstructure of leaf cuticle wax: Wollemia nobilis* (Dragota & Riederer 2007), etc.

5. *in the study of the chemical composition of surface waxes of other plant parts:* flowers (Rosa sp., Wollrab 1969; *Crataegus monogyna*, *Rubus idaeus*, Griffiths et al. 2000), pollen grains (*Corylus* hybrids, Caramiello et al. 2000), fruits (*Prunus avium*, Peschel et al. 2007), many varieties of fruits (Kolattukudy 1984), bark in many woody species (Streibl et al. 1978 after Maffei et al. 2004), etc.

6. *in the study of resistance to various types of environmental impacts:* genus *Picea* (*P. abies, P. rubens, P. mariana, P. glauca,* Gordon et al. 1998; P. abies,Cape & Percy 1993; *P. breweriana, P. sitchensis,* Oros et al. 1999); genus *Pinus* (*P. ponderosa, P. montezumae, P. engelmannii,* Oros et al. 1999; *P. strobus, P. thunberghii,* Simini & Leone 1986); genus *Abies* (*A. concolor, A. amabilis,* Oros et al. 1999); other conifers (*Juniperus communis,* Dodd & Poveda 2003; *J. occidentalis, Pseudotsuga menziesii, P. macrocarpa, Sequoia sempervirens, Tsuga mertensiana***,** Hadley & Smith 1990, after Oros et al. 1999); many other species (Bytnerowicz 1998); decidous trees (*Salix* sp., Rosenqvist & Laakso 1991, after Maffei et al. 2004), etc.
7. *in the study of impact of insect damage on the chemical composition of waxes*: genus *Picea* (*P. abies,* Grill et al. 1987), etc.
8. *in the study of plants as potential indicators of exposure to contaminants*: genus *Picea* (*P. abies,* Lutz et al. 1990; *P. sitchensis,* Percy & Baker 1990; *P. rubens,* Percy et al. 1993); genus *Pinus* (*P. sylvestris,* Cape 1986); decidous species (*Hedera helix,* Kerfourn & Garrec 1992), etc.
9. *in studies of combustion of biomass:* during the production of biofuels (Standley & Simoneit 1987), after fire (Fine et al. 2002), etc.
10. *in studies of air quality:* in urban, rural and isolated areas (Oros et al. 1999 and refs. cited therein), etc.
11. *in comparative studies with other chemical markers*: terpenes (*Pinus sylvestris,* Hellström 2003), carotenoids (*Picea sitchensis,* Hellqvist et al. 1992), etc.

FLAVONOIDS

Flavonoids are the largest group of plant metabolites with a heterocyclic (oxygen) ring.

They occur in *Gymnospermae, Angiospermae* (with the highest diversity), *Pteridophyta*, *Bryophyta*, while they very rarely occur in algae (Kovačević 2002). Over 4,000 flavonoids have been identified until present, out of which the majority is in form of glycoside or esters with tannic acid (Miloš & Radonić 2000; Marin et al. 2003, 2004, 2007; Marić et al. 2007). They are low molecular mass polyphenolic compunds, of different yellow nuances. It is considered that flavonoids take part in the same processes as other natural pigments, but in biological systems these compounds can also behave as antioxidants, regulators of beneficial soil microorganisms and enzyme inhibitors. Non-desirable in nourishment of insects, flavonoids are photosensibilisators and transmitters of energy, have a respiratory function in biosynthesis, exert antimicrobial effect, while some of them have estrogenic and anti-cancerogenic properties (Kovačević 2002).

In the basis of their structure, flavonoids contain $C_6C_3C_6$ (flavanic) skeleton and they are also called diphenylpropanes. They have two phenyl groups (rings) at the end and a heterocyclic ring in the middle. The propane part in $C_6C_3C_6$ skeleton does not need to be in form of heterocyclic ring, but it might form an open chain (chalcones). Flavonoids are created through chalcones from three activated acetates (ring A) and cinnamon acid derivatives (ring B), forming a basic flavanic skeleton in that manner. Subsequently, a cyclisation of the basic pyran ring and formation of flavanone molecules take place, while all types of flavonoid molecules are created by means of further transformation (Kovačević 2002).

There are several criteria for classification of flavonoids. One of them is a position of the second phenyl group (ring B) as compared to a benzopyrene (chromano) function, and according to this criterion, the following types of flavonoids can be distinguished: 2-phenyl benzopyranes (flavonoids), 3-phenyl benzopyranes (isoflavonoids) and 4-phenyl benzopyranes (neoflavonoids). Flavonoids in the narrow sense are most represented. Depending on a degree of oxidation and saturation in a heterocyclic ring, they can be classified into: flavones, flavanones, flavonols, flavanonols (dihydroflavonols), anthocyanidins (flavilium salts), flavan-3-ols, flavan-4-ols, and flavan-3,4-diols.

Principally, flavonoids can be classified into surface (aglycones) and vacuolar flavonoids. They are grouped in several classes: flavones (apigenin, luteolin), isoflavones (daidzein, genistein), biflavone, flavonols-the most represented in nature are (isorhamnetin, kaempferol, quercetin, laricitrin, myricetin, siringetin), flavanols (dihydroquercetin), flavanones (hesperetin, naringenin), flavan-3-ols (catechin), anthocyanins (theaflavin, thearubigin), anthocyanidins (cyanidin, delphinidin), chalcone (phloridzin, arbutin), dihydrochalcone, astragalin, galangin, hiperine, fisetin, isorhamnetin, crisin, morin, pinocembrin, pinobanksin, pinostrobin, pinosylvin, robinetin, rutin, etc.

According to Winkel-Shirley (2001) and refs.cit.therein, flavonoids constitute a relatively diverse family of aromatic molecules that are derived from phenylalanine and malonyl-coenzyme A (CoA; via the fatty acid pathway). These compounds include six major subgroups that are found in most higher plants: the chalcones, flavones, flavonols, flavandiols, anthocyanins, and condensed tannins (or proanthocyanidins); a seventh group, the aurones, is widespread, but not ubiquitous. Some plant species also synthesize specialized forms of flavonoids, such as the isoflavonoids that are found in legumes and a small number of nonlegume plants. Similarly, sorghum (*Sorghum bicolor*), maize (*Zea mays*), and gloxinia (*Sinningia cardinalis*) are among the few species known to synthesize 3-deoxyanthocyanins (or phlobaphenes in the polymerized form). The stilbenes, which are closely related to flavonoids, are synthesized by yet another group of unrelated species that includes grape (*Vitis vinifera*), peanut (*Arachis hypogaea*), and pine (*Pinus sylvestris*). Thus, it appears that branches in this pathway have evolved multiple times or been lost from specific plant lineages over the course of evolution. In recent years, much effort has been directed at elucidating the flavonoid biosynthetic pathway from a molecular genetic point of view. Mutants affecting flavonoid synthesis have been isolated in a variety of plant species based on alterations in flower and seed pigmentation. Maize, snapdragon (*Antirrhinum majus*), and petunia were established as the first major experimental models in this system. *Arabidopsis* more recently has helped facilitate analysis of the regulation and subcellular organization of the flavonoid pathway. Several important new genes required for flavonoid biosynthesis have been characterized in a variety of plant species over the past few years, including some with direct practical applications (*BANYULS* gene and LCR genes from *Arabidopsis*, IFS1 gene from *Arabidopsis*, tobacco and maize, etc.)

Application and importance of flavonoids in woody species are manifested in the following activities:

1. *in the interpretation of the course of evolutionary development, species migrations, and their roles in ecology: Pinus halepensis* and *P. brutia* (Kaundun et al., 1998), *Ulmus sp.* (Bate-Smith & Richens 1973; Harborn 1977), etc.
2. *in the study and detection of plant genera, hybrids and lower systematic categories: Pinus halepensis, P. brutia, P. eldarica* (Kaundun et al. 1997), *Eucaliptus diversifolia* subsp. *hesperia* and *megacarpa* (Wright & Ladiges 1987), *Carpinus* and *Betulaceae* (Jeon et al. 2007), *Nothofagus* (Wollenweber et al. 2003), *Quercus* sp. (Dawra et al. 1988), *Q. ilex*, *Q. rotundifolia* (Rafii et al. 1991), *Q. alba*, *Q. robur* (Miller et al. 1992), *Q. petraea*, *Q. robur* (Bodenes et al. 1997; Mariette et al. 2002; Prida et al. 2006), *Ulmus* sp. (Sherman & Giannasi 1988), etc.
3. *in the study of geographic variation*: genus *Pinus* (*P. halepensis*, Kaundun et al. 1998; *P. sylvestris*, Oleszek et al. 2002; *P. uncinata*, Lauranson & Lebreton 1991); genus *Quercus*: *Q. rubra*, (McDougal & Parks 1986), *Q. pyrenaica*, *Q. alba*, *Q. petraea* (Jordao et al. 2007), *Q. suber* (Conde et al. 1998), *Alnus glutinosa* (Daniere et al. 1991), *Pinus brutia, Juniperus communis, Pistacia lentiscus, Rosa canina, Rhus glabra, Quercus cerris* (Ozturk et al. 2006), etc.
4. *in the assessment of intra-species and population variability: Pinus uncinata* (Lauranson & Lebreton 1991); *Quercus alba* (Dumolin-Lapegue et al. 1997), ***Q.*** *ilex* (Lebreton et al. 1993), *Q. robur* (Covelo & Gallardo 2001; Batos 2010), *Q. rubra* (McDougal & Parks 1984, 1986), *Q. suber* (Conde et al. 1998), *Q. velutina* (Parker 1997), etc.
5. *in the study of genetic control of flavonoid biosynthesis: Pinus taeda* (Bomal et al. 2008), *Citrus unshiu (*Moriguchi et al. 2001), *Ginkgo biloba* (Shui Juan et al. 2000), *Morus alba* (Nomura et al. 2009), *Quercus ilex* (Lebreton et al. 1993), *Q. ilex, Olea europaea* (Karabourniotis et al. 1998), *Q. laevis* (Klaper et al. 2001), hybrids: *Populus deltoides* cv. S9-2 × *P. nigra* cv. Ghoy and *P. deltoides* cv. S9-2 × *P. trichocarpa* cv. V24 (Morreel et al. 2006), *Populus* spp. (Mellway et al. 2009), etc.*in the separation of morphologicaly similar species: Pinus leiophylla***,** *P. chihuanuana*, (Almaraz-Abarca et al. 2006), various species of genus *Taxus* (Krauze-Baranowska 2004), etc.

6. *in the study of the chemical composition (and identification) of wood: Pinus morrisinicola* (Fang et al. 1987), *needles: P. massoniana* (Shen & Theander 1985), buds and young needles, *Picea, Pinus* and *Abies* sp. (Slimestad 2003), *leaves: Quercus iberica* (Enukidze et al. 1972), *Q. acutissima, Q. miyagii, Q. stenophylla, Q. mongolica* var. *grosseserrata* (Ishimaru et al. 1987), *Q. robur* (Scalbert & Haslam 1987), *Q. phillyraeoides* (Nonaka et al. 1989), *Q. pontica* (Enukidze & Moniava 1971), *Q. pubescens, Q. cerris, Q. ilex* (Romussi et al. 1991; Karioti et al. 2009), *Q. laurifolia* (Romussi & Caviglioli 1992), *Q. robur* var. *stenocarpa* (Romussi & Parodi 1994), *Q. imbricaria* (Romussi et al. 1994), *Q. rubra* (Romussi et al. 1995), *Q. alba, Q. robur* (Mammela et al. 2000), *Q. laevis* (Klaper et al. 2001), *Quercus sp.* (Salminen et al. 2004), *Q. aucheri* (Sakar et al. 2005), *Q. ilex* (Brossa et al. 2009), various genera (*Acer, Betula, Coniferus, Eucalyptus, Juniperus, Picea* and *Quercus,* Bedgood et al. 2005), *Lithocarpus densiflorus* (Meyers et al. 2006), *Juniperus communis, Pinus brutia, Pistacia lentiscus, Rosa canina, Rhus glabra, Q. cercis* (Ozturk et al. 2006), *Malus* sp. (Tiberti et al. 2007), *bark: Q. acutissima, Q. miyagii, Q. stenophylla, Q. mongolica var. grosseserrata, Castanea crenata* (Ishimaru et al. 1987), *Q. robur* (Kuliev et al. 1997); *acorns: Q. rubra, Q. palustris* (Marquart et al. 2007); etc.
7. *in the study of plant resistance to various types of environmental impacts: Pinus laricio* (Cannac et al. 2011), *P. ponderosa, Quercus rubra, Pseudotsuga menziesii* (Warren et al. 2002), *Prunus avium* (Cohen et al. 1994), *Q. pyrenaica* (Ammar et al. 2004), *Quercus* sp. (Makkar et al. 2006), etc.
8. *in the study of resistance to pathogens (microorganisms, fungi and insects): Olea europea* (Heimler et al. 1996); *Quercus* sp. (Feeny 1969, 1970; Dawra et al. 1988; Parker 1997; Forkner et al. 2004; Makkar et al. 2006; Roslin 2006; Tweel & Menges 2008), *Q. robur* (Scalbert & Haslam 1987; Scutareanu & Lingeman 1994; Covelo & Gallardo 2001; Tikkanen & Julkunen-Tiitto 2003; Salminen et al. 2004), *Q. rubra* (Barbehenn et al. 2006); *Q. prinus, Q. velutina* (Reed & Mc Carthy 1996), *Q. pyrenaica* (Ammar et al. 2001), *Q. serrata* (Hikosaka et al. 2005), etc.
9. *in comparative studies with other chemical markers*: phenols (*Pinus roxburghii, P. wallichiana,* Maimoona et al. 2011), etc.
10. *in phytopharmacy using*: antimicrobial properties (*Picea abies, Pinus sylvestris, Rubus sp., Sorbus aucuparia, Salix caprea,* Rauha et al. 2000; *Q. aucheri,* Sakar et al. 2005), antioxidant properties (genera *Pinus, Cupressus, Juniperus,* Kilic et al. 2011; *Quercus* sp., *Robinia pseudoacacia*, Mrdaković et al. 2004; *Q. cerris,* Rakić et al. 2004; *Q. robur*, Rakić et al. 2005, 2006, 2007), etc.
11. *in wood and paint industry*: *Quercus robur* (Vivas et al. 1995), etc.

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CLIMATIC CHANGES AND THE CONCEPT OF SUSTAINABLE USE OF RENEWABLE NATURAL RESOURCES

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Abstract: *The most significant problem of forest and scrub communities adaptation to climatic changes is the rate of their change. The intensity of change of climatic parameters is much higher than the natural potential of many species to adapt to newly-created conditions. By the end of 21st century, the distribution of European plant species will be dislocated several hundred kilometres towards the north, forested lands will be narrowed in the south and extended in the north, whereas 60% of the mountain plant species will most probably become extinct.*

The paper presents the concept of sustainable use of renewable natural resources through adaptive activities focused on maintaining genetic variability and resistance of species to climatic changes; a change of technique and technogy of forest planting; protected natural areas; forest fire regimes; protection against insects and diseases; protection against erosion and floods; forest regeneration and sylviculture, etc. Additionally, an alternative use of natural resources through inclusion of the eco-centric approach into adaptive measures has been proposed.

Key words: forestry, climatic changes, climatic models, adaptive measures, eco-system approach

INTRODUCTION

Previously recorded changes of climatic parameters and examination of various climate change scenarios (global, regional) indicate that the Serbian territory belongs to a group of regions in which climatic changes endangers sustainable use of natural resources and, consequently, threaten the state of the environment. In the following decades, even more adverse effects on biological diversity (genetic, species and ecosystem) may be expected in the entire region of south-east Europe, which will be manifested through a change of vertical and horizontal vegetation zonality, an increased risk of extinction of species due to a synergic effect of climatic changes and habitat fragmentation, redistribution and migration or extinction of certain forest species, as a result of high temperatures and reduction of ground water level, etc.

Climatic changes cause changes of lasting importance in structural and spatial characteristics of global biodiversity. Apart from exerting a direct impact on plant phenology, through an increase of maxim or minimum annual temperature and amount and distribution of precipitation per season, they additionally influence vegetation through altered frequency of extreme events (for instance summer droughts, frost).

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The earth is facing a new mass extinction of plant and animal species, similar to that of 65 million years ago when dinosaurs became extinct. Human activity has destroyed a large number of habitats, which are most frequently fragmented or harmed by a long-term pollution from most diverse sources.

CHARACTERISTICS OF CLIMATIC CHANGES AND IMPLICATIONS FOR FOREST ECOSYSTEMS

Europe is getting warmer above the rate of global average. Until 2007, the average annual temperature of the European land area had been 1.2^{0}C higher than in the pre-industrial period, whereas in the combined land and sea area the temperature increased by 1^{0}C. The eight out of twelve years, between 1996 and 2007, had been amongst the warmest since 1850. The projections of annual temperatures, established on the basis of climatic models designed for various climate change scenarios, estimate that the temperature will increase from 1 to 5.5^{0}C by the end of this century. During winters, the highest warming is expected in the east and north, whereas in summers it is predicted in the south-west and Mediterranean part of Europe.

The domination of a negative trend of the annual air temperature in Serbia ceased in 1982. Since 1983, and particularly since 1987, positive trends have been detected, first in shorter, and later in increasingly longer intervals, so that the year 1983 can be marked as a beginning of a trend of the annual temperature increase, which still lasts.

A trend of precipitation amount in the region of Serbia, compared to the above-mentioned observed period, indicates that the annual precipitation sums have had a declining tendency in last 55 years. The intensity of decline is 5% of the regular amount in 50 years. As the duration of the observed interval decreases, so does the mark and intensity of the trend changes. In Serbia, the beginning of the period of the air temperature increase is accompanied by a period of reduced annual precipitation sum.

Apart from the recorded changes in the temperature and precipitation regime, changes of intensity and frequency of the occurrence of climatic extremes – droughts, floods, landslides, soil erosion, severe storms accompanied by hail, blizzards and avalanches, waves of extremely high air temperatures, frosts, heavy rains of short duration, forest fires, conditions favouring spreading of epidemics and pests have also been recorded, causing human casualties and material injuries.

The estimates based on climatic modelling, according to moderate scenarios, indicate that the annual temperature in Serbia will increase by 2.6^{0}C by the end of the century. The warming will not be equally distributed throughout a year; summers will be warmer by 3.5^{0}C, winters by 2.2^{0}C, whereas the temperature in spring will increase by 2.5^{0}C. According to the most unfavourable scenario, the increase of the average annual air temperature will be above 5^{0}C.

According to the moderate scenario, a decrease of the precipitation amount, ranging from 15-25%, is expected in Serbia, whereas the most unfavourable scenario envisages a decrease of the precipitation amount of up to 50%.

An increase of frequency, intensity and duration of droughts has already been recorded in Serbia, which represents a result of an increase of temperature, a decrease of summer precipitation and a higher number of dry periods. This trend will be particularly pronounced in the south-east and east parts of Serbia, since Serbia is territorially located in the area characterised by the highest frequency of drought occurrence. An increase of duration of vegetation period is expected.

Adverse effects will be particularly marked by frequency of extreme atmospheric phenomena such as drought, severe storms, extremely high temperatures, intensive erosion processes and occurrence of plant diseases and pests.

The increase of mean air temperature will cause a shift of climatic, and thereby vegetational zones towards poles and with respect to altitude. The 1^0C temperature change will cause a vegetation shift towards north of 200 to 300 km, along with a shift towards higher altitudes ranging from 150 to 200m.

Apart from a vegetation shift towards poles and higher altitudes, global warming will also cause a change of vegetation structure. Dying of trees (forests) will be increased due to inadequate ecological conditions of habitats and increased occurrence of entomological and phytopathological diseases. Climate changes will cause changes in the growth rate of certain species, hamper natural regeneration, due to a change of habitat humidity. An increased occurrence of forest fires and atmospheric disasters is also expected.

Climate changes will also cause changes in natural ecosystems, not only in terms of their dislocation, but with regard to their structure. Biological potential for adaptation will be reduced and diversity limited. Communities and species with limited adaptation potentials are most endangered.

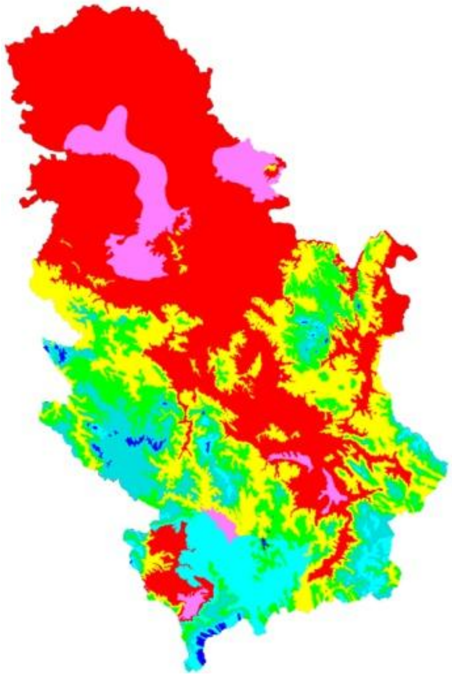
ADAPTATION OF FOREST ECOSYSTEMS TO CLIMATIC CHANGES

The most significant problem in adaptation of forest and shrub communities to climatic changes is the rate of the change, i.e., the intensity of change of climatic parameters is higher than natural potentials of many species to adapt to newly-created conditions. This is particularly apparent due to a fragmented structure of terrains, which will limit the shifts. Climatic changes during milder winters have caused shifts of many plant species in Europe towards north and higher altitudes. Mountain ecosystems in many parts of Europe are changing, the species adapted to the cold are driven out from their present habitats by the species adapted to a warmer climate. By the end of 21 century, the distribution of European plant species will be dislocated several hundred kilometres to the north, forested lands will be narrowed in the south and extended in the north, whereas 60% of the mountain plant species will most probably become extinct.

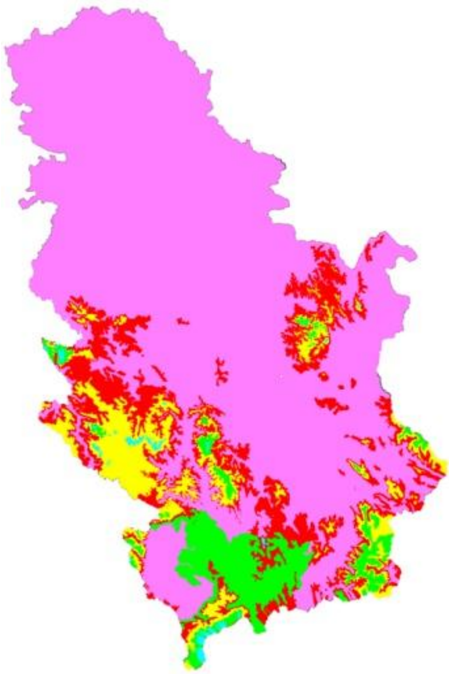
Impact of climate changes on forest and scrub ecosystems in Serbia

Monitoring changes in ecological conditions of habitats and their spatial distribution under climatic changes is of critical importance. For that purpose, a model of change of accumulated temperature >5.6^{0}C, contingent upon the increase of the forecast temperature by 1^0, 2^0, 3^0, 4^0 i 5^0 , has been designed (Ratknić, M. et all., 2010 (a)). Based on the designed model and scenarios, it can be concluded that a drastic change in number and structure of forest ecosystems in Serbia is about to occur in a relatively short period.

In Serbia, 160 habitats of broadleaved deciduous forests have been recorded. As the air temperature increases by 1^0, their number decreases by 4.4%; a 2^{0}C increase of air temperature decreases their number by 6.2%; an increase by 3^0 reduces their number by 20.6%, an increase by 4^0, that is, 5^{0}C reduces their number by 40%.



Map 1: Accumulated temperature for a multi-annual average (Ratknić M. et all., 2010 (a))



Map 2: Accumulated temperature for a 5^0 increase compared to a multi-annual average (Ratknić M. et all., 2010 (a))

The table presents the decline in number of forest habitats correlating to temperature changes. The total number of forest habitats in Serbia is 210. An increase of temperature by 1^0 reduces the number of habitats to 198, whereas a 2^0 increase reduces the number to 192. An increase of temperature by 3^0 reduces the number of habitats to

159, whereas a 4^0 increase reduces the number to 131. A 5^0 temperature increase reduces the number of habitats to 116, which is a decrease of 44.8%.

Out of 32 coniferous forest habitats, an increase of the air temperature by 1^0C will reduce their number by 12.5%, a 2^0C increase will reduce the number by 18.7%, an increase by 3^0C will reduce the number by 25%, a 4^0C increase will reduce their number by 65.6% and a 5^0C increase will reduce their number by 68.7%.

Out of 18 mixed deciduous and coniferous forest habitats, an increase of temperature by 1^0 will reduce the number of habitats by 5.5%, a 2^0C increase will reduce their number by 11.1%, an increase by 3^0C will reduce the number by 55.5%, an increase by 4^0C and 5^0C will reduce their number by 83.3%.

Table 2. The change in number of forest habitats correlating to the change of air temperature

Habitats	Number of habitats	Number of habitats correlating to the change of temperature by				
		1^0	2^0	3^0	4^0	5^0
G1 Broadleaf coniferous forests						
G1.1 –Willow (Salix), alder (Alnus) and birch (Betula) riverine woodland	11	11	11	3	2	0
G1.2 – Ash-alder (Fraxinus)-(Alnus) and oak (Quercus)-elm (Ulmus)-ash (Fraxinus) forests along small rivers	8	8	8	2	1	0
G1.4 – Broadleaf fen forests which do not develop on acid moss	3	3	3	0	0	0
G1.5 – Broadleaf fen forests on acid moss	2	2	0	0	0	0
G1.6 - Beech (Fagus) forests	25	25	25	23	18(2!)	7(2?)
G1.7 – Thermophilus deciduous forests	76	76	76	72	69	69
G1.8 - Acidophilus forests dominated by oaks (Quercus)	4	4	4	4	4	4
G1.9 - Non-riverine woodland with birches (Betula), aspen (Populus tremula), rowan (Sorbus aucuparia) or common hazel (Corylus avellana)	6	2(4!)	2	2	2	2
G1.A - Meso- and eutrophic forests with (Quercus), (Carpinus), (Fraxinus), (Acer), (Tilia), (Ulmus) and related forests	24	22(2!)	21	21	21	21
G1.B - Alder (Alnus) forests far from rivers	1	(1!)				
Total G1	160	153	150	127	96	96
G3 Coniferous forests						
G3.1 – Fir (Abies) and spruce (Picea) woodland	16	15(1!)	13	12	1	0
G3.4 – Scots pine (Pinus sylvestris) woodland south	2	2	2	2	1	1

Habitats	Number of habitats	Number of habitats correlating to the change of temperature by				
		1^0	2^0	3^0	4^0	5^0
G1 Broadleaf coniferous forests						
G1.1 –Willow (Salix), alder (Alnus) and birch (Betula) riverine woodland	11	11	11	3	2	0
G1.2 – Ash-alder (Fraxinus)-(Alnus) and oak (Quercus)-elm (Ulmus)-ash (Fraxinus) forests along small rivers	8	8	8	2	1	0
G1.4 – Broadleaf fen forests which do not develop on acid moss	3	3	3	0	0	0
G1.5 – Broadleaf fen forests on acid moss	2	2	0	0	0	0
G1.6 - Beech (Fagus) forests	25	25	25	23	18(2!)	7(2?)
G1.7 – Thermophilus deciduous forests	76	76	76	72	69	69
G1.8 - Acidophilus forests dominated by oaks (Quercus)	4	4	4	4	4	4
G1.9 - Non-riverine woodland with birches (Betula), aspen (Populus tremula), rowan (Sorbus aucuparia) or common hazel (Corylus avellana)	6	2(4!)	2	2	2	2
G1.A - Meso- and eutrophic forests with (Quercus), (Carpinus), (Fraxinus), (Acer), (Tilia), (Ulmus) and related forests	24	22(2!)	21	21	21	21
G1.B - Alder (Alnus) forests far from rivers	1	(1!)				
Total G1	160	153	150	127	96	96
G3 Coniferous forests						
G3.1 – Fir (Abies) and spruce (Picea) woodland	16	15(1!)	13	12	1	0
of taiga						
G3.5 - Black pine (Pinus nigra) forests	9	8(1!)	8	8	8	8
G3.6 - Subalpine Mediterranean pine (Pinus) forests	23	23	23	1	0	0
G3.9 – Coniferous forests dominated by (Cupressaceae) or (Taxaceae)	3	2(1!)	2	2	1(1!)	1(1)
G3.E - Nemoral wet coniferous forests	2	1(1!)	1	0	0	0
Total G3	32	28	26	24	11	10
G4 Mixed deciduous and coniferous forests						
G4.1 – Mixed mire forests	2	2	1(1!)	(1?)	(1?)	(1?)
G4.6 – Mixed fir-spruce-beech (Abies) – (Picea) – (Fagus) forests	8	8	8	1	0	0
G4.7 - Mixed Scots pine (Pinus sylvestris) and acidophilus oak (Quercus) woodland	1	(1!)				

Habitats	Number of habitats	Number of habitats correlating to the change of temperature by				
		1^0	2^0	3^0	4^0	5^0
G1 Broadleaf coniferous forests						
G1.1 –Willow (Salix), alder (Alnus) and birch (Betula) riverine woodland	11	11	11	3	2	0
G1.2 – Ash-alder (Fraxinus)-(Alnus) and oak (Quercus)-elm (Ulmus)-ash (Fraxinus) forests along small rivers	8	8	8	2	1	0
G1.4 – Broadleaf fen forests which do not develop on acid moss	3	3	3	0	0	0
G1.5 – Broadleaf fen forests on acid moss	2	2	0	0	0	0
G1.6 - Beech (Fagus) forests	25	25	25	23	18(2!)	7(2?)
G1.7 – Thermophilus deciduous forests	76	76	76	72	69	69
G1.8 - Acidophilus forests dominated by oaks (Quercus)	4	4	4	4	4	4
G1.9 - Non-riverine woodland with birches (Betula), aspen (Populus tremula), rowan (Sorbus aucuparia) or common hazel (Corylus avellana)	6	2(4!)	2	2	2	2
G1.A - Meso- and eutrophic forests with (Quercus), (Carpinus), (Fraxinus), (Acer), (Tilia), (Ulmus) and related forests	24	22(2!)	21	21	21	21
G1.B - Alder (Alnus) forests far from rivers	1	(1!)				
Total G1	160	153	150	127	96	96
G3 Coniferous forests						
G3.1 – Fir (Abies) and spruce (Picea) woodland	16	15(1!)	13	12	1	0
G4.G - Mixed forests of black pine (Pinus nigra) and calciphilic broadleaves	3	3	3	3	3	3
G4.H - Mixed Heldreich pine-Macedonian pine-beech woodland (Pinus heldreichii) - (Pinus peuce) - (Fagus)	4	4	4	4	0	0
Total G4	18	17	16	8	3	3
Total	210	198	192	159	131	116

The total number of scrub habitats is 72; a 1^0 or 2^0 increase of temperature reduces the total number of habitats to 70. A 3^0 temperature increase reduces the number of scrub habitats to 64, a 4^0 increase reduces the number to 51. A 5^0 temperature increase reduces the number of scrub habitats to 41, that is, by 43.0% compared to a present state.

Table 3. The change in number of scrub habitats in Serbia correlating to the change of air temperature

Habitats	Number of habitats	Number of habitats correlating to the change of temperature by				
		1^0	2^0	3^0	4^0	5^0
F2.1 –Dwarf willow scrub habitats near snow patches	2	2	2	0	0	0
F2.2 – Evergreen alpine and subalpine heaths and scrub habitats	12	11(1!)	11	8	5	0
F2.3 – Subalpine and oroboreal scrub habitats	5	5	5	4	3	0
F2.4 – Dwarf mountain pine scrub habitats (Pinus mugo)	3	3	3	3	1	0
F3.1 – Moderate thickets and scrub habitats	2	2	2	2	2	2
F3.2 – Mediterraneo-montane broadleaved deciduous thickets	23	23	23	23	23	23
F3.3 – Subcontinental and continental evergreen thickets	4	4	4	4	4	4
F3.4 - Montane and subalpine deciduous thickets	4	4	4	4	0	0
F4.2 - Dry heaths	2	2	2	2	1	1
F5.3 - Pseudomaquis	1	1	1	1	1	1
F7.4 – Hedge-hog heaths	1	1	1	1	1	1
F9.1 – Riverine and lakeshore (Salix) scrub	6	6	6	6	6	6
F9.2 - Willow carrs and fen scrubs (Salix)	5	5	5	5	3	2
F9.3 - Southern riparian galleries and thickets	1	(1!)				
F9.4 – Desert false indigo (Amorpha fruticosa) thickets	1	1	1	1	1	1
Total	72	70	70	64	51	41

The marks in the table columns have the following meaning: ! – community not recorded in the region of Serbia, but its existence can be expected; ? – out of the scope of the model

Most species will react to climate changes by migration, which will cause the change in composition, structure and representation of plant communities. Some species and plant communities will migrate, whereas the others will simply become extinct, due to a more rapid shift of climatic zones as compared to a rate of migration of certain forest species and types. As the two thirds of the Serbian territory is comprised of mountain terrains, there are species the population of which is limited to mountain peaks, where there are no natural corridors for their migration. Those species will be among those worst hit by climatic changes, since they are already sensitive, on account of a low population and isolation. Most of these species on mountain tops are endemic or steno-endemic, hence there is a high probability of their extinction, which will significantly contribute to the decrease of biodiversity of the region (Ratknic, M., 2006).

A change of climate creates favourable conditions for arrival and acclimatisation of new alien and invasive plant species. Invasive species exert adverse impact on biodiversity and they are considered globally a second most serious threat to biological diversity, immediately after a direct destruction of natural habitats. Invasive species drive out autochthonous species from their habitats, change the structure and composition of plant communities and reduce the entire richness of species. Ecosystems that have already been exposed to the adverse impact of human activities and have had their natural diversity reduced, manifest extreme sensitivity to invasive species.

The expected effects of climatic changes with respect to forest ecosystems, forest communities and species of tree, shrub and ground vegetation, are the following:

1. shift of boundaries of certain forest types with respect to geodetic latitude and altitude;
2. different natural re-distribution of surface areas of various forest types with respect to geodetic latitude and altitude;
3. considered from a long-term perspective, extinction of certain plant communities;
4. different composition of certain plant communities with respect to a multi-storey and social position, involving extinction of some species and appearance of others;
5. change of attitude of certain species towards light;

Forest communities will be more exposed to various adverse impacts that are a direct or indirect result of climate change. In addition to the above-stated, it is significant that a higher level of risk, related to the expected adverse effects, is associated to relict, rare and endangered forest communities and basic tree species, which make them distinctive. Considered cumulatively, the above-mentioned effects will have a direct impact on the possibility of preservation of biological diversity and viability of rational management of these resources.

As the microclimatic conditions change at the global level, a soil moisture regime is also changed. If aridisation takes place in a vegetation period, as a consequence, dry periods, i.e., the period when soil lacks sufficient moisture, are also prolonged. The soil water reserve drops below the lentocapilar capacity, while forest trees slow down the transpiration process. The transpiration slowdown causes the slowdown of all other physiological processes. Under such conditions, even with very favourable chemical properties and high fertility of soil, as a result of slowed physiological processes, forest trees are not capable of exploiting the production potential of the soil. In the event of further moisture reduction to the point of withering, dying of certain forest trees will occur. Dying of mesophilic species in forest ecosystems will occur first, followed by dying of xerophytic trees of lower vitality. Such change leads to a change of floristic composition of relevant phytocenoses. Apart from the change of quantity and chemical properties of organic matter that annually reaches the soil, the change of floristic composition of phytocenosis in relevant habitats may result in a change of a protective and hydrological function of a forest. In such situations, under the influence of exogenuous forces, a new balanced state of pedogenesis and physical degradation is established. Depending on orographic, edaphic and newly-created vegetation factors, soil may succumb to intensive erosion processes.

Adaptive activities in forestry

The existing concept of sustainable use of natural resources and, therefore, forest ecosystems, is experiencing a crisis. While developing a 'new' concept of sustainable use of forest ecosystems, answers must be provided to a series of questions, among which the most important ones certainly are:

- What are the types of research that will aid a development of the strategy for adaptation to climatic changes?
- What are the educational needs aimed at raising awareness of climate changes and facilitating easier adaptation?
- What must be known when estimating a level of forest response to climatic changes?
- What activities in forest management can be performed without endangering ecosystem functions in future?
- What are the obstacles to implementation of adaptation measures in forest management?
- Do current monitoring systems adequately follow the changes caused by climatic changes and enable implementation of acceptable responses?
- What forest ecosystems and species are capable of autonomous adaptation and where can we aid adaptation by intervention?

Adaptation ought to reduce sensitivity of forest ecosystems towards climatic changes. Despite the fact that forest ecosystems will adapt to climatic changes on their own, bearing in mind the importance of forests for the society, it is necessary to influence the course and dynamics of adaptation in certain fields. In many cases, the society will have to adapt to changes that it will not be able to influence directly.

Activities related to a process of adaptation of forest ecosystems must be accomplished now, in order to obtain their full effect in future. Researches in forestry must estimate a long-term impact of climatic changes and determine how and in which habitats should be reacted to this threat. A sustainable forest management must include built-in elements of forest ecosystem adaptation (Holling, C.S., 2001), where it should be emphasised that the inclusion of adaptation to climate changes, as a part of sustainable management of forest ecosystems, does not require large financial investments into an unknown future.

Even without a clearly established dependence between forests and climatic changes, it is even now possible to develop the adaptation strategy. Adaptation to climatic changes refers to adjustments in ecological, social and economic systems (Smit, B. et all., 2000; Smit, B. and Pilifosova, O., 2001). Having in mind the lack of understanding regarding the impact of climatic changes on ecosystems, the development of adaptation measures and social context must be highly speculative (Barton, I. at all., 2002). However, the applied adaptation measures must not have an adverse effect on the present state of forest ecosystem, therefore, an effective adaptation policy must provide a response to a broad spectrum of economic, political and ecological circumstances (Spittlehouse, D.L., 1997; Dale, V.H. et all, 2001; Holling, C.S., 2001; Smit, B. and Pilifosova, O., 2001; Spittlehouse, D.L. et all., 2003).

Adaptation requires:

- establishing objectives for future forests, which will be under the influence of climatic changes
- raising awareness of the importance of adaptation to climatic changes
- determining a vulnerability level of forest ecosystems and forest communities
- development of present and future cost-effective flexible activities
- forest management aimed at mitigating vulnerability and improving conditions for rehabilitation
- monitoring the state of changes and identification of a critical threshold for survival
- a successful impact reduction, shortening of a rehabilitation period and reduction of vulnerability towards future climatic changes.

The most significant problem of adaptation of forest and scrub communities to climatic changes is the rate of change. It is expected that the application of adequate measures in forest ecosystem management could reduce ecological and socio-economic effects of deterioration of forests.

The change of climatic characteristics will cause a shift of species areals towards higher altitudes, along with a shift towards the north. Therefore, it is necessary to guide adaptive activities in afforestation towards maintaining genetic variability and resistance of species with respect to adaptation to these changes, as well as towards changing techniques and technology of planting:

- determine the adaptability of species and genotypes in relevant climatic conditions, the boundaries of their transferability, and the development of climate-related characteristics of seed in the zones which are to be changed in the course of time (Parker, W.C. et all., 2000; Ratknić, M., 1999). Provenances should be tested at the boundaries of their ecological range, with understanding of relevant physiological processes (Tyree, M.T., 2003).

- planting of specific genotypes resistant to pests and showing a higher tolerance to climatic extremes (Namkoong, G., 1984; Wang, Z.M. et all., 1995).
- planting of forest fruit trees. With the change of climatic conditions, certain forest fruit trees will disappear from some forest ecosystems. As they represent the basis for a regular functioning of ecosystems, genotypes resistant to changes ought to be discovered (Ratknic, M., 2005).
- in selection of species and planting type, forest stands of mixed provenances ought to be established (Ledig, F.T. and Kitzmiller, J.H., 1992).
- change the principle of preservation and re-introduction of rare and endangered plant species. Rare and endangered plant species usually have specialised ecological needs and low genetic variability (Peters, R.L., 1990; Hansen, A.J. et al. 2001). A long-term preservation of certain rare species is easier to accomplish in archives (Ratknić, M., 2005), artificially established stands or arboreta, than in natural stands (Parker, W.C. et all. 2000).
- develop an afforestation technique and technology that will enable survival of seedlings in first years of life in newly-created conditions (mulching, use of polymers, etc) (Ratknić, M., 2004; Ratknic, M., 2007).

The existing forests are, for the time being, resistant to climatic variability, but their regeneration represents a phase that is very uncertain under the impact of climatic changes. By means of adaptation to climatic changes, spreading of genotypes or species adapted to new climatic conditions ought to be enabled. Spreading of non-commercial trees and vegetation will present a particular economic problem. Adaptive activities in the field of forest regeneration involve:

- identification of genotypes tolerant to drought (Farnum, P., 1992; Ratknić, M., 2007).
- aiding migration of commercial tree species from their present to future habitats by means of artificial regeneration (Parker, W.C., et all. 2000). Shift of species towards the north or higher altitudes may be hindered by inadequate soil conditions, such as lack of nutrient matter, the depth, deficiency of mycorrhizal fungi, etc.
- plantation of provenance growing in a broader spectrum of conditions as compared to current habitat provenances (Ledig, F.T. and Kitzmiller, J.H., 1992).
- control of undesired plant species, which become competitive species in conditions of changed climate (Parker, W.C. et all. 2000).

In near future, climatic changes may increase productivity of forests (Cohen, S. and Miller, K., 2001). However, in long-term, the availability of nutrient matter and adaptation of tree species to a higher content of carbon dioxide may limit productivity.

In warmer habitats, stabilisation of productivity at the present level can be expected. Changes may also be expected in forest distribution border areas in the zone of scrub and grass habitats. Based on these changes in forest ecosystems, a change of positions and procedures in the field of forest sylviculture is essential. Adaptive activities aimed at responding to changes are the following:

- non-commercial thinning or selective removal of individually driven out, damaged or trees of poor quality, with a view to increasing light, water regime and nutrient matter, which would all be more accessible to remaining trees (Smith, D.M. et all., 1997; Papadopol, C.S., 2000). This adaptive measure, however, if applied on larger areas may have an impact on a current regular functioning of ecosystem.
- reducing endangerment, with a view to decreasing disturbances in future, by controlling a stand thickness, type and structure of a forest (for instance, supplemental planting, planting of species from subsequent successive phases, etc) (Dale, V.H. et all, 2001, Ratknić, M. et all, 2010 (b)).
- planting of other species or genotypes, in cases which natural regeneration is not acceptable from the perspective of forest ecosystems in future
- decrease of rotation period and plantation of adaptive species with a view to a more rapid establishment of resistant forest ecosystems.
- Natural protected areas present a specific problem, in the framework of which the adaptive measures involve:
- reconsidering our current positions and approaches to protection of natural protected areas (by postponement, improvement, direct change) (Lopoukhine, N., 1990; Henderson, N. et all., 2002; Suffling, R. and Scott, D., 2002).
- identification and plantation of alternative tree species (Suffling, R. and Scott, D., 2002; Henderson, N. et all., 2002, Ratknić, M. et all, 2010 (a), Ratknić, M. et all, 2010 (b)).
- preservation of biodiversity and maintaining a diverse and dynamic terrain, a function of which is to aid vegetation and migration of wild animals during climate changes through ecological corridors (Noss, R.F., 2001; Carey, A.B., 2003, Ratknić, M. et all, 2010 (b), Ratknic, M., 2011).
- minimising fragmentation of habitats and maintaining association of habitats into functional units on larger areas (Peters, R.S., 1990; Noss, R.F., 2001, Ratknić, M. et all, 2009).

Rapid changes of forest age structure and changes of terrains can be caused by more frequent and intensive disturbances such as fire, stormy winds and outbreak of pests. There is a high possibility of occurrence of interaction between climatic changes (warmer and drier climate), pest outbreak and forest fires (Fleming, R.A. et all., 2002).

Adaptive activities must be concerned with changes in the regime of forest fires, which involve:

- focusing on protection of regions of high economic and social value (Ratknic, M., Smit, S., 1999; Ratknic., M. et all., 2009).
- changing a forest structure (distance between trees, stand thickness, removal of dry upright trees, removal of dead trees) aimed at decreasing a risk and a degree of ecosystem disturbance (Dale, V.H. et all., 2001). In the process of reduction and removal of dry trees, it should be borne in mind that this material has a particular ecological importance for functioning and preservation of ecosystems, therefore it is necessary to reconcile a threat of fire with the ecological component (Ratknić, M., 2010 (b)).
- development of a 'smart' fire landscape. By means of cut, regeneration, stand activities as systems of management of the amount of combustible material in the process of control of fire occurrence and spreading. For instance, an aspen stand, a species resistant to fire, can be planted in several localities in coniferous cultures or in natural forests, with the aim of mitigating vulnerability of ecosystems in large fires. This is an example of an adaptive activity, a positive effect of which will be felt for several decades (Spittlehouse, D. et all., 2003).
- increase of a rate of recovery of forest ecosystems after fires (Ratknić, M., 2011).

Climate changes will increase warmth and humidity in present forest ecosystems, create conditions for increased occurrence of insects and diseases. Adaptive activities in protection of forests against insects and diseases may involve:

- partial cut or thinning aimed at increasing stability and lowering sensitivity to attacks (Wargo, P.A. and Harrington, T.C., 1991; Gottschalk, K.W., 1995).
- sanitation cut of infected trees, where it should bear in mind that this practice may increase the sensitivity of ecosystems to other pests (Smith, D.M. et all., 1997).
- shortening of a rotation period with a view to decreasing the period of vulnerability of a stand to harmful insects and diseases (Gottschalk, K.W., 1995), aimed at effecting a more rapid transition to more suitable species (Lindner, M. et all., 2000).
- use of insecticides and fungicides in situations where other activities are ineffective of inappropriate (Parker, W.C. et all., 2000).
- use of genotypes grown for the purpose of increasing resistance to pests (Namkoong, G., 1984).

Biological and climatic changes will also have implications on use of forests and forest ecosystems. An increased amount of precipitation during winter and a decrease in the summer period may have an impact on water resources in forest ecosystems, increase the risk from erosive processes and endanger fish habitats and hatcheries. Adaptive activities in the field of use of forest ecosystem resources are the following:

- an increased amount of wood from sanitation cuts, which are carried out after fires and damage of stands inflicted by insects, along with a reduction of treatment in natural stands left to natural adaptation.
- maintenance and rehabilitation of roads, damaged as a result of erosive processes due to an increased amount of precipitation and abrupt snow melt
- mitigation of the impact upon infrastructure, fishery and reserves of potable water
- inclusion of adaptive planning measures into forest certification, as a part of the risk management strategy
- mitigation of climatic changes through carbon management (Parker, W.C. et all. 2000; Spittlehouse, D.L., 2002; White, T. and Kurz, W., 2003;, Kurz, W. and Apps, M.J., 1996; Fleming, R.A. et all., 2002, Ratknić, M., 2008 (b)).
- an increased use of biomass as an energy generating product
- development of policy aimed at facilitating creation and implementation of an adaptive response to climate changes (Duinker, P.N., 1990; Spittlehouse, D.L., 1997; Parker, W.C. et all. 2000; Burton, I. et all. 2002).

AN ALTERNATIVE TO USE OF NATURAL RESOURCES

An alternative to adaptive activities in adaptation to climatic changes is the eco-centric (or bio-centric) use (management) of resources based on principles of close-to-nature management. An ecosystem represents a complexity of living organisms and has a VALUE PER SE. These ecological paradigms examine human needs and attitude to nature from a different perspective. A manner in which nature creates and maintains ecosystems is respected. There are no undesirable species in natural ecosystems, apart from those introduced by man. In forestry, for instance, upon removal, every tree or product is assessed from the aspect of functioning of an ecosystem. It is the nature alone that continues to develop and maintain stability of ecosystems, not the people on the basis of their notions of that. An ecosystem belongs to all species living in it, including humans. Therefore, man has no right to destroy it for his own interests.

The eco-centric concept insists on protection of remaining old natural forests as the last resort of plant species, and other types of organisms. The integral part of it is a care of soil, water, biodiversity and biomass. The policy of ecosystem use under climate changes should enable extension of forest areal into regions that are not used for other purposes (demarcation of agricultural and forest land), improvement of a state of degraded and devastated forests and thickets, an increase and improvement of production of wood mass and other products and services, and protection of remaining natural forests from degradation and devastation.

Only if the eco-centric approach is included in adaptive activities with respect to use and adaptation of forest ecosystems to climatic changes, they can have their full justification.

CONCLUSION

The existing global climate models are formed on the basis of the data that prevent a on obtainment of detailed spatial structure of the variables, primarily temperature and precipitation, above heterogeneous areas. In order to reduce the drawbacks of the existing global climatic projections, it is essential, for the purpose of quantification of reliability and uncertainty of forecasts, to use regional climatic and impact models. It is necessary to build-in the results of these models into activities that enable timely adaptation to climatic changes, or their mitigation (if possible).

For forest ecosystems to adapt to newly-created climatic changes, it is necessary to preserve forests in their most natural form, with avoiding mono-cultures and formation of mixed forests, with respect to both type and age. Maintaining natural or close-to-nature regeneration is recommended, as the method of maintaining genetic diversity and, consequently, reducing sensitivity of forest ecosystems. It is also essential to strategically increase the size and number of protected areas, particularly in exceptionally valuable habitats, create artificial reserves or arboreta, with the aim of preserving rare species and providing multiple protection to climatic refugia, and to include climatic parameters into the models of forest growth and yield. It is necessary to aid changes in distribution of endangered and sensitive species by means of their introduction into new areas, with a view to preventing invasion of habitats by allochthonous species or autochthonous species which are not native for the relevant habitat, to constantly control those species, since they will enter a stronger competition with the species that are exploited. In artificially established forests and mixed cultures, natural genetic diversity should be fostered, the structure of surrounding forests should be imitated and a direct substitution of a natural ecosystem should be avoided. In order to increase the potential of an ecosystem to respond to climatic changes, it is essential to reduce stress factors that are not related to climatic conditions. With a view to preventing adverse changes in distribution of plant and animal communities, it is necessary to maintain seed sources (seed banks and seed facilities) and increase genetic diversity of trees that are used for establishment of plantation. With regard to seedling nursery production, seedling nurseries should be prepared for potential extension of their capacities, while intensifying experimentation with various plant species and production, growth and plantation of genotypes resistant to drought and other climatic extremes, insects and diseases.

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PROVENECE RESEARCH IN SERBIA – BASE FOR EVALUTING THE SPATIAL PETERN OF FOREST TREES GENETIC VARIATION

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Abstract: *Austrian pine (Pinus nigra Arnold) Scots pine (Pinus sivestrys) and Norway spruce (Picea abies L. Karst), are the most important indigenous conifer species, in Serbia and Douglas-fir (Pseudotsuga menziesii Mirb. Franco) is the most important introduced one. European beech (Fagus sylvatica L.) will be considered as example for broad-leaved species. In this paper, each of these five species will be examined in some detail. Attempts will also be made to summaries some causal and findings.*

Investigation of genetic structure of the provenances of these species acquiring information regarding group and individual variability by applied genetic markers as the tools for better understanding the nature of; a) genetic similarity, i.e. diversity of populations studied by analysis of protein complexes from assimilation organs; b) interrelation of ecological traits characteristic for habitats from which samples originated, and results obtained by laboratory analyses. Analyses results obtained by applied genetic markers revealed that interpopulation diversity was higher than it was registered within studied black pine seed stands. On the basis of obtained results black pine provenance regions in Serbia were defined in accordance with the Law on reproductive material of forest trees.

Key words: Austrian pine, Scots pine, Norway spruce, Dougla-fir, European beech, provenances research, Serbia

INTRODUCTION

Forests in Serbia are biologically very diverse and among the richest of all terrestrial ecosystems. They are not only important habitats for many plant and animal species but they have abiotic key functions. For instance, forest act as essential carbon sinks mitigating climate change. At the same time, forests have important economic, social and cultural roles. To many people biodiversity simply refers to a list of different species existing in a particular area or region. But biodiversity refers not only to the multiplicity of species. It includes the genetic variation within species and the variation of communities and ecosystems to which the species belong, and thus represents diversity at all levels of biological organization – the gene- the species, the community and the ecosystems. Genetic diversity, i.e. diversity at the intraspecific level is a critical component of biodiversity because it allows the species to evolve over time and in space and thus plays a key role for the long-term survival, Ledig 1986. and for ecosystems stability Pimm 1984., Friedman 1997. Many European forests, notably in central Europe, share the influence of similar traditions in silviculture, which provides a common basis for incorporating concerns over genetic resources into forestry practice. Besides

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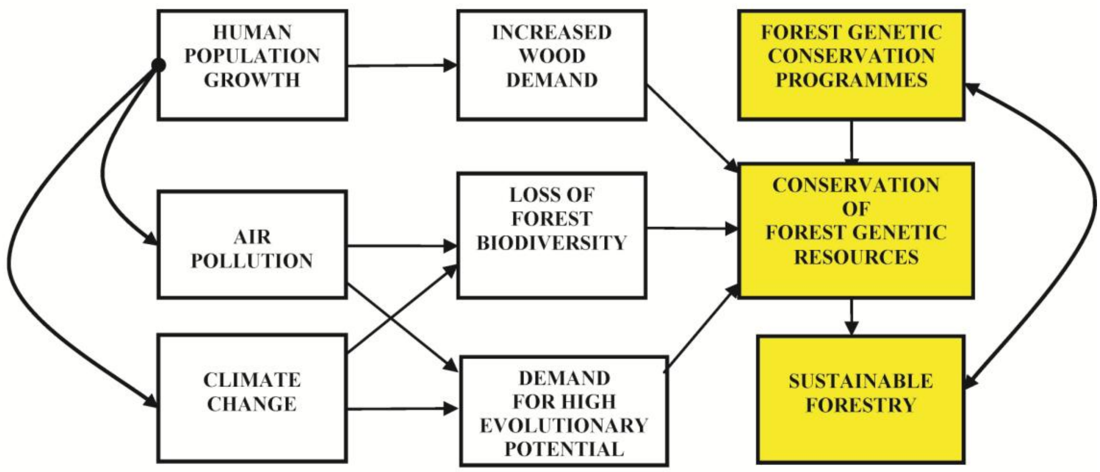
transboundary atmospheric polutonians the overall environmental changes, there is a list of serious affecting the conservation and management of genetic resources. These include past intensive management, artificial regeneration including wide-scale transfers of forest reproductive material, decreased population sizes especially due to forest fragmentation and introduction of exotic forest tree species. They often to a loss or-at least- to an alteration of the genetic identity of autochthonous tree populations. Since it is neither feasible nor desirable to set aside large unmanaged nature reserves is most parts of Serbia, forest genetic conservation- also integrated in regular, sustainable forest management – is urgently needed (Fig.1).



Forces leading to the conclusion that conservation of forest genetic resources is necessary. Eriksson G., 1997.

The detection of some productive provenances cannot be considered as the ultimate result. In older experiments, with few samples, sometimes single outstanding provenances have been identified, but the question must be raised whether they are representative for the particular region from which they are coming. Furthermore, single stands may have been felled before results have become available and therefore cannon be used as a seed source in the future. Provenance experiments should at least reveal some kind of a geographic variation pattern and this pattern can then be used to group provenances of similar performance and to delineate regions of provenance in the case where neighboring provenances are similar. However, in most cases the ecological conditions have been the basis for the delineation of provenance regions. This might be due to the lack of adequate provenance experiments, or that environmental factors have been considered as the main factors in shaping genetic variation, as is frequently the case.

Austrian pine (*Pinus nigra Arnold*), Scots pine (*Pinus sivestrys L.*), Norway spruce (*Picea abies /L./ Karst*), are the most important indigenous conifer species, in Serbia and Douglas-fir (*Pseudotsuga menziesii Mirb. Franco*) is the most important introduced one. European beech (*Fagus sylvatica L.*) will be considered as example for broad-leaved species.

The investigations encompassed the following:

- determination of the precise area of these species in Serbia

- geographic distribution, geographical latitude and longitude, scope of heights above sea level, area, location;
- definition of ecological characteristics of their populations – climatic, pedological, phytocenological etc.
- separation of provenance regions, and
- creation of maps of provenance regions in GIS

Establishment of field experiments network enabled testing of seed stand populations of spruce, black pine, fir Douglas-fir and beech, i.e. provenances of these species in Serbia. Multi-annual studies included ecological characteristics and stand condition of seed objects and productivity and yield quality of individual subpopulations, which is the basis for location of seed objects, i.e. separation of provenance regions. Studies at population level – in seed stands and in laboratories (Faculty of forestry, Belgrade, Institute of forestry, Belgrade, and in the Laboratory of biotechnology, Institute of maize “Zemun Polje”, Zemun) have been carried out since 2000. In conveyed studies the testing of structure of the genome of their population was done by protein markers application as the most often used polimorphic markers at the level of gene products and molecular DNA markers based on PCR phenomenon. In this paper, each of these five species will be examined in some detail.

AUSTRIAN PINE (*Pinus nigra Arnold*) PROVENECE RESEARCH IN SERBIA

In Serbian forestry, Austrian pine (*Pinus nigra Arnold*) is one of the most important economic species, irreplaceable in the re/afforestation of large areas affected by erosion processes, or completely degraded, denuded areas. The definition of Austrian pine, provenances in Serbia was accomplished by studying genetic potential and characteristics of different habitats of seed stands of this species, Mataruga et al 1997. The ecological characteristics of the sites of Austrian pine seed stands were studied based on the documents from the Register of Austrian pine seed stands in Serbia. The seed material used in the analyses originates from parent individuals from six Austrian pine seed stands two of which are in FE "Šumarstvo" Raška, and one in each FE "Prijepolje" Prijepolje, FE "Užice" Užice, Faculty of Forestry-Beograd-Goč, FE "Stolovi" Kraljevo, Lučić 2007.

The first level of the study of intra- and interpopulation variability of Austrian pine seed stands in Serbia was the study of variability of cone and seed morphometric characteristics and the yield quality, by standard ISTA methods of laboratory analyses. The study results show the existence of intrapopulation variability of cone and seed physiological and morphological traits, which confirms a high genetic diversity, as the base of the differentiation of Austrian pine ecotypes in a part of its range in Serbia.

The testing of structure of the genome of Austrian pine populations was done by protein markers application as the most often used polymorphic markers at the level of gene products and molecular DNA markers based on PCR phenomenon, Lučić 2007., Lučić et al.2008., 2010.

The research of the genetic structure of Austrian pine seed stands by the study of group and individual variability by using genetic markers was the base of the closer study of:

- the degree of variability of cone and seed morphometric characteristics and the interdependence of the analysed characteristics;
- genetic similarity, i.e. the distance of the studied Austrian pine populations, by the analysis of seed proteins and molecular-DNA markers based on PCR method;
- the relationship of ecological attributes characterising the site from which the analysed seeds originate and the results of laboratory analyses.

The analysis of the similarity index of the seed DNA of Austrian pine populations after *Jaccard* and *Sokal-Michener* by using cluster analysis dendogram, shows that the greatest genetic distance from other populations occurred in MU "Divan-Lokva" and MU "Šargan"

Based on the application of the above markers, it was concluded that all six Austrian pine seed stands were characterised by a higher intrapopulation diversity compared to interpopulation variability. The final regionalisation of Austrian pine seed stands should be based on two aspects – genetic differentiation and gene pool conservation of this species (in-situ and ex-situ), in order to protect the genetic specificities of Austrian pine natural populations in Serbia. The values of intrapopulation diversity in the applied markers are much higher than it was recorded among the study six Austrian pine seed stands. From the aspect of commercial forest seed production, the study results are significant for future activities on defining Austrian pine provenance regions in Serbia.

SCOTS PINE (*Pinis sylvestris* L.) PROVENECE RESEARCH IN SERBIA

The study of genetic potential and ecological characteristics of the sites of Scots pine populations in Serbia and the degree of their interaction is fundamental for the improvement of forest establishment.

Seven Scots pine populations were researched in Serbia: two Scots pine seed stands selected in natural stands, (MU "Šargan", 25 b., FE "Užice" Užice; MU "Radočelo-Crepuljnik" 4b., FE "Stolovi" Kraljevo); two seed stands established in artificial stands of good production characteristics outside the Scots pine natural distribution in central and eastern Serbia (MU "Jablanička Reka" 33 d., FE "Rasina" Kruševac; MU "Bukovik-Aleksinački", 23b. 24g., FE "Niš" Niš); two Scots pine populations in the vicinity of the seed stands with which they have identical morphological and physiological characteristicse (MU "Kaluđerske Bare", 1a., NP “Tara“ Bajina Bašta; MU "Zlatar I", 22a., FE "Prijepolje" Prijepolje) and one natural Scots pine population in the southernmost part of Scots pine distribution in Serbia (MU “Dubočica Bare“ 60 a., FE “Golija“ Ivanjica).

The research was performed at two levels: a) Research at the level of initial populations which included: the analysis of site conditions (soil, parent rock, climate characteristics), analysis of forest communities, analysis of plus trees phenotype characteristics, cone and seed analysis, genetic characterisation of initial populations (seed protein polymorphism, polymorphism of seed DNA using RAPD, seed DNA polymorphism using SSR (micro-satelites), analysis of two-year-old seedlings, Lučić 2011, Lučić et all. 2011, and b).established and research at the pilot plot level. The study results are significant because they pointed to the necessity of research, i.e. integral analysis of all the site parameters (physico-chemical properties of the soil, parent rock, climate characteristics). The analyses of the afforestation site area and the initial populations should include all the significant parameters: physico-chemical composition of the soil, parent rock, climate characteristics, floristic composition. The study results should be examined integrally, which will decrease the probability of making incorrect decisions in the selection of seed sources for afforestation.

Based on the multiannual research in the scope of these investigations, a Scots pine pilot plot was established in the function of long-term research, protection and conservation of Scots pine gene pool, possibility of its conversion to seed orchard, mass production of seeds, etc, Lučić, 2011. The pilot plot was established at the site "Jelova Gora", Forest Enterprise "Užice" – Užice, based on the principle of metapopulation structure, Tucović et al. 1992. It consists of 4 blocks (sub-orchards). Total number of plants incorporated in the pilot plot is 1746 individuals.

The study results within those investigations are fundamental in the process of uprgrading the establishment of artificial forests with this tree species. This research points to the necessity of in-depth analyses of genetic-ecological characteristics of initial populations and ecological parameters of the afforestation area, by the definition of the required level of genetic-ecological research. In the group of ecological researches, the analyses should include climate characteristics, physico-chemical properties of the soil, and potential vegetation, and in the group of genetic research, the analyses should be based on the use of SSR markers.

NORWAY SPRUCE (*Picea abies* /L. / Karst.) PROVENECE RESEARCH IN SERBIA

Norway spruce *(Picea abies /L. / Karst.)* provenance tests in Serbia consist of eight provenances. Three provenances of this species are from Slovenia – Mašun, Menina and Jelovica; and five provenances are from Serbia – Golija, Zlatar, Čemerno, Radočelo and Kopaonik. The monocultures near Ivanjica were established by planting four-year old seedlings at three localities, at the altitudes of 600, 1100 and 1600 m. Isajev et al. 1992., 1999. The aim of the research was to identify the spruce differential characters and variability in the part of its natural range in the south-east Europe and to study the production capacity and the differences between individual provenances in more or less identical and different ecological conditions in Serbia, Šijačić-Nikolić et al. 2000.

In Norway spruce plantations, numerous researches have been undertaken included several morphometric characters of juvenile plants, for each year between 7 and 14 years of age, Ivetić 2004. The measured characters are height and height increment at the annual level, root collar diameter and diameter increment and the number of branches. The study results of metric properties were analysed by standard statistical methods.

The data on the variability of air temperature and precipitation at the study localities were obtained from the Republican Hydro-Meteorological Institute of Serbia. The effects of air temperature and precipitation on the study parameters were determined by Pearson's correlation coefficient. The values of temperature and rainfall were previously fitted separately for each locality. The soil characteristics were investigated by topographic observations and the soil profiles were opened for soil sampling. The laboratory analyses were performed at the Faculty of Forestry in Belgrade.

The results of the study of spruce potentials of different provenances confirm that the free genetic variability of this species is very high, and that, according to the results of the analyses, the Serbian provenances are characterised by higher adaptivity to very different ecological conditions. In this provenance test, in the plantation at the montane beech site where, as a rule, spruce does not occur naturally, its growth and adaptation are successful. This indicates that, in addition to the natural optimum in the zone of spruce belt *Picetum abietis serbicum,* its technogenic optimum can also occur at the site of other species.

The study results obtained from all three altitudinal belts confirm the specificity of the spruce gene pool in Serbia, which conditions the phenomenon of its special climatogenic belt in Serbia, compared to other countries of the Balkan Peninsula.

After the culmination of height increment of spruce trees and after the test plantations pass from the juvenile stage into the reproductive stage of development, by the establishment of tests with generative progeny, the nature of the interprovenance variability will be closer understood. The test results will enable the more reliable use of provenances with the most suitable potential for the establishment of stable and productive cultures on the concrete sites in Serbia.

The comparative research of eight provenances shows that the provenances Golija and Zlatar are characterised by high adaptability and growth dynamics, so they should be more intensively applied in future activities of plantation establishment or afforestation of bare lands in Serbia.

DOUGLAS-FIR (*Pseudotsuga menziesii Mirb. Franco*) PROVENECE RESEARCH IN SERBIA

Douglas-fir (*Pseudotsuga menziesii* /*Mirb.*/ *Franco*) provenance tests in Serbia consist of 29 provenances, originating from almost entire natural range of this species. One experiment is in the area of Mt. Juhor (central Serbia) at the site of the montane beech forest (*Fagetum moesiaca montanum* Jov. 1976) and the other one is at Tanda near Bor (eastern Serbia), at the site of Hungarian oak and Turkey oak forests (*Quercetum frainetto-cerris* Rud. 1949).

In Douglas-fir plantations, numerous researches have been undertaken in various spheres of forestry, Lavadinović V. et al.1995. 1997., 1998., 2001., 2003., 2005. However, the interaction between the genetic potential of introduced provenances and the ecological characteristics of the locations at which the plantations are established has not been sufficiently researched to date. For this reason, the aim of investigations are to study the interaction between the genetic potential of the introduced provenances and the environmental conditions at the provenance test sites, aiming at the more reliable selection of forest-economic works on the establishment, silviculture, tending and utilisation of Douglas-fir plantations in Serbia.

A considerable number of quantitative and qualitative properties were analysed in Douglas-fir test plantations on Mt. Juhor and in Tanda. The analysed environmental characteristics of the sites of test plantations included climate characteristics and soil properties. The analysis of climate characteristics was based on the data of the local meteorological stations at Juhor and Tanda, and the soil samples for standard soil analyses were taken from the soil profiles opened in each plantation. The degree of correlation of the study results of variability of tree characteristics with the plantation site environmental characteristics was determined by statistical methods Lavadinović V. 2008.

The multi annual researches included comparative analyses of intra- and inter- provenance variability of several quantitative characters: a) trees – volume, basal area and volume increment, b) needles – variability: width and length, number of hypodermal cells on the abaxial and adaxial sides and in needle axils, diameter of resin canal and the number of epithelium cells in the resin canal, width and height of the transfusion parenchyma, as well as of qualitative characteristics: a) content of major nutritive macroelements in the needles, b) content of essential oils in current-year and second-year needles, c) the main physical and mechanical properties of felled stem wood at the height from 0.3 to 1.3m.

Based on the provenance ranking by all analysed parameters of tree growth and development, and based on the statistical verification of the study data, two groups of extreme provenances differentiated clearly at both localities. The best provenances were: 3 (Oregon 202-27), 4 (Oregon 205-38) and 18 (Oregon 202-19) on Juhor, and 31 (Washington 205-17), 3 (Oregon 202- 27) and 18 (Oregon 202-19) in Tanda; the worst provenances were: 9 (Washington 204-07), 16 (Oregon 201-10) and 24 (Oregon 202-31) on Juhor and the provenances 9, 19 (Washington 204-09), 24 and 29 (Oregon 204-18) in Tanda. Based on the above ranking, it can be concluded that the provenances 3 and 18 showed good adaptation to site conditions, both at beech site, and at oak site; provenances 9 and 24 were poor and at both localities.

The results of multiannual researches of the interaction of a complex of factors affecting the adaptation of Douglas-fir provenances contribute to: identification of ecological parameters essential for the selection of Douglas-fir provenances for the transfer from North America to the sites in Serbia; study of the scope of variation of economically significant quantitative properties, and as a selection criterion, for the ranking of provenances significant for wider cultivation in Serbia.

The fact that the provenance origin is known and that the ecological parameters of the provenance test sites are researched makes the study results applicable in future establishment of special-purpose Douglas-fir plantations for the production of good-quality wood. By different silvicultural measures, it is possible to control and direct the dynamics of tree increment in artificially established populations, which is the base for the production of raw materials suitable for both wood processing industry and end users of wood products. The gene-ecological variations manifested in the introduced material, most often as modification variability of quantitative and qualitative characters, are the consequence of the interaction of the introduced material and the environmental conditions at the places of transfer. The scope of variations depends directly on climate, edaphic and coenological characteristics of the site where the experiments are established, as well as on the effect of the altitude and geographical coordinates of the original populations from which the introduced material originates.

SPATIAL PETERN OF EUROPEAN BEECH (*Fagus sylvatica L.*) GENETIC VARIATION IN SERBIA

The research until the end of the fifties of the last century in Serbia did not elucidate sufficiently the variability of beech morphometric properties and the degree of their genetic condition. The activities of beech breeding in scientific research and professional work were mostly directed to the conservation of genetic resources, the selection of the corresponding provenances for different sites, enhanced production and trade of planting stock, study of the species evolution development, and the establishment of live archives and seed orchards.

Based on the results of the biochemical and molecular analyses at the level of the selected population and individuals of different beech provenances in Europe, it can be concluded that the adaptation and survival capacities at the level of population are favoured by a higher genetic diversity, and at the individual level - by a higher degree of heterozygosis.

In Serbia, 19 seed stands of beech, total area 137.57 *ha*, were designated for the beech gene pool conservation in situ and for the enhancement of nursery production, i.e. sufficient quantities of healthy and selected seed and nursery material.

Delineation of beech provenance regions in Serbia by spatial analysis of genetic diversity has be done in the last decade, Ivetić 2009., Ivetić et al. 2012. The results of spatial analysis of genetic diversity have practical application in the definition and delineation of regional provenances of forest trees. Research, was based on the material from 27 natural populations of beech in Serbia. The genetic component of the research is based on the analysis of RAPD markers from bulk samples, using 28 primers. The spatial component of the research is based on the geographical position of the studied populations. Grouping of the studied populations in the regions, as well as their separation, was performed using the Monmonier's algorithm of maximum differences. To visualize the results and mapping the regions of beech provenances in Serbia, GIS was used, with database included the results of this study.

Further breeding of beech in Serbia, depending on the current requirements of forestry and on the state of forests, should be performed in two directions: in the direction of improving the natural populations and in the direction of obtaining the new selected beech genotypes and hybrids, which will have superior target characteristics than the existing types. The selection of parent individuals, i.e. their combination, with good general and special combining capacity and heritability, is the initial point for the establishment of clonal seed orchards for the production of beech intraspecific hybrids. Which of the genetic compositions of the obtained hybrids will be interesting, depends primarily on the bioengineering demands for planting stock, as well as on market demands? The above factors must be taken into account in the future mass production of seed, so that the genotype of the desired variety is clearly planned already in the initial phases. In general, the multi-line varieties of beech, which will be the results of controlled hybridization and the seed orchard composition, should provide a greater stability of yield and adaptation.

The previous research shows that there are genetic differences between beech populations in Europe and Serbia. This requires the programs of closer research and of directed application of beech genetic variability, Isajev 2005.

CONCLUSIONS

For widely dispersed trees, such as are Austrian pine, Scots pine, Norway spruce, Beach and Douglas fir, or reduced populations it might be difficult to define the provenance in the biological sense, especially when the remnant trees do not constitute an interbreeding community. The results of provenance tests, using samples of dispersed trees, then show probably just the performance of a few progenies whereby mating effects (e.g., self-pollination) may confound the true provenance value. However, a provenance may be reconstituted, it the dispersed individuals are brought together in a seed orchard, thus enabling cross-pollination.

The main objectives of provenance research have been stated as the most appropriate seed sources for silvicultural purposes and match provenances to sites. However, the detection of some productive provenances cannot be considered as the ultimate result. In older experiments, with few samples, sometimes single outstanding provenances have been identified, but the question must be raised whether they are representative for the particular region from which they are coming. Furthermore, single stands may have been felled before results have become available and therefore cannon be used as a seed source in the future. Provenance experiments should at least reveal some kind of a geographic variation pattern and this pattern can then be used to group provenances of similar performance and to delineate regions of provenance in the case where neighboring provenances are similar. However, in most cases the ecological conditions have been the basis for the delineation of provenance regions. This might be due to the lack of adequate provenance experiments, or that environmental factors have been considered as the main factors in shaping genetic variation, as is frequently the case.

The aspects discussed in the present review are intended to assist in assessing the importance and potential of provenance research. They highlight the particular features of older experiments and indicate new uses which could be made of them which extend beyond the objectives for which they originally established. Therefore, existing field experiments should not be abandoned but thorough consideration should be given to their potential use in future research. They are often increasing in value because the genotypic responses to varying environmental influences are accumulating over time. With regard to the establishment of new field experiments the present review provides some guidelines and aims to stimulate the motivation to continue with this research.

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POTENTIAL VEGETATION AND SELECTION OF SPECIES FOR REFORESTATION OF CENTRAL SERBIA

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Abstract: *Amelioration of forest sites, reforestation of barren land and reconstruction of degraded coppice forests have always been just a routine job carried out in a non-systematic manner and with more or less favourable outcomes of the implemented operations.*

Since there is a need for a viable strategy of reforestation that can be successfully put into practice, the authors of this paper, together with their associates, have set themselves a goal of compiling all prior investigations of site factors, forest ecosystems, state of forests and deforested areas and the selection of appropriate species and lower taxa for reforestation and amelioration.

It is necessary to draw up a new strategy of reforestation based on modern scientific discoveries that are already in practice in Central Europe. This goal calls for drastic changes in all segments of reforestation practice – from gene pool conservation, seed stand establishment and broadleaved-oriented nursery production to adjusting bio-ecological characteristics of different species to the site condions of the terrains that are to be reforested.

We hope that our efforts will make a substantial contribution to developing and adapting a new, modern strategy of reforestation in Central Serbia.

Key words: reforestation, amelioration, strategy, potential vegetation

INTRODUCTION

Reforestation of barren land, amelioration of forest sites and reconstruction of degraded coppice forests have always been just a routine job carried out in a non-systematic manner and with more or less favourable outcomes of the implemented operations. The main criteria have been the size of the reforestation programme and the greatest possible quantity of wood mass attained in a short period of time. The selection has been limited to a small number of native and introduced species: Austrian pine on southern aspects, sometimes but not so frequently Scots pine at higher elevations, spruce on northern aspects, Douglas-fir and Weymouth pine on beech forest sites, locust at lower elevations and Euramerican poplars in alluvial plains.

In recent times, scientists have proposed several scientifically proven theories that develop systems of reforestation and amelioration in compliance with site conditions. Unfortunately, none of them have been put into practice which is still aimed primarily at increasing the volume of work and improving the technology. Moreover, most of these theories are based on the selection of species or even taxa and proveniences with

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respect to individual site factors such as elevation, aspect, parent rock, heat factor, etc. None of them study whole complexes or ecosystems, i.e. ecological units that are determined not only by edificatory species, but also by natural vegetation and soil. The first attempt in that direction was done at the end of the last century by Jovic N, *et al* (1998) in the monograph on the selection of species. This is somehow understandable since in the previus period the classification of forest ecosystems had rarely been a subject of scientific research.

Since there is a need for a viable strategy of reforestation that can be successfully put into practice, the authors of this paper, together with their associates, have set themselves a goal of compiling all prior investigations of site factors, forest ecosystems, state of forests and deforested areas and the selection of appropriate species and lower taxa for reforestation and amelioration. We hope that our efforts will make a substantial contribution to developing and adapting a new, modern strategy of reforestation in Central Serbia.

SITE CHARACTERISTICS

Central Serbia has a remarkably diverse natural environment suitable for the development of forest vegetation. It can be clearly seen from the following description of the ecological conditions.

There are two distinctive climate regions *a.)* continental region which can be divided into five subregions, from the most extreme Timocka krajina (Timok frontier), Subpannonian edge and Leskovacka kotlina (Leskovacka depression) to the most mesophilous mountains south of Valjevo; *b.)* temperate-continental (mountain) climate region in the southern part of Central Serbia, where the weather conditions are somewhat steadier and less contrasting, with lower monthly mean temperatures and higher precipitation. It includes Pester and Kosovo plateau.

Parent rock is also diverse and in its interaction with petrographic composition and vegetation, a number of different soil types have been formed. They are mostly automorphic:

In class (A)-C lithosols (skeletal soils), regosols, arenosols, and colluvium;

In class A-C calcomelanosols, rankers, chernozem, and smonitza;

In class A-(B)-C cambic soil types: eutric cambisol (eutric brown) and dystric cambisol (acid brown);

In class A-E-B-C eluvial-illuvial soil types: podzol, loessivized brown and brown podzolic soils.

Hydromorphic soils are less frequent. They occur only in river valleys:

Fluvisol is a genetically young soil in alluvial deposits and it covers only 5.6% of the territory.

Humofluvisol, humoglay and euglay are formed only in the valleys of major rivers (the rivers Sava, Danube and Great Morava).

Peat soils with a TG profile – histosols – are very rare and they can be found only in Vlasinska and Pesterska plateau.

Due to intense erosion processes and frequent degradation, especially in barren mountainous terrains, the soils are classified according to their productivity and usability into the categories ranging from `suitable ` to `permanently unsuitable`.

On the basis of the above presented facts we can conclude that the natural resources of Central Serbia are suitable for the establishment of various forest plantations. This diversity is decreased by the processes of degradation of the existing forest ecosystems and by the processes of irreversible degradation and erosion.

The relative area under forests in Central Serbia is mostly satisfactory – forests cover 2 098 400 ha. A part of this area belongs to national parks, protection and amenity forests. A significant part is in private ownership (Nevenic, R. 2006), while PE `Serbiaforest` manages 766 531.84 ha, which make 41.1% of our forest reserves. Natural high forests make 41% of this growing stock, 15% are artificially-established high stands and 30% coppice forests. Brushland and scrub forests make 14%.

In terms of species, broadleaves make up 86.9% (beech trees - 43.9%) of the total growing stock. Conifers are less frequent – only 13.1% (spruce makes 5.6%, Austrian pine 3.6%, fir 2.5% and Scots pine1.1% of the total volume). The percentage of endemic, endangered and pioneer broadleaved species is insignificant, with the exception of white ash and birch.

The average values of volume (157 m^3/ha) and volume increment (4.1 m^3/ha) in 2009 were higher in comparison to the same values in 2006 by 5.4% and 7.9% respectively, as a result of improving the quality structure.

The success of reforestation depends on a number of equally important factors. The main ones are: site, bio- ecological characteristics of species (varieties, provenances...), type of planting material, genetic, physiological, and morphological characteristics of seedlings, seedling production technology, handling seedling before planting, soil preparation, planting techniques, planting time and density, control measures, etc.

With 2 252 400 ha of forest land, Serbia belongs to the group of countries rich in this economically and ecologically important resource. However, the current state of Serbian forests and the field data reveal a sad fact that Serbia has a large area of poor forests. They have been long exploited, with little or no investments. A high level of degradation by erosion, water shortage, an increasing demand for timber and recreational areas, together with the fact that the relative area under forest in Serbia used to be even 80%, and now it is hardly 30.6% (29.1% in Central Serbia and 7.1% in Vojvodina) make reforestation a pressing need.

Taking into account the existing site conditions and the actual need for rational land use, the optimal area under forest in Serbia is estimated at 41.4% (49.8% in Central

Serbia and 14.3% in Vojvodina). The aim is to achieve this optimal state by 2050, both by reforestation and by natural regeneration.

According to the Spatial Plan of The Republic of Serbia (1996), the expansion of the growing stock primarily related to reforestation of the areas of lower site classes (site classes 6 and 7) and the areas subjected to erosion processes as well as to establishment of protective forests (shelterbelts, forests around roads, water sources and reservoirs, industrial facilities and city centers). The planned reduction of the total agricultural land would be achieved by turning the agricultural land of the lowest quality into forests. However this projection failed to be achieved on 61 900 ha.

By setting the goal of increasing the forest cover by 41.4% by the year 2050, forestry got a number of different tasks, the most important of which were to reforest, restore and improve the quality of existing forests. By establishing new forests, forest plantations, shelterbelts and by increasing the area covered by forests, not only would we improve the current state of Serbian forests, but also improve the quality of general living conditions and ensure faster sustainable development of Serbia.

Forest resources are considered to be the resources for the future because they are renewable. With the help of science and technology, they can replace numerous natural resources that have been greatly exploited and whose complete depletion is just a matter of time. By establishing new and improving the quality of existing forests, their climatic, protective, antierosive, esthetical, touristic-recreational and other similar functions would come to the fore. It would further increase the yield of other forest resources, such as forest fruits, mushrooms, medicinal and aromatic plants. Hunting conditions would also improve and the whole society would feel the beneficial effects of these actions (Brašanac, Lj, 2003).

Reforestation in Serbia started as early as the 19th century. The largest areas were reforested after the Second World War. The most frequent species used for reforestation up to 1955 was locust, then poplar until 1965 and since then the most frequently planted species have belonged to the class of conifers. Coniferization of broadleaved forests was a common practice and the most commonly used species were spruce and pine. The submontane and montane beech sites in beech coppice forests were reforested with Austrian pine trees. On the other hand, spruce was most frequently introduced into degraded stands on beech-fir and beech-fir-spruce sites. The unforested areas characterized by xerothermic conditions (dry and hot climate) and degraded soil were reforested with Austrian pine, while the barren land belonging to the belt of montane beech and mixed forests of beech and conifers was reforested with spruce (Isajev, V. et al., 2006).

Reforestation was carried out on the sites of different production characteristics, mostly without applying necessary measures of soil preparation or proper planting techniques, which often led to the wrong selection of species. Plantations were often established on the sites whose production capacities could not be completely utilized by coniferous tree species. Due to these and many other failures in the establishment of artificial stands of coniferous tree species, these stands are today characterized by poor silviculture, as well as poor quality and health. They are untended, with reduced crowns, prone to snowbreaks and windthrows, susceptible to entomological and phytopathological injuries and threatened by forest fires.

By harmonizing the plans, policies and activities with previously determined needs, it can be concluded that approximately 1, 000, 000 ha of new forests have to be established in Serbia in order to achieve the optimal forest cover of 49.8%. The scope of previous reforestation activities has changed in accordance with the socio-political and economic situation in Serbia and according to the projected dynamics of reforestation, given in the Spatial Plan of Serbia, it is insufficient if the goal is to achieve optimal forest cover by 2050. Therefore, the establishment of new forests should be intensified.

The selection of species for reforestation was the weakest point in the previous strategy of reforestation. There was a striking contrast between the rich biodiversity of species and phytocoenoses and the small number of taxa of both native and introduced tree species that were used in the reforestation practice. These were mostly conifers: *Pinus nigra* (rarely *Pinus sylvestris*), *Picea abies, Pseudotsuga mensiesii, Larix europaea, Pinus strobus,* sometimes *Abies alba, Abies nordmanniana, Abies grandis* and others. The choice of broadleaves was even more limited and it was mostly reduced to *Populus euramericana* in alluviums and *Robinia pseudoacacia* on all other terrains. The attempts to introduce Green ash (*Fraxinus lanceolata* and *Fraxinus pensylvanica*), Eastern black walnut (*Juglans nigra*) or some other non-native species were scarce and mostly unsuccessful. Consequently, the established plantations were not equally successful and there was a high percentage of those in which the selection of species was not done with regard to their site conditions. Furthermore, a great number of successful plantations do not exploit the full potential of the sites or they do but only for a short period of time.

POTENTIAL VEGETATION

Potential forest vegetation can be defined on the basis of general principles of vegetation zoning in different plant-geographic regions of Serbia (Tomic, Z., 2004). According to modern scientific views, vegetation can be classified into the following types: zonal vegetation (climazonal – climatogenic and climaregional), which is defined by the regional macroclimate on the placoric sites at lower elevations or in climaregional belts at higher elevations; extrazonal vegetation, which is a modified type of a zonal forest from a neighbouring plant-geographic region; azonal vegetation, which is determined by some other (usually extreme) site factors, not by the regional climate and it can be found in several different zones; intrazonal vegetation, which is also affected by some extreme site factors, but its distribution is limited to one zone only.

Climazonal – climatogenic forests are at first sight uniform in the whole country and they are represented by the community of Hungarian oak and Turkey oak - *Quercetum* *frainetto-cerridis* Rudski 1949 (alliance *Quercion frairnetto* Ht 1954). However, the community of Hungarian oak and Turkey oak in its extensive area of distribution, occurs in several geographic variants, two of which are limited to Central Serbia and they are considered to be a unique regional zonal vegetation:

- In Sumadija, in a part of eastern Serbia, and in Central Serbia, the climatogenic forests are represented by the typical community of Hungarian oak and Turkey oak - *Quercetum frainetto-cerridis* Rudski 1949.
- In Timocka krajina, and in a part of eastern and southeastern Serbia climazonal forests are represented by more thermophilic forests of Hungarian oak and Turkey oak with Oriental hornbeam – *Quercetum frainetto-cerridis* Rudski 1949 var. geograph. *Carpinus orientalis* (Knapp 1944) B. Jovanovic 1956.
- The monodominant forest of Hungarian oak - *Quercetum frainetto* B. Jovanović 1982, which is found in Negotinska krajina, is considered to be the zonal forest of the extreme northeastern Serbia.
- The mesophilous community of sessile oak and hornbeam, very similar to the Illyric zonal forest *Querco-Carpinetum illyricum* Ht et al.1974 occurs on placoric positions at lower elevations in the northwest (in the region of Macva and Pocerina, which is a transitional Illyric - Illyric-Moesian province) and in the heart of Fruska Gora.
- There are no large climatogenic forests in the Pannonian forest-steppe zone. There are `groves` - smaller stands of xerothermic communities of different oak tree species from the alliances *Quercion pubescentis-petraeae* Br.-Bl.1931 and *Aceri tatarici-Quercion* Zol. et Jak.1956.

<u>The climaregional belt of beech and beech-fir forests</u> – alliance *Fagion moesiacae* Blecic et Lakusic 1976. Being characteristic for mountainous regions, this belt is well defined and fairly homogeneous throughout the whole Serbia. It is divided into four subbelts (suballiances) with regard to different elevations: *Helleboro odori-Fagenion moesiacae* Soó et Borhidi 1960 (syn: *Fagenion moesiacae submontanum* Jov.1976); *Asperulo-Fagenion moesiacae* Knapp 1942 (syn: *Fagenion moesiacae montanum* Jov.1976); *Abieti-Fagenion moesiacae* B. Jovanovic 1976 and *Aceri heldreichii-Fagenion moesiacae* B. Jovanovic 1957. (syn: *Fagenion moesiacae subalpinum* Jov.1976).

<u>Subalpine belt of coniferous forests</u> is developed in the conditions of cold and humid boreal climate, at the altitudes between 1 300 - 1 400 and

1 800 - 1 900 m. It is dominated by spruce forests – alliance *Vaccinio-Piceion* Br.-Bl. 1939. This belt is divided into two suballiances - subbelts – a lower and a higher one: *Abieti-Piceenion* Br.-Bl. 1939 and *Vaccinio-Piceenion* Oberdorfer 1957.

In Metohija, which has an authentic floristic-geographical composition (Skadar – Pindus province), whitebark pine forests – alliance *Pinion heldreichii* Ht 1946 – occur in the Subalpine region, on limestone and serpentinite, at 1 400 to 1 800 m above sea level. Outside Metohija, whitebark pine forests are only found in Negbina and on the mountain Ozren near Sjenica.

Another endemorelict – highmountainous pine - Macedonian pine - alliance *Pinion peuces* Ht 1950, also occurs only in Metohija on the silicate rocks of the mountains Prokletija, Sar-planina and Mokra gora, and perhaps only locally in southeastern Serbia.

High mountain shrub vegetation is found at tree line, above 1800 m.a.s.l. It is represented by shrub communities of coniferous and some broadleaved species. There are two alliances and two orders: *Pinion mugo* Pawlowski 1928; *Juniperion sibiricae* Br.-Bl-1939; *Vaccinietalia* Lakusic 1979 and *Adenostiletalia* G. Br.-Bl. et J. Br.-Bl. 1931.

Extrazonal xerothermic deciduous forests of Submediterranean type occur on warm aspects and steeper slopes in the hilly-mountainous region. In most parts of Serbia, from Central Serbia (with the river Ibar as the boundary) to eastern and southeastern Serbia, extrazonal xerothermic forests of Oriental hornbeam belong to the alliance *Syringo-Carpinion orientalis* Jakuch 1959 and they are most commonly represented by various Oriental Hornbeam (*Carpinus orientalis*) communities.

Extrazonal mesophilous forests of Central-European type, which belong to *Carpinion betuli* Ht (1950) 1963 alliance, differ from the zonal sessile oak-hornbeam forests of the Illyric province in the higher percentage of steppe and moesian xerothermic elements. They occur as mesophilous communities of sessile oak and hornbeam – *Querco petraeae-Carpinetum betuli* Rudski 1949 (syn: *Querco-Carpinetum moesiacum* Rudski 1945) in shaded cool valleys and cold aspects in lowlands, or on broad flattened ridges on the border between the submontane and the montane zone.

Hygrophilic – alluvial forests, which as azonal vegetation need additional moisture, are found mostly in lower water courses. They occupy larger areas in the northern (lower) parts of Serbia.

The forests of willow and poplar (alliance *Salicion albae* Soó 1940), as well as the pioneer communities of shrubby willow (alliance *Salicion triandrae* Müller- Görs 1958) are more or less the same in the riparian areas of all rivers. However, the pioneer shrubby communities of hoary willow (alliance *Salicion elaeagni* Aichinger 1933) are restricted to the southern highland region, from the serpentinites of Central Serbia to the mountains of Metohija.

Within the marshy, hygrophilic forests of sallow willow and black alder (*Salicion cinereae* Müller-Görs 1958 and *Alnion glutinosae* Malcuit 1929), certain regional differentiations can be observed: in most parts of Serbia black alder grows in lines along river banks, while in Posavina it occupies smaller areas and forms groves on marshy-gleyic soils. Small mosaic stands of gray alder (alliance *Alnion incanae* Pawlowski 1978) and some submontane types of black alder forests are found at higher altitudes, along upper water courses.

The central part of the alluvial plain, which is less exposed to flooding waters, is dominated by pedunculate oak `floodplain forests` (alliance *Alno-Quercion roboris* Ht 1938). They also express some regional differences: Syrmia (Srem), the region of Macva and Pocerina as well as the region of Posavina and Tamnava have broad zones of pedunculate oak and narrow-leaved ash forests, monodominant forests of pedunculate oak and forests of pedunculate oak, narrow-leaved ash and hornbeam. On the other hand, the floodplains of the rivers Great Morava, South Morava, West Morava, Jasenica, Mlava and other rivers in Central Serbia are characterized by mixed forests of pedunculate oak and ash, neighbouring the forests of pedunculate oak and hornbeam, which are beyond the influence of flooding waters. In Negotinska Krajina, which has the most contrasting climate in Serbia, specific communities of pedunculate oak and Balkan-ash (*Fraxinus pallisae)* and steppe common oak (*Quercus pedunculiflora*) are found.

Azonal forest vegetation of the (sub)montane region, influenced by orographic, edaphic and oro-edaphic elements, is represented by numerous `permanent stages` and it is highly diverse:

Xeromesophilous sessile oak and Turkey oak forests – alliance *Quercion petraeae-cerridis* Lakusic et B. Jovanovic 1980 occur on the warmer aspects of the submontane regions throughout the whole Serbia. These forests usually alternate with beech submontane forests and occupy southern aspects at 400 to 800 m above sea level. Monodominant Turkey oak forests, mixed forests of sessile oak and Turkey oak and monodominant sessile oak forests have been formed within the alliance. However, these forests reach an altitude of 1 400 m in the southern (especially in the southeastern and southwestern) Serbia. Therefore an increasing number of authors believe that the monodominant sessile oak forests form a climaregional belt in these parts of Serbia.

- In the transitional Illyric-Moesian province (with the boundaries on Rudnik and Kopaonik) and in Skadar-Pindus province (Metohija), basophilic hop-hornbeam forests – alliance *Fraxino orni-Ostryon carpinifoliae* Tomazic 1940. – occur on limestone of the (sub)motane region, at 600 to 1 000 m above sea level. They are sporadically relict (in refuges).
- Basophilic pine forests on limestone, dolomites and serpentinites of the mountain region – from (400) 600 to 1 450 m above sea level- are also azonal communities. If they are primary forests, they are also relict (in refuges). There are two alliances in Serbia: *Orno-Ericion* Ht 1958 (the forests of Goc Austrian pine and Scots pine on serpentinite) and *Pinion nigrae* R. Lakusic 1976 (the forests of Austrian pine on limestone).
- Acidophilic forests of sessile oak and sweet chestnut – alliance *Quercion roboris-petraeae* Br.-Bl. 1932 – belong to the azonal type of vegetation. Since they thrive under highly acidic conditions, they can be found on a small area of Metohija and southern Serbia, and rarely in western Serbia.

- The presence of shrub communities should be mentioned as well. They occur as border vegetation in the forests of both lowland and highland regions.

Azonal vegetation in the belt of beech forests is represented by several alliances and suballiances:

- Great maple and common ash forests – alliance *Fraxino excelsioris-Acerion* Fukarek 1968 are sporadiacally scattered in the beech and beech-fir belts, at an altitude of about 1 000 m.
- Beech and hop-hornbeam forests – alliance *Ostryo-Fagenion moesiacae* B. Jovanovic 1976 are xeromesophilous (mesothermal) communities that are found almost exclusively on limestone of western and southwestern Serbia and Metohija.
- Beech and Turkish hazel forests – suballiance *Fago-Corylenion colurnae* Borhidi 1963 are also xeromesophilous communities on limestone, but in eastern and southeastern Serbia.
- Acidophilic beech forests – suballiance *Luzulo-Fagenion moesiacae* B. Jovanovic 1976 are determined by edaphic conditions. They occur in a very wide range of altitudes – from the submontane, over the montane to the subalpine belt – on highly acid, extremely acid or on podzolized acid brown soils.

Intrazonal vegetation of Serbia occurs in two groups of communities, both of which are comprised of herbaceous plants characteristic for Pannonian Plain and its rim: sandstone vegetation and slatina (salty spring) vegetation.

`Relict` communities present a particular rarity of the rich forest vegetation of Serbia. They are distributed in numerous refuges – mainly gorges and canyons on limestone. Their sites are not affected by contemporary conditions. They are determined by the historical development of vegetation from the Tertiary, over the glacial period up to the present time. The meaning of the term `relict` community should not be taken literally because none of these communities have remained virtually unchanged since the Tertiary - with unchanged floristic composition, physiognomy and structure. The best known relict communities in the refuges of Serbia are the forests of: Serbian spruce (on the mountain Tara and in the canyon of the rivers Drina and Milesevka); Austrian pine (canyon Jerme, Polom near Zlot, Goles on Suva Planina, Kozje stene on Tara); walnut and hackberry (Djerdap); polydominant communities with Turkish hazel in eastern Serbia; hop-hornbeam communities on limestone cliffs in the canyons of western Serbia and many others.

Using the zonation of the forest vegetation of Serbia as a framework, an elaborate study of the potential vegetation of the Pester plateau was done and a map at 1:300 000 was created (Rakonjac, Lj.2002).

If we observe the Pester plateau as a whole, we can notice certain rules in zoning potential vegetation into altitudinal belts. At the same time, we can notice different directions and intensities of degradation within different complexes.

Hygrophilic vegetation (*Salicetum purpureae*, *Salicetum incanae, Alnetum glutinosae, Alnetum incanae and Alnetum glutinosae-incanae*) occur on alluvial sediments, gley and pseudogley soils, covering larger areas in valleys and smaller along the water courses. This is an azonal type of vegetation that is subject to degradation and even conversion into wetland meadows. On the other hand, it can be restored by progradation when the human impact ceases to exist.

The next belt is composed of potential zonal forests *Querco-Carpinetum*, up to 1 100 m above sea level, on brown soil and pseudogleys. They have been irreversibly destroyed and converted into agricultural land. The remnants of sesile oak and hornbeam forests have endured in the form of Oriental hornbeam scrub forests on a small limestone area, unsuitable for agriculture. This belt includes the azonal vegetation of limestone cliffs *Ostryo-Pinetum illyricae.*

Slightly higher elevations of about 1 000 to 1 200 m are alternatively covered by oak and beech forests.

All aspects within the ultramafic complex belong to the zonal forest of Balkan sessile oak (*Asplenio cuneifoliae-Quercetum dalechampii*) and the azonal forest of Goc Austrian pine (*Potentillo heptaphyllae-Pinetum gocensis*). The latter is a primary forest in the Dubocica canyon, while in the zone of sessile oak and some parts of beech-fir forests it occurs as a second-growth forest (as one of transitional degradation stages). The last stage of degradation in both communities are the pastures of the *Poetum molinieri* and *Danhonietum calycinae* types.

Within the complexes of acid silicate rocks, this belt is occupied by the alternation of sessile oak and Turkey oak forests (*Quercetum petraeae-cerridis*) on southern aspects and montane beech forests (*Asperulo odoratae-Fagetum moesiacae silicicolum*) on northern aspects. Sessile oak and Turkey oak forests are degraded first into hazel scrubs and then into pastures of *Nardetum strictae* and *Festuco-Chrysopogonetum grylli*. In the beech forests, the process of degradation goes over pioneer communities of aspen-birch and aspen-birch-hazel to hazel scrubs and pastures of *Nardetum strictae* and *Festuco-Chrysopogonetum grylli*.

Since the limestone complex has been irreversibly degraded, the possible presence of oak forests in the past couldn`t be determined. Therefore the whole belt is considered to be a potential montane beech forest on limestone (*Cephalanthero-Fagetum moesiacae calcicolum*). This potential community undergoes degrading transformations over hazel scrubs and juniper stages to the pastures of *Festucetum, Danthonietum calycinae, Cariceto-Brometum erecti* and eventually almost entirely bare rocks.

Beech-fir forests (*Abieti-Fagetum moesiacae*) have a mosaic structure. They occur at 1 100 to 1 300 m above sea level. We cannot say for sure that they make an oroclimatogenic belt.

Within the ultramafic complex, these forests are degraded into pioneer communities of Austrian and Scots pine, which are then transformed into hawthorn and similar shrubs and then into *Agrostidetum (vulgaris) capilaris* pastures.

On acid silicate bedrocks, degradation of beech-fir forests goes over aspen-birch or pure birch forests into hazel forests, yielding eventually into *Festucetum fallacis* and *Festuco-Chrysopogonetum grylli* pastures.

There are no traces of beech-fir forests on the bare limestone massifs. Only the remnants of beech coppice forests can be found at higher altitudes. They only imply the presence of this belt. These forests would undergo the same degradation stages as the montane beech forests.

At an altitude of 1 200 – 1 500 m, the largest areas of oroclimatogenic belt are on the Pester plateau and in some parts of western Serbia. This belt is composed of potential beech-fir-spruce forests (*Piceo-Fago-Abietetum*). Degradation of this community occurs in the form of secondary forests of Scots pine, which have been studied in a great number of localities.

The beech-fir-spruce forest within the ultramaphitic complex follows the degradation pattern from Goc Austrian pine on warm aspects and Scots pine and whitebark pine on cold aspects to the pastures of *Poeto molinieri-Plantaginetum carinatae, Halacsia sendtneri-Potentilletum mollis etc.*

Within the acid silicate complexes, regressive succession begins with Scots pine and birch, somewhere with Scots pine and aspen and it ends with the bluebery community and the pastures of *Nardetum strictae, Festucetum falacis etc.*

On the limestone massifs at 1 200 to 1 500 m above sea level, except for some solitary specimens of spruce and stunted coppice beech, there are no other tracks that could indicate the regression succession of potential beech-fir-spruce forests. Individual tracks indicate that it follows the pattern from Scots pine and aspen, over juniper to the pastures of *Festucetum, Danthonietum calycinae, Cynosuretum cristati etc.*

The potential vegetation of the areas above 1 500 m, which are rare on the studied area, is comprised of the oroclimatogenic belt of whitebark pine (*Pinetum heldreichi* and s.l.). The remnants of whitebark pine are found within the ultramaphic complex, while we can only assume its former existence on limestone.

The ecological-degradation sequences were used together with the eco-vegetational zoning of natural vegetation to create the Map of potential vegetation, which is a necessary precondition for the successful selection of species for reforestation and amelioration.

SELECTION OF SPECIES FOR REFORESTATION

In this procedure, the chosen locality should be small in size and with uniform site conditions. The first task is to define the natural vegetation of its immediate environment and to reconstruct its potential natural vegetation. For a successful selection of species, it is also necessary to determine the degree of degradation of individual phytocoenoses, which can be achieved by studying degradation stages in the field. The main drawback of this procedure is that it can be applied only to a smaller locality with similar environmental conditions.

Selection of species on the basis of potential vegetation

A map f potential vegetation and the field investigations of the degradation stages have been used to analyze the process of previous reforestation of the Pester plateau and to develop guidelines for further actions (Rakonjac, Lj. 2002).

By analyzing the reforestation actions that have been carried out on Pester and the regions of similar environmental conditions, we can conclude that the selection of autochthonous pioneer species (Scots pine, Austrian pine and spruce) for reforestation of significantly degraded sites has proved to be successful. Apart from poor technology and inappropriate time of planting, the most common reasons of poor success of some plantations are a.) introduction of Austrian pine at the altitudes above 1200 m, since low temperatures are unsuitable for this submediterannean species; b.) establishment of spruce plantations on the sites with insufficient amount of moisture in the soil; c.) the risk of introducing planting material of unknown intraspecific taxa and provenance into unsuitable sites.

Summarizing the prior researches, we can propose the following taxa for reforestation:

- Scots pine (*Pinus sylvestris*) should be used on strongly degraded sites of potential beeh-fir and beech-fir-spruce forests, i.e. at the altitudes above 1 200 m. When purchasing planting material, relevant ecotypes defined by Stefanovic, V. and Milanovic, S. should be taken into consideration. For instance, ecotype C (medium deep to shallow soils) should be primarily used within the ultramafite complex, ecotype B (deep and fresh soils) in the complex of acid silicate rocks and ecotype D (shallow and dry soils) in the limestone complex.

Introduction of broadleaved species - *Acer pseudoplatanus,Acer platanoides, Acer heldreichii, Populus tremula, Corylus colurna* (the last one only on limestone) is recommended on better preserved and deeper soils with moderate degradation.

- Austrian pine (*Pinus nigra*) should be used on strongly degraded sites below 1 200 m.a.s.l. on alkaline parent rocks (Scots pine should not be used for reforestation of areas in the complex of acid silicate rocks). These are potential sites of Balkan sessile oak, sessile oak-hornbeam, montane beech and partially of beech-fir forests. When using Austrian pine, extra attention should be paid to its subspecies: *Pinus nigra ssp. Gocensis* should be used in the ultramafite complex and *Pinus nigra* ssp. *Illyrica* on limestone. Apart from Austrian pine, these strongly degraded sites can be reforested with pioneer broadleaved species: flowering ash (*Fraxinus ornus*) in all areas, Mahaleb cherry (*Prunus mahaleb)* on serpentinite and hop-hornbeam (*Ostrya carpinifolia*) on limestone.

In the complex of acid silicate rocks, instead of basophilic Austrian pine, Scots pine - ecotype C - (on medium deep to shallow soils) should be used on degraded sites of sessile oak-Turkey oak and montane beech, while aspen and birch - ecotype B - should be used on less degraded (on deep and fresh soils) sites.

On better preserved sites, with deep and well-developed soils, there is a much wider choice of broadleaved species for reforestation. Sessile oak should be the first choice: *Quercus petraea* on acid silicate rocks and *Quercus dalechampii* on ultramafites. The next best choice would be one of the folowing species: *Acer pseudoplatanus*, *Populus tremula*, *Tilia parvifolia*, *Acer platanoides*, *Prunus avium*, *Pyrus pyraster*, *Betula verrucosa* (of different provenances on ultramafites and acid silicate rocks), *Corylus colurna*, *Ostrya carpinifolia* (the last two species should be used only on limestone) etc.

- Whitebark pine (*Pinus heldreichii*) has not been used in reforestation so far. Nevertheless, it should be used as a pioneer high mountain species at elevations above 1400 m. The provenance from the serpentinite and peridotite should be used for reforestation of ultramafic terrains, while the provenance from the limestone should be used only on limestone.
- Spruce (*Picea abies*) has been the least frequently used conifer in the reforestation so far. It has the lowest survival rate, although it can be one of the edificators of potential vegetation on larger areas. Due to the lack of edaphic moisture, particularly on limestone, it is recommended to introduce the appropriate ecotype of spruce only into depressions with pseudogleys and luvisols (in the silicate complex) and into the bottom of corries with well-developed soils (over limestone). Reforestation with spruce should also be undertaken on larger areas of hygrophilic forests on pseudogleys and gleys because the temperatures are low and there is a sufficient amount of moisture.

The sites of hygrophilic forests can be reforested with a great number of broadleaved species: (sub)montane type of pedunculate oak (*Quercus pendunculata* Ehrh. ssp. *montane* M. Jov.), birch (*Betula verucosa*), and hairy birch (*Betula pubescens*), edificators of the autochthonous vegetation *Alnus glutinosa* and *Alnus incana* and other species.

Aspen (*Populus tremula*) is a broadleved species with the greatest chances of establishing highly productive plantations on larger areas and at higher elevations, particularly if we use an improved sort suitable for higher elevations and colder climates.

Selection of species on the basis of ecological differentiation

The most elaborated multidisciplinary scientific method for the selection of species for reforestation and amelioration uses the ecological differentiation of forest ecosystems, i.e. previously established ecological units (main forest types) as its basis. These ecological units are defined by the combination of the following three parameters: edificatory species, vegetation, and soil, which means that they include the greatest number of site and vegetation factors of forest ecosystems.

The most comprehensive source of information about the selection of suitable taxa for reforestation in Central Serbia, based on this principle, was provided by Jovic, N. *et al* 1998. Their study is based on data collected in 14 forest estates in Central Serbia. The obtained results do not refer to all areas that should be reforested. They refer only to the areas that are, according to the criteria of certain forest estates, considered to be suitable for reforestation. W e can only assume what percentage of these areas is covered by forest gaps within more or less preserved forests or by severely degraded scrub forests, completely barren land and degraded soil. Therefore, there are three categories of species recommended for reforestation: a.) main species – edificators of autochthonous phytocoenoses of potential vegetation which can be used in the early stages of degradation, while the processes are still reversible; b.) accompanying species – mostly pioneer species suitable for specific sites where the processes of degradation are stronger: c.) shrubs occurring in the natural degradation stages as ameliorators, i.e. primary vegetation on the barrens with irreversible processes of degradation. Because of the need to operate with verifiable data, only autochthonous species of natural potential vegetation have been taken into account, with the recommendation to introduce allochthonous species only in certain suitable sites.

All the results, obtained for individual areas have been statistically processed so that they can relate to a large part of Central Serbia. This paper lists the most suitable species for reforestation of the most common ecological units on degraded terrains.

In the group of ecological units of Hungarian and Turkey oak forests, certain differentiations can be observed not only in the selection of accompanying, but also in the selection of main species:

Hungarian oak (*Quercus frainetto*), as an acidophilic species, is not recommended as the main species on characteristically alkaline parent rocks: serpentinite, shallow soils over limestone, and marlstone.

Beside fruit trees, linden, flowering ash and similar species, pedunculate oak (*Quercus robur)* is recommended as an accompanying species on lower positions, sessile oak (*Quercus petraea*) on dystric brown soils and broad-leaved pubescent oak (*Quercus virgiliana*) on marlsone.

Introduction of suitable ecotypes of Austrian pine, which has been widely used for large-scale reforestation on all Hungarian oak-Turkey oak sites, is recommended only on shallow soils over limestone.

Two groups of ecological units – hop-hornbeam and flowering ash forests and Oriental hornbeam forests, especially in the ecological units on chernozems over limestone – are the most suitable for the introduction of Austrian pine. However, certain broadleaves, such as Turkish hazel (*Corylus colurna*), flowering ash (*Fraxinus ornus*), Mahaleb cherry (*Prunus mahaleb*), white linden (*Tilia argentea*) and similar species are recommended as accompanying species on deeper, better developed soils.

Submontane sessile oak forests present a particular problem due to the processes of forest dying back and immense diversity of soil types. Our recommendation is to keep sessile oak (*Quercus petraea*) as the main species in the whole group. Accompanying species should be different. Hornbeam (*Carpinus betulus*), birch (*Betula pendula*), aspen (*Populus tremula*) and in the western and southern Serbia sweet chestnut (*Castanea satica*) should be introduced on dystric brown soils and ranker. The most favourable species for eutric brown soils are flowering ash (*Fraxinus ornus*), white linden (*Tilia argentea*) and Mahaleb cherry (*Prunus mahaleb*). Hop-hornbeam (*Ostrya carpinifolia*) is suitable for brown soils over limestone in western Serbia, while Turkish hazel should be introduced in the eastern parts of the country.

Although the group of beech forests is characterized by considerable diversity, there are certain general principles that can be applied to all eco-vegetational units of potential vegetation, only in varying degrees. They are as follows:

- The main edificator – beech – should not be replaced, especially not with coniferous species, except in extreme cases, i.e. in completely deforested areas with degraded soil, or in the beech-fir belt, where fir should be forced.
- The sites of beech forests on brown – dystric and eutric – soils should be reforested mainly with noble broadleaved species (*Acer pseudoplatanus*, *Acer platanoides*, *Fraxinus excelsior*), lindens (*Tilia argentea, Tilia cordata, Tilia platyphyllos*), fruit trees (*Prunus avium*, *Sorbus torminalis*) and other similar species.
- Apart from the above enumerated species suitable for brown soils over limestone, hop-hornbeam (*Ostrya carpinifolia*) should be used in western and Turkish hazel (*Corylus colurna*) in eastern Serbia.
- In montane and subalpine beech forests which are at the upper limit of the beech elevational range, beech should not be always forced. At these elevations, Balkan maple (*Acer heldreichii*), rowan (*Sorbus aucuparia*), fir (*Abies alba*) and spruce (*Picea abies*) are recommended as accompanying, sometimes even as main species. Apart from these species, whitebark pine (*Pinus heldreichii*) and Serbian spruce (*Picea omorika*) can be considered for limestone soils while Scots pine (*Pinus sylvestris*) and Macedonian White Pine (*Pinus peuce*) can be used on acid silicate parent rocks (the latter one being suitable only in southern Serbia).
- A gradual increase in the number of frigoriphilic spruce elements in spruce-beech-fir, fir-spruce and spruce forests together with the occurrence of brown podzolic soils and chernozems (mostly acid) over limestone restricts the number of species for reforestation to only two accompanying species in all ecological units: Balkan maple (*Acer heldreichii*) and rowan (*Sorbus aucuparia*). Besides them, Scots pine (*Pinus sylvestris*), whitebark pine (*Pinus heldreichii*) and Serbian spruce (*Picea omorika)* can be used on limestone soils.
- Beech, as a neutrophilic species should not be forced on extremely acid soils in acidophilic beech forests. These sites are suitable for the introduction of acidophilic conifers and broadleaves. At lower elevations, they include sessile oak (*Quercus petraea*), sweet chestnut (*Castanea sativa*), birch (*Betula pendula*) and

rowan (*Populus tremula*), while higher elevations may be suitable for all above enumerated species plus Scots pine (*Pinus sylvestris*) and spruce (*Picea abies*).

- In basophilic pine forests, subspecies, ecotypes and provenances of Austrian pine should be taken into account, which hasn`t been the case so far. *Pinus nigra* ssp.*illyrica* should be introduced into limestone sites in western Serbia, *Pinus nigra* ssp. *banatica* and *Pinus nigra* ssp. *Pallasiana* in eastern and southern Serbia and *Pinus nigra* ssp. *Gocensis* on serpentinite. Furthermore, better preserved sites should be reforested with the following accompanying species of broadleaves: hop-hornbeam (*Ostrya carpinifolia*) and Bosnian maple (*Acer obtusatum*) should accompany *Pinus nigra* ssp.*illyrica* and *Pinus nigra* ssp. *Gocensis*. Turkish hazel (*Corylus colurna*) and Balkan maple (*Acer intermedium*) should be introduced with *Pinus nigra* ssp. *banatica* and *Pinus nigra* ssp. *Pallasiana,* while Balkan sessile oak (*Quercus dalechampii*) and birch (*Betula pendula*) should accompany *Pinus nigra* ssp. *Gocensis*. Flowering ash (*Fraxinus ornus*) and Mahaleb cherry (*Prunus mahaleb*) can be introduced into all pine sites, regardless of subspecies.

The results of the site-related selection of species indicate the absolute dominance of broadleaved species on approximately 85% of the total area, which is in complete contrast to the earlier practice of reforestation.

CONCLUSIONS

1. Natural environment for the development of forest vegetation in Central Serbia is highly diverse, as can be seen from diverse ecological conditions.

Basic natural conditions include diverse potential forest vegetation – zonal, extrazonal and azonal - within which 200 associations with approximately 100 edificatory species have been studied.

The climazonal - climatogenic forests are represented by Hungarian oak and Turkey oak forests with different phytogeographical variants.

The clima-regional belt of beech and beech-fir forests includes montane, submontane, beech-fir, and subalpine beech forests.

The Subalpine belt of coniferous forests in Central Serbia is primarily composed of spruce-beech-fir and spruce forests.

The high mountain belt, at the upper timberline, is represented by shrub communities of mountain pine, bilberry and green alder.

The extrazonal xerothermophilic deciduous forests of sub-Mediterranean type are predominantly represented by the communities of Oriental hornbeam and lilac, while extrazonal mesophilous forests of Central-European type are composed of sessile oak-hornbeam communities.

The hygrophilic – alluvial forests are the forests of willows and poplars, swampy forest communities of common sallow, black alder and narrow-leaved ash, while there are `floodplain forests` of pedunculate oak-narrow-leaved ash, pedunculate oak, and pedunculate oak - hornbeam in the central part of the alluvial plains.

The azonal forest vegetation of the montane and submontane belt is composed of diverse broadleaved and coniferous forests: sessile oak - Turkey oak, hop-hornbeam, Turkish hazel There are also basophilic pine forests, acidophilic sessile oak - sweet chestnut forests and many others.

The azonal vegetation in the belt of beech forests is composed of the following forests: mountain maple - common ash, beech – hop-hornbeam, beech – Turkish hazel, acidophilic beech forests etc.

For a long period of time, phytocoenologists have been studying only the existing vegetation. However, for the purposes of reforestation, especially on partly deforested terrains, it is necessary to reconstruct and map potential vegetation. So far, it has been done only for the Pester plateau (Rakonjac, Lj., 2002).

Ecological classification of the forest areas, based on three inputs (edificators, phytocoenoses, and soil) should be used as the most comprehensive basis for successful reforestation. By combining these three inputs we define different ecological units, i.e. basic forest types.

2. The selection of species for reforestation was the weakest point in the previous strategy of reforestation. There was a striking contrast between the rich biodiversity of species and phytocoenoses and the small number of taxa of both native and introduced tree species that were used in the reforestation practice. These were mostly conifers: *Pinus nigra* (rarely *Pinus sylvestris*), *Picea abies, Pseudotsuga mensiesii, Larix europaea, Pinus strobus,* sometimes *Abies alba, Abies nordmanniana, Abies grandis* and others. The choice of broadleaves was even more limited and it was mostly reduced to *Populus euramericana* in alluviums and *Robinia pseudoacacia* on all other terrains. The attempts to introduce Green ash (*Fraxinus lanceolata* and *Fraxinus pensylvanica*), Eastern black walnut (*Juglans nigra*) or some other non-native species were scarce and mostly unsuccessful. Consequently, the established plantations were not equally successful and there was a high percentage of those in which the selection of species was not done with regard to their site conditions. Furthermore, a great number of successful plantations do not exploit the full potential of the sites or they do but only for a short period of time.

Ecological classification of forest ecosystems, or ecological units (main forest types) based on three inputs (edificatory species, vegetation, and soil) is the most comprehensive basis for selection of species.

The selection of species carried out by this methodology suggests three categories: a.) main species – edificators of autochthonous phytocoenoses of potential vegetation which can be used in the early stages of degradation, while the processes are still reversible; b.) accompanying species – mostly pioneer species suitable for specific sites where the processes of degradation are stronger: c.) shrubs occurring in the natural degradation stages as ameliorators, i.e. primary vegetation on the barrens with irreversible processes of degradation. Because of the need to operate with verifiable data, only autochthonous species of natural potential vegetation have been taken into account, with the recommendation to introduce allochthonous species only in certain suitable sites.

Summarizing the results obtained for the territory of Central Serbia, we have made general recommendations for the selection of autochthonous species for reforestation.

Generally speaking, reforestation does not necessarily involve drastic changes of potential ecosystems and their main edificators. The paractice of reforestation with coniferous monoplantations should be abondoned since it has demonstrated a great number of shortcomings in Central Europe in the past decades.

Apart from its economic benefits, introduction of suitable, primarily broadleaved species that are members of the natural succession has a very important role in the conservation of ecosystems (shade, leaf fodder production, organic matter production, soil binding, nectar production, forest fruits, etc.)

3. Furthermore, it is impossible to introduce any radical changes to the selection of species without making effective changes in the production of planting stock. However, there haven`t been any practical changes in the field of seed production and nursery practice so far.

Both the number and the quality of the seed orchards in Central Serbia are generally unfavourable. The number of coniferous seed orchards is satisfactory and they are mainly seed stands. The greatest number belongs to fir (*Abies alba*), then to spruce (*Picea abies*), Austrian pine (*Pinus nigra*), Scots pine (*Pinus sylvestris*) and Serbian spruce (*Picea omorika*). When it comes to broadleaved species, the situation is a bit different. The total number of broadleaved seed orchards is significantly smaller. Half of it belongs to seed stands and the other half is composed of groups or individual trees. The most frequent species are: beech (*Fagus moesiaca*), sessile oak (*Quercus petraea* agg.), sycamore maple (*Acer pseudoplatanus*) Norway maple (*Acer platanoides*), common ash (*Fraxinus excelsior*) and linden.

Nursery practice in Serbia should be reorganized with the aim of improving the quality of the existing more or less extensive production. This attitude can be supported by several documents of prime national importance, such as The Spatial Plan of the Republic of Serbia or Forestry Development Programmes, or by the fact that the forestry sector has increaed its share in the gross national income and finally by the potential value and significance of the national seed sources.

4. The practice of reforestation should cease to be a routine job. It should be based on the principle of site-related selection of species. In other words, both economical and ecological site potentials should be fully utilized.

Reforestation should not be limited only to the areas suitable for this purpose because in that case it is reduced to amelioration of degraded coppice and scrub forests by substitution. It should include terrains unsuitable for reforestation – strongly degraded and eroded terrains and barrens.

The final conclusion is that it is not enough to present elaborate and scientifically proven theories. It is necessary to draw up a new strategy of reforestation based on modern scientific discoveries that are already in practice in Central Europe. This goal calls for drastic changes in all segments of reforestation practice – from gene pool conservation, seed stand establishment and broadleaved-oriented nursery production to adjusting bio-ecological characteristics of different species to the site condions of the terrains that are to be reforested.

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BIOLOGICAL CONTROL – CURRENT TREND IN FOREST PROTECTION

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Abstract: *In the fight against plant diseases apply different methods of biological control that are based on various specific and nonspecific types of relationships between pathogens and microorganisms. Significant biological control, as defined above, most generally arises from manipulating mutualisms between microbes and their plant hosts or from manipulating antagonisms between microbes and pathogens. Direct antagonism results from physical contact and/or a high-degree of selectivity for the pathogen by the mechanism(s) expressed by the biological control agent. Hyperparasitism by obligate parasites of a plant pathogen would be considered the most direct type of antagonism because the activities of no other organism would be required to exert a suppressive effect.*

The utilization of hypovirulence as a biological control relies on the ability of the hypovirulent strains to disseminate and transmit their hypovirus to virulent strains. A classical example is the virus that infects Cryphonectria parasitica, a fungus causing chestnut blight.

While various epiphytes and endophytes may contribute to biological control, the ubiquity of mycorrhizae deserves special consideration. Mycorrhizae are formed as the result of mutualist symbioses between fungi and plants and occur on most plant species. Because they are formed early in the development of the plants, they represent nearly ubiquitous root colonists that assist plants with the uptake of nutrients.

Entomopathogenic organisms, various types of viruses, microsporidia, bacteria, protozoa, fungi, nematodes, which can under the favourable conditions cause the massive insect mortality and are of great breeding capacity, normally live in nature. Epizootics caused by naturally occurring viral and fungal pathogens are often responsible for spectacular crashes of insect pest populations. Although there are numerous entomopathogenic microorganisms, relatively small number of them has so far being practically used in the harmful insect control. Fungal entomopathogens have been used more frequently than other types of pathogens for classical biological control. The most comonly introduced species were Metarhizium anisopliae and Entomophaga maimaiga.

Key words: forests pathogens and harmful insects, biological control, natural enemies

INTEGRATED FOREST PROTECTION AND BIOLOGICAL CONTROL

The usual definition of the term "integral protection" implies the range of all methods and instruments which can be applied for the protection of the forest facilities (natural forests, artificially established plantations and nurseries). It does not mean that all the familiar methods of protection must be applied for the suppression of some harmful factor. In addition, the integral protection is not the simple sum of the different methods of fight which are applied either simultaneously or successively. This term mainly implies the comprehension of the way in which humans treat nature, of the

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complexity of forest ecosystems and interactive influence of all factors, which means that the elimination of one adverse agent can cause other negative phenomena. Since all phenomena in nature are interrelated, the integral forest protection implies the knowledge of the complexity of forest ecosystems, and no individual measure (no matter how much it is efficient at some point of time) is as important for the stability of them and for the role of humans in the maintainance of the good health condition, as the conceptual approach to this task. There is a widespread opinion that the term integral protection must be used in the wide context, which implies the strategy of protection not from one harmful agent, but from all adverse factors in the forest ecosystem. Therefore, it implies the integration of numerous activities, including biological ones, aimed at eliminating the causes of the damages and preservation of the stability of forest ecosystems (Tabakovic-Tosic et al., 2011).

Due to the environmental conditions, the forest ecosystems are more or less subject to the certain harmful agent, but it should be emphasized that the environmental factors interact, which should be taken into account during the integral protection. Some damages can be tolerated from the economical or aesthetic point of view, which this type of protection also takes into account. Thus, the integral protection strives at the minimization of the damages, but not at the complete elimination of the causes, thereby using the methods which vary depending on the variability of other factors. Consequently, the integral protection consists of the following elements:

- Forecasting potential outbreaks - The main purpose of pest control is to protect the crop and not to kill as many pests as possible. In preparing the forecast for potential outbreaks, not only quantitative data such as numbers of egg masses or larvae per unit area are to be considered. The qualitative aspects must also be properly taken into account, namely the effect of natural enemies must be measured and the trend of the gradation (outbreak) assessed.
- Reduction of chemical insecticide application – In Serbia, the general directive in the protection of forest plant species is the application of integral control measures. One of them is the exclusion of chemicals and the application of biological preparations. This method prevents environmental pollution, which is essential for the production of ecologically safe food (Tabaković-Tošić et al., 2003).
- Forest management - The augmentation of natural mortality factors in the cultural and biological control of pest organisms can be achieved in forest management. Planned forest protection as part of general management is becoming widely acknowledged. To say it in a few simple words: the aim is to plant, to grow and to maintain forest types that will be, according to present experience, as pest-proof as possible within the framework of the economic task assigned to the forest. The foundation of susceptible monocultures should be avoided and special care must be taken with the use of tree species and strains outside of their natural distribution area. Selection of more resistant strains of trees will be one possibility. Disruptive types of forest operations should he avoided. Sustained yield in forest production should become as important a target as productivity.

- Silvicultural control - Usually understood by foresters as any application of cultural measures to prevent existing pest organisms from reaching outbreak dimensions. The alteration of a susceptible forest into another, more resistant type can be achieved in the planning stage (forest management) as well as later on, during maturation. Techniques of thinning, of protection against storm, sometimes even of fertilization can contribute to the general aim: to increase the environmental resistance of the forest to potential pest organisms. This type of control can, if successful, result in a low average level of pests and make other control operations unnecessary.
- The biological control of pests.

BIOLOGICAL CONTROL OF PESTS

In general terms we may say that biological control is the utilization by man of natural enemies for the (regulative) reduction of pest populations. Biological control, like silvicultural control, is applied ecology. A forest, even an artificial plantation, represents a relatively undisturbed and lasting environment in which a complex network of regulating biotic factors can develop. If these are naturally insufficient, alterations such as the colonization of beneficial species will have time to express their full impact. Foresters also favour biological control because of the low costs involved as compared with repeated chemical treatments. The low monetary value of the annual increment of trees necessitates economical control methods. Fortunately, the level of pest damage that can be tolerated by healthy forests is usually rather high. The fact that relatively great numbers of pest organisms can be tolerated makes possible the survival of sufficient natural enemies that depend on these organisms for food supply. Foresters are therefore more interested in economical, possibly self-perpetuating control rather than in reduction to extremely low pest densities or in eradication. Population dynamics of forest pests have been studied intensively because forest ecosystems are long-lasting and offer ideal conditions for such investigations (Franz, 1971).

Some techniques available for the biological control of pests are: importation of entomophagous arthropods and vertebrates, microbial control, genetic manipulation, conservation, biological control of forest-tree pathogens and biotechnical control.

Importation of entomophagous arthropods and vertebrates

The classic technique of importing from the country of origin natural enemies of previously introduced pests is well known. It is based on the assumption that natural enemies play a vital role in the natural regulation of pests and that introduced insects often become pests because these essential limiting factors are not present in the new environment. It can be stated that some of these biotic agents show a remarkable tendency to act in a density-dependent way, others do not, or not sufficiently.

Correspondingly, some of the numerous efforts to establish parasites or predators of pest insects in foreign areas were completely successful and led to economic control; other attempts yielded only partial control, and still others produced no practical results whatsoever. The utilization of parasites and predators from related host species and genera has been practiced for many years. This procedure has a certain superiority over the traditional approach because no ecological homeostasis has yet evolved and the association between parasite or predator and host is new. At any rate, this additional source of beneficial insects has not yet been fully exploited (Franz, 1970).

Intra-areal transfer of indigenous natural enemies within the same continental area may help to speed up their natural spread. Although dispersal might occur unaided, this often takes too much time or is hampered by geographical barriers.

Microbial control

The utilization of disease-causing microorganisms has become an important field of biological control. Although efforts in this direction are about 80 years old, development has depended largely on a better knowledge of such pathogens as viruses, bacteria, protozoa, and fungi.

For example, naturally occuring enthomopathogens are important regulatory factors in insect population. Entomopathogenic organisms, various types of viruses, microsporidia, bacteria, protozoa, fungi, which can under the favourable conditions cause the massive insect mortality and are of great breeding capacity, normally live in nature. Epizootics caused by naturally occurring viral and fungal pathogens are often responsible for spectacular crashes of insect pest populations (Evans, 1986; McCoy et al., 1988).

Although there are numerous entomopathogenic microorganisms (for instance, nuclear polyhedrosis viruses, granuloviruses, reoviruses, bacterials, fungi), which cause the insect mortality and in this way have one of the dominant roles in the regulation of their number in nature, relatively small number of them has so far being practically used in the harmful insect control. It is important to emphasize that bioinsecticides which are efficient because they contain entomopathogenic bacteria, a few of which have sporagenic features, such as *Bacillus popilliae, Bacillus lentimorbus*, *Bacillus sphaericus*, as well as the most popular *Bacillus thuringiensis* Berliner, the entomopathogenic features of which started in 1900, account for 80% of the total bioinsecticide production.

There is a general view in Sebia that the integral measures of the fight should be applied for the protection of the forest plants. For instance, these methods refer to the exclusion of the chemical insecticide and the application of the biological ones. In this way the enviromental pollution is avoided, which is of a great importance for the production of the ecologically healthy food. The satisfactory results in the suppression of the economically harmful insects belonging to the Lepidoptera order are obtained in our country by application of the foreign origin preparations based on *Bacillus thuringiensis* var. *kurstaki* (Foray® 48B, Condor®) and var. *berliner* (Bactospeine®

WP) and var. *berliner* (Bactospeine WP). Realising how serious the above problems are in Serbia, Technological Ecological Center in Zrenjanin, now A.D. Bioecological Center in Zrenjanin has been working on developing new technology of production bioinsectides based on crystal and spore complex of *Bacillus thuringiensis* ssp. *kurstaki* bacteria since the early 1990s. During the research, preparation had several temporary names (BTG, Tekocid-20, Tekocid G), with the different amount content of the active ingredient and inert substances, until 2002, when it got its final form, was registered and given a permanent permission for distribution in the Republic of Serbia, under the commercial name D-STOP. (Tabakovic-Tosic, 2008).

Fungal entomopathogens have been used more frequently than other types of pathogens for classical biological control. Among 136 programs using different groups of arthropod pathogens, in 49.3% the fungal pathogens were introduced. The most comonly introduced species was *Metarhizium anisopliae* (Metschnikoff) Sorokin, which was released 13 times, followed by *Entomophaga maimaiga* Humber, Shimazu & Soper *(*Entomophtorales: Entomophtoraceae*)*, which was released seven times (Hajek and Delalibera, 2009).

The entomopathogenic fungus *Entomophaga maimaiga* was isolated and described as the natural enemy of the gypsy moth in Japan, where it causes the periodical epizootias. It is also spread in some parts of China and the Russian Far East. In spite of the fact that it was introduced in North America in 1910-1911 (Speare and Colley, 1912), its presence in the natural populations of gypsy moth was determined only in 1989 (Hajek et al., 1996), when the pathogen caused pandemic in several countries (Andreadis and Veseloh 1990, Hajek et al., 1990b, Smitley et al., 1996; Reardon and Hajek, 1998). Today E. maimaiga is very significant pathogen of gypsy moth in North America and in Canada (Balser and Baumgand, 2001; Hajek, 1997; Hajek et al., 2005; Howse, 2002; Hoover, 2000). Bulgaria has been the third country in the world and the first one in Europe in which E. maimaiga was introduced successfully. The first epizootic of it occurred in 2005, and the latest ones were reported in the very vicinity of the Bulgarian borders with Serbia, Greece and Turkey (Pilarska et al., 2000, 2006; Georgiev et al, 2007, 2010).

In 2010, the higher mortality rate of the older gypsy moth larval instars was reported in the some forest complexes, in the culmination phase of the new outbreak of the gypsy moth in Serbia. By the field and laboratory studies of the causes of their death, the presence of conidia and resting spores of the entomopathogenic fungus *E. maimaiga* was reported in the dead caterpillars. It has been the first discovery of this kind in Serbia, i.e. Serbia is the third European country in which this fungus has been reported. It proved to be a powerful reducer of the population size of the gypsy moth, and in all cases it caused the collapse of the outbreak in 2011 (Tabakovic-Tosic et al., 2012).

The artificial spread of pathogens is recommended where natural spread will be insufficient, either because of shortage of time or because the density of the host population is too low to allow satisfactory natural spread. The availability of insect pathogens that lend themselves to mass production for use on a commercial scale has shown remarkable progress. Obviously, this method has advantages because only small amounts of the pathogen and no costly equipment for field application are needed. Also, the dispersal of pathogens is achieved by the insect itself and soon spreads throughout the host population. Particularly where forested areas are widely distributed, the spread of pathogens through the release of contaminated adults as healthy carriers, or the distribution of latently infected individuals might be a very useful method. These possibilities demonstrate the great differences between chemical and microbial control.

As with entomophagous insects, diseases are not always restricted to one host. Consideration of factors aiding the persistence of biological controls is as important for introduced as for indigenous pests. In the transmission of diseases, predators or parasites may play a role as vectors which is easily overlooked. As a matter of course, we judge the value of biotic agents by the direct mortality they produce. Vectors which naturally spread a disease are not easily assessed as to their efficiency. We know that the passage of some pathogens even through the intestinal tracts of such predators as voles, birds, and insects does not inhibit their infectivity. Parasitic Hymenoptera can transmit microorganisms into hosts, either when feeding or during egg deposition. The spread of pathogens from dead carcasses, from excrement, or in several other ways shows how an epizootic may be furthered by vector activity.

Genetic manipulation

Natural populations exist in a state of continuous change. Not only numbers, sex ratios, age classes, and other phenotypic changes, but also the genetic composition is modified by each individual that drops out or is born into the group. Artificial manipulation of populations has been tried in two directions: (a) to improve them; or (b) to make them less fit for survival.

The accumulation of as much genetic variability as possible is the modern basis for the importation of beneficial insects. From this pool, natural selection will preserve the strains that are superior under the prevailing environmental conditions. In future, the selection of strains more tolerant to pesticides might be profitable for release in greenhouses, in isolated areas, and for beneficial species like predatory mites which have a low power of dispersion. In many situations the maintenance of the integrity of new stocks will be endangered and the desired qualities lost unless selection pressure for this new quality is usually low and other, nonselected individuals can invade the release area.

The control of an insect through its own actions requires production of genetically inferior strains. It is, therefore, the antithesis of selective breeding for superior strains as mentioned above.

In forests, two types of pest infestation lend themselves most clearly to autocidal control methods: the appearance of a new introduced pest; and the control of pests in isolated areas such as islands, valleys, or in new plantations in nonforested areas. Obviously, isolated populations are advantageous, although not an absolute prerequisite, for autocidal control methods. A period of low population level is necessary for beginning the autocidal treatments; this may occur naturally or be obtained by other control techniques. In conclusion, we may consider the autocidal control method as one of the great new achievements in biological control. Its applicability is being considered in all fields of pest control. Autocidal control is part of biological control because living organisms are utilized. The self-destruction of a population may end with suppression or with eradication, whereas all other biological control methods at best create a new and low level of the pest that must continue if the regulation is to persist.

Conservation

There are three aspects of conservation: (a) protection of the natural enemies from silvicultural practices that destroy them; (b) encouragement of the natural enemies by not removing requisites needed for survival and increase; (c) augmentation of the natural enemies by deliberately providing these essential requisites (Franz, 1970).

Examples of these phases of conservation can best be understood by defining the aims of modern silviculture. The ideal is no longer simply the maximum yield of forest products in the minimum time; the concept of the sustained yield has gained more and more acceptance in forest management. If we are to maintain over the years adequate sources of forest products, some of our current procedures must be modified.

The pest-control aspect of this approach is to realize that, for instance, uniform and even-aged forests frequently are more susceptible to pest outbreaks than others having a more diversified flora and a range of age classes. Promoting the mixed forest type is part of silvicultural control and, simultaneously, of biological control. Several important pest insects have parasites which need alternate hosts. These frequently live on other plants. Radical weed control automatically reduces the numbers of beneficial species. Adults of many beneficial insects require food from wild flowers or other plant sources. Many predacious insects must have alternative prey on which they may survive temporary scarcities of the pest. More vectors of disease-causing microorganisms will be available in a diversified fauna. To protect such requisites, to avoid unnecessary destruction of these essential facets of the habitat is the conservation phase of biological control.

Biotechnical control

In some cases it is possible to utilize specific innate behaviour characteristics which are responsive to certain physical or chemical stimuli. The effect is usually not a direct kill, as with convenient physical or chemical control methods. Because of the close connexion between biological properties of the responding organism and the stimulus, such control has been named "biotechnical". Its effect consists usually in attraction, repellence or physiological disorder of pest organisms in a very specific manner (Franz, 1970).

BIOLOGICAL CONTROL OF FOREST-TREE PATHOGENS

The control of plant diseases can rarely be achieved without careful combination of many techniques. Breeding of resistant host trees is, no doubt, a "biological approach," but is beyond the scope of this review, although it may well be part of integrated control of insect pests. Application of fungicides is usually too expensive in forests. There are some ways to avoid or suppress infestations by silvicultural measures - choice of site, removal of alternate hosts for pathogens, soil management and use of disease-free seed.

The plantation of the mycorrhizal seedlings is recommended as the most efficient way of using the biological measures for the successful fight against the pathogens, as the presence of the mycorrhizal fungi at the root of the seedlings has the multiple beneficial effects, the most important of which is the influence on the survival of the seedlings the root of which is attacked by the pathogenic fungi (Chakravarty and Mishra 1986; Haug et al., 1988). The mycorrhizal fungi act as the antagonists to the pathogens (Qian et al., 1998).

The studies by Zak (1964) and Marx (1973) serve as the proof that there are numerous modes of action of the mycorrhizal fungi during the protection from the soil pathogens. The fungal sheats envelop the tip of the root and the cortex, thereby forming the unique and different types of the mechanical barriers to some pathogens. Ectomycorrhizae can provide the protection by secreting the antibiotic secretion from the fungi or by the stimulation of the root cells of the host plants to secrete the antimicrobial metabolites, thereby killing (Dehne, 1982) or inhibiting some pathogens (Graham and Menge, 1982; Golubović Ćurguz et al, 2010). Hydrolitic enzymes of the different mycorrhizal species of fungi degrade the cell wall of the plant pathogens which belong to oomycetes (*Pythium ultimum*), ascomycetes (*Fusarium equisetii*) and basidiomycetes (*Rhizoctonia solani*). (Inglis and Kawchuk, 2002). The population of pathogens is considerably greater in the rhizosphere of the non-mycorrhizal roots of the seedlings (Chakravarty and Mishra, 1986), which is also reflected in the lower growth rate of the plants. In order for the antagonistic microorganism to be ideal, it should produce the sufficient quantity of inoculum and be tolerant to the unfavourable abiotic conditions (low temperatures, increased salinity...) (Antal et al., 2000).

Phytoterapy

Phytoterapy is a new type of the biological methods of the fight against pathogens. The extracts from the different parts of some plants inhibit the growth of pathogenic bacteria and fungi (Hirai et al., 2000; Deepa et al, 2004).

Hypovirulence

Viruses occurring in the fungi which cause the diseases by lowering their pathogenicity level most frequently do not kill the cells of the host, but they are just transmitted by the intercellular routes, assexual spores and the fusion (anastomosis) of hyphae (Buck,1986). Within the hypha, the viruses are transmitted by moving protoplasm in the direction of its growing top. The transmittion by anastomosis of the hyphae is limited by the vegetative incompatibility, which is under the control of (vc) genes.

Hypovirulence (lowered virulence) in fungi can occur in several ways. Some of them refer to mitochondrial DNA mutations (Mahanti et al., 1993; Monteirro-Vitorello et al., 1995), mutations of the genome of the nucleus or to the presence of mycoviruses, such as double-stranded (ds) RNA viruses (Smart and Fulbright, 1996). Double-stranded RNA viruses occur in different pathogenic fungi, the most important of which to forestry are *Sphaeropsis sapinea*, *Rhizoctonia solani* and *Cryphonectria parasitica*.

Hypovirulence is nowadays most frequently used as the biological method of fight against *C. parasitica* (agent of the chestnut blight) and is based on the introduction of hypovirulent forms of the fungus of the infected chestnut stand. The hypervirulence of this species is caused by the presence of the double-stranded ribonucleic acid (dsRNA), which is of the viral origin. The hypovirulent strains of *C. parasitica* are characterized by the decreased pigmentation and production of oxalates and enzymes of laccase, they produce smaller number of fruiting bodies (Rigling et al., 1999), and they create the surface wounds on the host, without the significant infection. Also, they prevent the infections by the virulent strains (prevention), and when they are applied at the periphery of the canker wounds caused by the virulent strains, act as the medicine, i.e. they are able to eliminate virulence (the ability of exclusion).

The majority of mycoviruses belong to Totiviridae, Partitiviridae, Narnoviridae and Hypoviridae families. The viruses which occur in *C. parasitica* belong to Hypovirus genus and Hypoviridae family Nuss et al., 2005). So far four strains have been described and marked as: CHV-1, CHV-2, CHV-3 and CHV-4. They have different effects on *C. parasitica*. CHV-4 does not affect its virulence, while CHV-1, CHV-2, and CHV-3 significantly reduces it.

In addition, two viruses of the new Mycoreovirus genus, Reoviridae family, have been found in C.parasitica, as well as the viruses from Partitiviridae and Crysoviridae families. Virus Cryphonectria mycoreovirus 1, strain 9B21, causes hypovirulence and does not disturb the pigmentation and sporulation processes. It could be used in the future as the alternative to the most frequently used CHV1. The characteristics of the viruses Partitiviridae and Crysoviridae have not been sufficiently studied yet (Hillman and Suzuki, 2004).

Hypovirulence has been applied in Europe since 1974 (Heiniger and Rigling, 1994; Robin et al., 2000). This method has proved to be very efficient in the treatment of the individual shoots in the United States (Anagnostakis, 1987; Liu et al., 2002).

CONCLUSION

On the end of this report, the main conclusions are:

Integrated control means more than the invention or imitation of technical tricks to reduce the amount of pesticides used in forests and to consider the conservation and augmentation of biotic regulating agents.

Biological control, as a current trend and significant part of integrated forest protection is so intellectually satisfying, so biologically intriguing, and so ecologically rational a means of pest control.

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DEVELOPMENT OF MAJOR PATHOGENS AND PESTS INFLUENCED BY THE ABIOTIC AND BIOTIC FACTORS

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Abstract: *The environment is the immediate environment in which are placeing various biological processes. Abiotic and biotic factors has great influence on the development of pathogens and pests. Abiotic factors are the primary factors that determine whether some organism are livining in an environment, while the biotic factors are interaction which modify the way of living of the organism in a structured environment and that change the fine details of its ecology. If the organism is'nt initially adapted to their physical and chemical environment, he can not persist. Climate change, especially increasing the average of annual temperature and changes in the distribution of rainfall during the year, changes may affect on the relationship between insects and their host. This effect is achieved through changes in the spatial distribution of their hosts and their herbivorous, but also through changes in synchronization phenomena of sensitive stages of insects, and for them the favorable phase in the seasonal development of plants. The importance of synchronization was presented in the example of relations between the gypsy moth (Lymantria dispar L.) and four species of oak that have econmskog significant for the Balkans and Quercus petraea (Matt.) Liebl., Oak Q. robur L.,. turkey Oak Q. cerris L. and hungarian Oak Q. frainetto. The study of eriophyid mite fauna in urban forestry and horticulture provides new opportunities for monitoring phytophagous relationships, host plant and the environment. Since the eriophyid mite and host plant is stable and unique relationship, changes in behavior of mites or plant reaction can be seen as indicators of changes in the environment.*

Key words: abiotic and biotic factors, pathogens, pests

INTRODUCTION

For the emergence and development of diseases and pests it needed three basic factors - susceptible host plant, a virulent pathogen or pest and favorable environmental conditions (Karadzic et al., 2011). Environmental variables may be abiotic, biotic, and more recently of biotic, as a special significance among groups by the anthropogenic factor, or human influence. Basic features of all of these factors are that they operate as complex, that is constantly changing in time and space and are mutually interdependent.

Pathogenic microorganisms are parts of ecosystems, unique functional units of all living organisms and inanimate nature, in such a limited space. As part of biotic component of ecosystems, microorganisms are the subject of the study of ecology, the study of relationships caused by the organism and the environment. In the biosphere there are very diverse ecosystems, each with a certain range of biotic and abiotic

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factors. There are large regional ecosystems, such as sea, lakes, deserts, forests and so on and small, specific microorganisms clod of earth, leaf surface.

Macroscopic dimensions of microorganisms allow very close contact with the environment, and they are particularly sensitive to changes in environmental factors (T, pH, light, the concentration of organic and inorganic compounds, water, etc..). Conditions of microenvironment are highly measurable, for example. for bacteria that grow and reproduce in the microenvironment clod of earth is more important than makroenvironment (forests or fields) in which there is a pice of soil.

Qualitative and quantitative composition of microorganisms in different ecosystems depends on a number of biotic and abiotic factors. Populations of microorganisms vary in their number. In stable ecosystems, unchanged conditions in the microenvironment, the number and types of microorganisms remain relatively constant. Population size is determined by some of the limiting factors, the most important are nutrients. Comparisons of the growth rate of certain microorganisms in nature with the speed of growth in controlled conditions show significant differences. Different types of microorganisms are capable of growing in the same environment, however, due to competition for food resources and energy is going to be just a few or even only one kind of microorganisms takes a microenvironment. A number of different properties, in addition to the speed of propagation, can increase the competitiveness of a species invasion microenvironment. The most important features are: high tolerance of environmental conditions, ableness to produce toxins or antibiotics, the ability of crossing into metabolically inactive state (spores, microcysts). Any of these properties made to species successful invasion by a given space. In addition to competition, in ecosystems occurr and other forms of interaction between two or more organisms (symbiosis, parasitism, etc..).

As is well known, abiotic factors are the primary factors which determine whether an organism living in a certain environment and represent a complex of physical and chemical conditions of the environment (a set of factors inorganic environment) and can be climatic (heat, light, humidity, water pressure, air movement), chemical (concentration of active chemical substance in the environment, pH, hardness, conductivity), orographic (terrain factors, modify the value / impact of other environmental factors), pedology (biotic or abiotic).

Biotic factors (predation, parasitism, competition, mutualism, protocooperation, komensalism, amensalism, neutralism) are interactions that modify the way in which the organism lived in the structural environment, and that changing the fine details of its ecology. It is organic factors of living nature, which effects can be very complex and involves the interaction and impact of all living beings, they perform to organism. Practically, the survival of all plant and animal species implies the vital activity of other organisms. Harmful biotic factors which endanger forest tree species in nurseries, cultures, and stands require constant supervision to be able to intervene by applying methods and tools that are at our disposal. Early detection of plant diseases epifitotians, and other harmful agents eliminates the need for intervention in large areas, saving manpower and financial resources (Vasiljevic et al, 2005).

In accordance with the legislation on plant protection, in forestry are apply quarantine measures and monitors the occurrence and intensity of pest organisms.

However, due to lack of understanding of the importance of forest protection, preventive measures are mainly absent, and the acute problems, only occasionally apply repressive measures on large areas of forest. Because forestry have major losses, pointing to the urgent need to implement principles and methods for monitoring of population levels of harmful organisms are constantly being improved and revised. This primarily involves identification of existing organisms and the development of methods of control of density if population trends and tendencies of the level of economically important pest of forest trees. One of the basic requirements is to investigate the influence of just changing environmental factors on the population dynamics of organisms in complex forest ecosystems (Vasiljevic et al, 2005).

Adaptation to diseases caused by changes of the environmental conditions, can be viewed from several perspectives, in which a host plant and the pathogen are in specific conditions. Changing of the environmental conditions directly affect to the change of physiological processes and resistance in plants, and the pathogen adapts its life cycle and agressive, expressing them through pathogenicity.

The effects of all environmental factors (and the abiotic and biotic) depend not only ofthe species but also on the intensity of their effects on the body. Of course, all organisms have adapted during evolution to a certain range of the effect of certain factors. This means that any organism, be it plant, animal or micro-organism, evolving at a precisely defined range of environmental factors, optimum effect. Reduce or increase the effects of environmental factors in relation to the optimum range effect reduces life activity of the organism. When the effect of factors reaches a minimum value, there are no longer necessary conditions for survival and not possible future existence of the organism.

Influence of the most important environmental factors caused by the activity of abiotic and biotic factors on the occurrence and development of fungi epixylous, destroyers of timber

Decay fungi have a very active role in the destruction of forests, although they may not be the primary cause. In many cases, damaged trees survive, unless subsequently attacked by fungal organisms, primarily of wood decay. It is well known that a large number of decay behaves as a saprophyte and attacks harvested and processed wood, but it is also known that there are a number of parasites that are rotting and attack standing trees in the forest, some of which colonize and completely healthy and not physiologically weakened tree, which reinforces the importance of wood quality wood in the forest, or in forest economy in general.

Diagnosis is very difficult by incubation of fungi that inhabit completely healthy tree takes a long time, sometimes several years, the primary symptoms do not appear on the superficial, and the reproductive period (carpophores phenomenon), can be extended for a decade or more (Markovic, Tabakovic -Tosic, 2002). The appearance of fruiting bodies of fungi in the forest epixylous directly depended on climatic conditions during the year (activity fungus favors rainy and humid weather, so spring and autumn climate in our area be designated as a period of intensive cropping). However, the initial phase of decay is very difficult to establish, and it is only possible to review and pith so that the fragments are removed from the tree preslerovim drill, which is then placed on the appropriate selective media and analyzed in order to obtain pure cultures, but this measure only applies on valuable tree species (Karadzic, Andjelic, 2002). This means that in the presence of decaying forest notes only in the closing stages, when it is already largely made of wood decomposition and remains as the only measure of hygiene forest.

For achieving the main goal of forest hygiene is necessary to implement timely and appropriate phytosanitary measures, for which the prerequisite is knowledge of the main factors that influence on the occurrence and develop of these harmful organisms.

One of the main environmental conditions necessary for the development of fungal organisms is temperature. Minimum temperature values necessary for the development of most types of epixylous fungi are around 0^0C, up to about 40^0C, with some exceptions, as is the case with *Lenzites termophila* at 50^0C (Jačevski, 1933). Optimal temperatures are generally close to the maximum rather than a minimum of about 5 to 10^0C (Petrovic, 1980). When we are toking about extreme temperatures, it is important to emphasize that the decay at these temperatures must not lose vitality, because it also depends and of the other factors. As reported by several authors, fungi are generally more resistant to lower than at higher temperatures. According Jačevski (1933), carpophores of some fungi may retain vitality and over several years, although during the winter they were exposed to extremely low temperatures.

So spores of *Merulius lacrymans* retain germination 3 hours at a temperature of-3^0C, while *Coniophora cerebelli* mycelium remains viable at the same time at a temperature of-30^0C. Liese (1975) for example found that it does not individual cases, and that more than 30 species of fungi show resistance to the temperatures of-2^0C. Fruiting bodies with lower humidity and can withstand much lower temperatures, thus *Schizophyllum commune* and survives extreme low temperature of-175^0C. This shows that the type of resistance to temperature, has a significant role and humidity.

In terms of maximum temperatures for the development of epixylous fungi, it is difficult to make safer conclusions, but the most important thing that can be said that the importance of moisture in terms of resistance to high temperature of mushroom is high. Cartwright and Findlay (1946) found that the fungus resistance to high temperatures is primarily determined by the physical properties of the substrate and moisture content in it. It is well known that all living organisms, including fungi, show greater resistance to high temperatures, if the contents of moisture in the substrate are below. In addition, an important factor is the length of the effect of adverse conditions and high temperatures. As reported by Petrovic (1980), Schnell noted that at a temperature of 44^0C mycelium *Lenzites saepiaria*, *Lentinus lepideus* and *Trametes serialis* can remain viable in the tree 72 hours at a temperature of 55^0C 12 hours. At a temperature of 65^0C mycelium of these fungi in the wood specimens survive 1 hour, and nutrient media 9 hours.

Lower resistance to high temperatures have a great importance for the control of the fungus, because by increasing of temperature the timber can be sterilized. According to the literature, are recommended specific temperature for sterilization. Thus, the toughest wood recommended temperature of 62^0 with duration of exposure of 75 minutes, 82^0 for 20 minutes, or 100^0 for 5 minutes (Petrovic, 1980).

Between the boundary values of temperature, there is a temperature interval of development of the fungus. In this zone there is an optimum temperature of development, but it is not a mean interval of development. If that were the case, then the fungi were able to win wide climatic area, which is not the case in the nature, not only with mushrooms, but also with all other living organisms.

It is also important to emphasize that these temperature values are primarily related to the laboratory research, that under natural conditions, the actual value is always lower by 2 to 3^0.

When besides the temperature we take account and other factors that influence on the fungus development, then on the first place we must put moisture in the substrate (Petrovic, 1980). In nature, temperature and humidity tends to work in correlation, so the same moisture at different temperatures act differently. It is known that fungi in the wood can not develop if moisture content is lower than a certain percentage of between 10 and 20%. On this basis the possibility of saving wood from fungal attack. However, this applies only to the possibility of fungal attack, and not on the development of fungi that are already in the tree. Primary humidity can be reduced, but it fungi compensate in the decomposition of wood. According Gebisch-in (1959), the hyphae *Merulius lacrymans* from rhizomorphes can penetrate into the tree that contains only 5% moisture. This is explained by the ability of rhizomorphes that can take from the previous substrate the required amount of water to start their normal development and wood decomposition.

Relative humidity of air is also of great importance. According Bavendamm-in (1938), the air temperature of 24^0C, the wood will be dry air when the relative air humidity not exceeding 85%. The moisture content of air is of particular importance in the case of its frequent fluctuations, with the increased moisture content in the air, the outer parts of the wood may be affected, although the moisture content of the wood is low.

According to Scheffer-in (1940), and some *Lenzites* and *Poria* species retained the vitality of 3 years in wood with 12% moisture. Under laboratory conditions, the viability of certain species can be maintained much longer time. Certain species of *Trametes* and *Polyporus* stay vitale 2 to 5 years, even though the moisture content of wood was only 6 - 9%. The importance of air humidity can be seen from the data presented by the Cartwright and Findlay (1946). According to these authors, *Merulius lacrymans* may retain vitality 81 days if the humidity is 21%, and 343 days if the humidity is 77%. It is similar and at the fungus *Conophora cerebelli* and *Poria vailantii*.

It is of interest to note the importance of relative humidity for germination of spores. It is known that spores can germinate only in areas where the relative humidity of the air at least 92 to 95%, and the highest percentage of germination is if the humidity is approaching to full saturation. The vitality of the spores depends on several factors wich act simultaneously in the nature and complement each other, and one of the main factors is also a relative air humidity. If the air humidity falls below 90% spores after some period slowely completely lose vitality.

Another one of the abiotic factors that affect the development of epixylous fungus is light, but it have not such importance as there are in the development of higher plants. Montana (by Jačevskom, 1933) said that the light needed for fruiting mushrooms. The author cites the case of fungus *Lentinus lepideus* whose fruiting bodies formed in darkness have changed shape, size and color. On the other hand, the Mage (by Jačevskom, 1933) for the species, such as *Poria vailantii*, *Schizophyllum commune*, *Laetiporus sulphureus*, in the complete absence of light recorded very vigorous mycelial growth and destruction of the wood, but they are educated carpophores sterile. To a similar conclusion came and Elfing (according to Jačevskog 1933), cultivating mushroom of epixil mycelium on artificial nutrient media. This author noted that the absence of light fungi produce a large quantity of dry weight of mycelium.

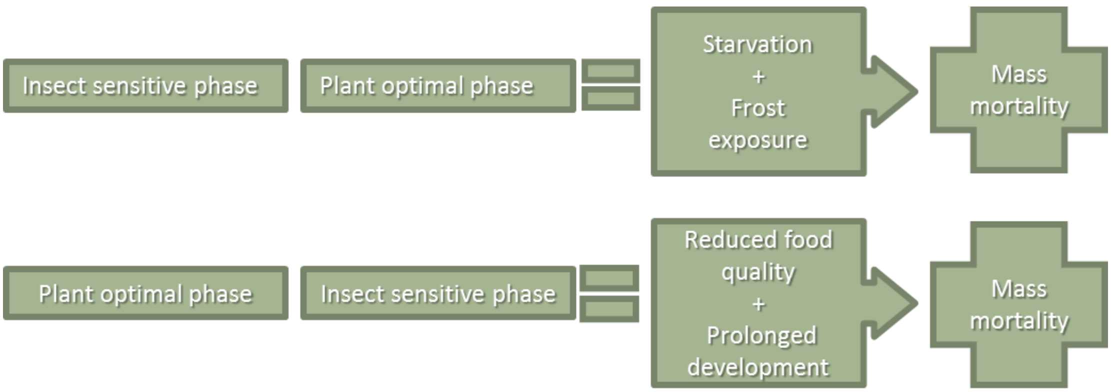
Of the most important biotic factors for the emergence and development of epixylous fungus in the forest, can be extracted anthropogenic factor. In order to preserve the timber, or reduce losses, primarily wood must be kept where it is and where it is formed and develops the largest number of harmful organisms - in the woods. Assuming that most of the loss was inevitable, due to the lack of complete control and prevention of the development of fungi and other organisms, many of them resulting from improper exploitation and failure to take protective measures (Markovic, Tabakovic-Tosic, 2002).

Under field conditions there are invariably environmental factors that greatly influence the occurrence and course of decay, and that is practically not be affected because they change depending on weather conditions and they can be classified above all abiotic factors. Another unchangeable factors that also has significance for the development of rot is soil type, as it was noted that wood rots quickly when in the fertile than the poor zemljšte. Other factors, which may affect in the forests, of which also depends the number and type of fructification fungi are primarily hygiene stands, as well as the composition and quality of the forest. Sanitary and phytosanitary measures which be implemented on the woods certainly have the most impact on the general health of the forest.

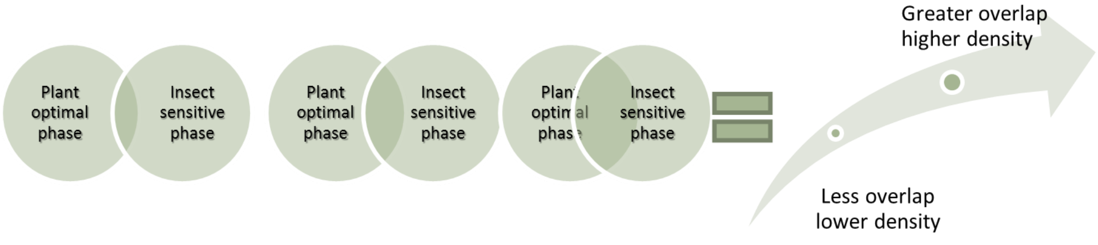
Improper management, numerous injuries to trees caused by careless handling during harvesting, greatly influence the occurrence and spread of decay fungi. For example, by carefully opening the circuit to prevent inflammation of the bark, which is very common in the beech forest, after which so often damaged wood colonizing by epixile fungi, then, we should not forget the mechanical injury to trees from destruction and attraction that opened the way for the colonization of decay etc.. On the other hand, regular sanitary felling and removal of fruiting bodies reduces the source of infection, thus preventing their spread, and the possibility for the emergence of new infections to a minimum, which significantly improves the general health of forests.

Influence of the most important environmental factors caused by the activity of abiotic and biotic factors on the occurrence and development of pests

On the quality of host affecting the external environment factors, which can vary in spatial and temporal planes and thus made differences in their suitability for food herbivornih insects. Many insects are not only specialized for a particular type of host, but also for the type of tissue. This is a huge risk, if the tissue is accessible only during a very short period of time, as is the case with the opening buds of perennial plants in temperate regions. There are differences in the timing of opening buds among populations of plants, which is geographically conditioned (Lawrence et al., 1997), as well as differences between individuals within a population (Hunter, 1992; Quiring, 1994), among the branches of a plant (Carroll and Quiring, 1994) and one branch buds (Quiring, 1993). This variation can affect the growth and survival of herbivore insects, and the strength of this effect depends on the previous experience of insects, the degree of specialization towards a particular type of tissue, the ability of dispersion and lifetime. Insect life stage in nature are synchronized with the appearance of the appropriate plant tissues during the season. This means that much of insect populations in most years can efficiently use of food resources. However, the resistance of plants may occur if the resources in their tissues that are important to develop insect, for some reason they are not synchronized with the main part of the insect population. Phenology of plants, in terms of morphological changes in the leaves during the growing season or elongation of shoots, is almost always accompanied by changes in the composition of the chemically. Changes in chemical composition that accompany aging in oak leaves are the typical example of the season, when there is a decrease in the concentration of protein and tannin concentration increases with increasing hardness (Feeny, 1970). Research Salminen et al., (2001) shows that the change concentration of tannins in the leaves of birch throughout the season effects on the growth of insects (Ossipov et al., 2001). So, what we commonly refer to as "phenological" trait is usually the chemical or physical nature (Larsson, 2002). A growing number of researchers who emphasized the importance of synchronization on successfully developing of insects, or the appearance of the corresponding phase in the development of plants at a time when the herbivore is able to maximize use (Hunter and Elkinton, 2000; Ivashov et al., 2002). Sometimes this optimal period, when plants are best suited to develop certain sensitive stages of insects, is very short and if there is a "disagreement," the consequences on herbivores developing can be drastic (Stoyenoff et al., 1994). Depending on whether it is a sensitive stage in the insect larval development occurred before or after the optimal stage for them in the development of plants we can expect different effects (Scheme 1 and 2). In the first case there will be a phase-sensitive phenomena in insect larval development before the onset of these optimal of plants that will prevent food due to lack of adequate food and lead to starvation. Insects usually can apply for a short period without food, but it will certainly affect on their development if they survive. There is also a great opportunity to be exposed to the negative effects of abiotic environmental factors such as late frosts, which is very often the case with early defoliator of oak. In extreme cases, the lack of food, can cause mass mortality. In the second case, when a sensitive stage in the insect larval development occurs after the optimal stage for her host plants, we have a situation with enough food that can not be used in an optimal manner due to reduced nutritional value. This as a result can have, as in the first case of complete failure or reduced food consumption and prolonged development, respectively. So we come to the SG-HM (slow growth - high mortality) theory which explains the negative effect of the slow growth stage on insect survival. Due to inadequate food diet comes a decline in growth, extension of development and long exposure of natural enemies leading to increased mortality.



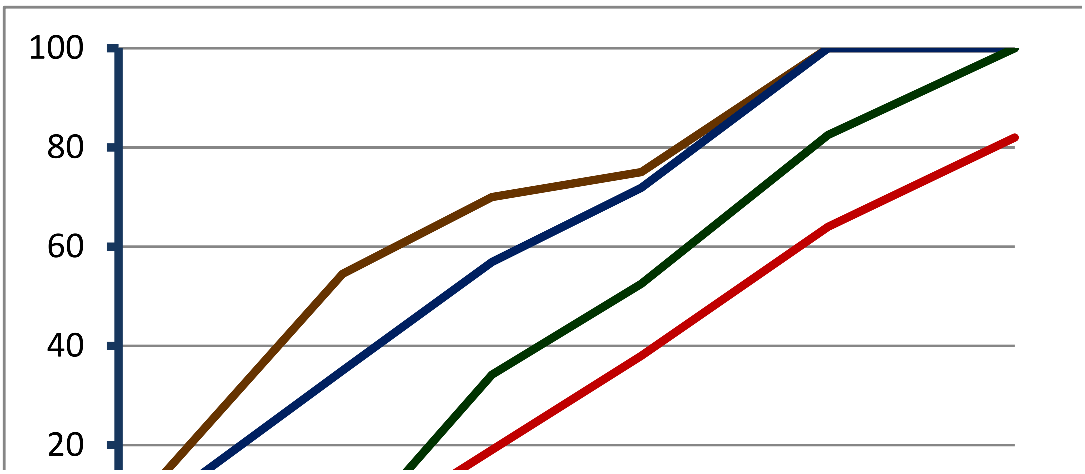
Scheme 1: Fully divergence appears sensitive phase in larval development stages of insects and optimum plant



Scheme 2: Different degrees of overlap in the sensitive phase of insect development and optimal plants phase affect different on population dynamics

Due to changes in environmental factors (eg, high average annual temperature due to climate change), can be expected to change the dynamics of populations of the gypsy moth, which can manifest itself directly, via its impact on the shortening of development, before sawing and start eating caterpillars and indirectly via its impact on its host key. The expected increase in temperature by the end of this century as compared to the 196-1990 range from 3 ° C in the northwest to 6°C on the south and in the Mediterranean basin (Fronzek et al., 2012). Previous studies have shown that for nutrition of gypsy moth the optimal host are hungarian oak, due to the best synchronization of start listing with the start of this type of caterpillar feeding (Milanovic, 2011). Scrolling of turkey and sessile oak begins at the end of March and early April, while the process in the case of pedunculate and hungarian oak moved to the end of the first week of April (Figure 1), when starts the mass sawing of gypsy moth caterpillar, which begin to eat at the same month. The question of coffee will leave consequences predicted rise in temperatures on gypsy moth and the relationships between the four major types of oak trees in Serbia. The question is what consequences predicted rise in temperatures to leave the relationships between gypsy moth and the four major oak species in Serbia.

Global warming will affect on the begining of listing all kinds of oaks and the beginning of the cutting process. However, the intensity changes in the phenology of these two different groups of organisms will not be identical. This is evident from the study of impaired synchronization between *Operophtera brumata* L. and oak in the Netherlands over the last two decades (van Asch et al., 2007). Oak and *Operophtera brumata* L. respond to an increase in temperature, but the reaction in the case of an insect is so strong start cutting move forward than in the case of host's, which lead to a distortion of synchronization.



Graph. 1: Development of foliage in April for the four most important species of oak in Serbia

In the case of the gypsy moth expected climate changes will impact positively on the synchronization of the analyzed species of oaks, it will be with his earlier sawing improve the performance on turkey, sesil and pedunculate oak. The presence of young leaves of various species of oaks over a long period in one area will reduce mortality due to starvation and increased fecundity of the gypsy moth, which will be reflected in the frequency and extent of an outbreak of this pest.

CONCLUSION

Environmental factors have been linked as a whole, mutually cause and change, and together as a complex effect on living beings. Organisms adapt to these changes in an attempt to survive. Therefore, each species is characterized by specific features which have arisen during evolution, are caused by hereditary factors and are referred as adaptation. Adaptations are always in accordance with the habitat they live in and maintain the character of the habitat.

Habitat is the area on the Earth with a specific combination of conditions of life (environmental factors).

A set of adaptive property, that occur in the body of one species, as answer on ecological factor impacts, makes environmental (ecological) form. Life forms, at first glance, indicates the environmental conditions to which the organisms are adapted. It is realized on the basis of possibility of genetic types in the course of long-term adaptation to environmental conditions.

The phenomenon that so far species have similar morphological and physiological features, indicating that they are similarly adjusted to the same environmental conditions, and have made the same organic form.

In the related species encountered quite different life forms because these species live in different environments.

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OVERVIEW OF SUSTAINABLE GOVERNANCE OF NATURAL RESOURCES AND NATURE CONSERVATION

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Abstract: *The transformation of sustainable management into sustainable governance of natural resources can be conceptualized as a social learning process involving scientists, experts, politicians and local actors, and their corresponding scientific and non-scientific knowledge's. Sustainable governance of natural resources thus requires a new space for communicative action aiming at shared, inter-subjectively validated definitions of actual situations and the goals and means required for transforming current norms, rules and power relations in order to achieve sustainable development. There is a gradual shift from administrative hierarchy and exclusively ecological criteria towards attempts to democratize biodiversity governance, with regard to both the policy processes and the policy goals.*

Key words: Sustainability, Effectiveness, Protected area, Serbia

INTRODUCTION

Conservation-based management is logistically and politically challenging because forests ecosystems are inherently complex and management decisions affect a multitude of groups. Forest ecosystems, in protected areas, provide an array of ecosystem services to different groups. Survey goals of conducted case studies provide illustrative insight into practical appliance of these objects as challenges. According IUCN[2] statements, Briefing note 7: if anything, "governance" is important for conservation well beyond protected areas, to encompass all that needs to be valued and well managed to maintain biodiversity and ecosystem integrity. Governance is about power, relationships and accountability. It thus has a major influence on the achievement of management objectives (effectiveness), the sharing of relevant responsibilities, rights, costs and benefits (equity), and the generation and sustenance of community, political and financial support for wise and sustainable use (sustainability).

"Governance" seems a fashionable term, which over the last years has become more and more important and is used in nearly every political and scientific research regarding regional development and nature conservation. However, there is still no common understanding of the term and a clear definition is missing. Furthermore, it is

[1] Institute of forestry, Belgrade, Serbia

[2] The International Union for Conservation of Nature is the world's oldest and largest global environmental organization. Founded in 1948 as the world's first global environmental organization, today it is the largest professional global conservation network. A leading authority on the environment and sustainable development, more than 1,200 member organizations including 200+ government and 900+ non-government organizations. Almost 11,000 voluntary scientists and experts, grouped in six Commissions in some 160 countries.

a complex term and it is used in different, complicated contexts and disciplines (Mehenen *et al*. 2009). Governance can be qualified in at least two major ways. One has to do with "type", the other with "quality". Governance of natural resources can be understood as the interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken, and how citizens or other stakeholders have their say in the management of natural resources-including biodiversity conservation.

Governance types:

From the same source IUCN, types of governance of natural resources can be distinguished on the basis of "who holds management authority and responsibility and is expected to be held accountable according to legal, customary or otherwise legitimate rights". Out of the broad context of all existing land and natural resources, which would take us very far, we are concerned here only with the governance of crucially important ecosystems and biodiversity, which demand strong and well-focused conservation efforts. It could be defined as:

- Governance by the government— Authority, responsibility and accountability rest with government ministry or an agency at national, regional or municipal level. The land and resources are subjected to use rules and regulations under the law, and often included as part of a system of protected areas. Management may be directly exercised or delegated but the government retains full ownership and control. At times, the government is committed to inform or consult other concerned parties prior to making management decisions.
- Joint governance by several concerned parties— Authority, responsibility and accountability are shared among a variety of parties, likely to include one or more government agencies, local communities, private landowners and other stakeholders. The parties recognize the legitimacy of their respective entitlements and chose or are required to collaborate. Examples include co-managed protected areas and conservation easements. Ecosystems designated for trans-boundary conservation and high-seas protected areas are other promising candidates.
- Private governance— Authority and responsibility rest with the landowners, which may exercise it for profit (e.g., tourism businesses) or not for profit (e.g., foundations, universities, conservation NGOs). Usually, the landowners are fully responsible for decision making and their accountability to the society at large is quite limited.
- Community governance— Authority and responsibility for managing the natural resources rest with the indigenous peoples and/or local communities with customary and/or legal claims over the land and natural resources. The communities have in placed some forms of traditional governance, or otherwise locally agreed organizations and rules. Land and resources are usually collectively owned and managed, but partial private or clan-based "ownership" can also be accommodated. Accountability to society at large remains usually

limited, although is at times achieved as a counterpart of recognized rights or economic incentives.

Discussion about governance types could be leads in several directions, one is: while no governance type is in principle superior to another, under similar circumstances different types are likely to produce different conservation outcomes. Importantly, they also tend to produce different equity outcomes. Equity is related to a fair share of the relevant costs and benefits of conservation and to the opportunity of participating in decision-making on the basis of entitlements and rights— both of which depend upon who holds decision-making authority and responsibility and whether and how those are held accountable.

Following Rose and Miller it can be conclude that focus on natural resource management generally obscures the dimension of governance (Rose and Miller, 1992): the aim of a management focus is to define regulations, procedures and technologies, and these are based on tacit conceptions of the relationship between humans and nature that shape the norms, values and power relationships which govern management structures. Management structure in conservation areas in Serbia are mainly formulated by state enterprises. State enterprises are established on government initiative and its business directly dependent from government decisions. Research on organization of state forest enterprise and its influence on capacity to manage nature protected areas show that there is a need to understand how specialization runs as a process. It implies knowledge management of employees in state enterprises as well as flowing of information inside forest enterprise, together with interactions between enterprise and other actors with tendencies managing toward governance of protected areas.

Beside state enterprises in management of conservation areas local people are involved, non-government organizations as well other institutions and business or non-business entities. Communications have crucial importance in settings like these, where menu different actors playing important role in protected areas. As the different groups of actors usually rarely share the same norms and values, with frequencies of an unequal distribution of power among them, this often leads to conflicts about natural resource use and management, and hinders sustainable development (Berger, 2003).

The well-known concept of „sustainability“ is under researcher concern but from specific aspects. Norms and values of sustainability in modern society, especially in transition economies rapidly changes planned actions to participative actions. Different actors are no more parts of plans but they through participation and communication build those plans. This understanding how the norms and values of ‘‘sustainability’’ can be concretized in specific situations where actors can move from strategic action to what communicative action (Mitrovic, 1999).

SOCIAL LEARNING PROCESS

The transformation of sustainable management into sustainable governance of natural resources can be conceptualized as a social learning process involving scientists, experts, politicians and local actors, and their corresponding scientific and non-scientific knowledge's. Knowledge management in state enterprises resulted in innovative organization, processes and products as well as services. The same process of enlargement of knowledge in local population especially through development projects should force transformation of norms, values and power relationship.

Management of public resources like forests and forest land in nature protected areas is no more concern of State enterprises and planed economy. It became mutual communicative process between all actors. A development of area under protection and conservation is no longer considered as a process purely driven by governments, bureaucracies, and markets alone: it is understood in terms of governance rather than government (Rist, 2007).

Governance can be defined as ''emerging new forms of collective decision-making at local level which lead to the development of different relationships, not simply between public agencies, but between citizens and public agencies'' (Goss, 2001).

The shift from the government to the governance paradigm also implies a modification of the concept of participation, which now points beyond formal democratic representation. Indeed, if development is understood as the outcome of interaction between multitudes of highly diverse social actors, the existing social and political spaces need to be reshaped in order to allow collective action to reach beyond the formal system of present states. Participation is thus not an end in itself but a means to facilitate processes of deliberation between different categories of actors, who collectively use and broaden public spaces, based on the principles of fairness. This double transformation is necessary to achieve the kind of sustainable development the actors are pursuing (Webler and Tuler, 2000). Such a perspective of governance is based on the (implicit) belief in the possibility of collective action through an intensification of interaction between the actors involved at all levels. Within the context of natural resources, more intense interaction between the actors involved has proven to be closely related to a more reflexive construction or renewal of personal and collective identities (Carroll and Bebbington, 2000; Goodwin, 1998). In terms of social action, this contributes to a more reflexive relation to the basic patterns of interpretation involved in shaping the relationship between humans and nature. This leads in turn to a critical revision of the norms, rules and power relations through which the actors involved define the ways in which natural resources should be used (Platteau and Abraham, 2002; Tait and Campbell, 2000).

The more prominent focus on power issues inherent to dealing with natural resource use allows all those involved to better perceive the link between knowledge and power.

GOVERNANCE OF NATURAL RESOURCES - Case studies

In order to translate the principles of sustainable development into institutional practices while taking into account the increasing importance of non-state actors, it is necessary to accept that relations between actors are based less on ‘command and control’ models of policy-making and more on giving importance to communication, deliberation and negotiation.

Sustainable development implies to move beyond a simple aggregation of individual preferences. This is especially important in the case of sustainable use of natural resources, where the principle of sustainability calls for taking into account the needs of ‘‘present and future generations.’’ Since future generations cannot participate in the current negotiation processes regarding natural resource use, policy models must explicitly go beyond unilateral privileging of the pursuit of self-interest (of present generations).

Trough participation process in Serbia present generations agrues that thay are able to sustainable use natural resources. The base for this arguments could be found in the fact that all generations of local population perseve nature from past to preset. Especialy in nature protected areas where all values that nominate nature to be so special to become legaly proceted orginate from past generation who was awere what is sutainable/everlasting princip in nature utilisation.

Successful sustainable-based management of forest ecosystems requires incorporating scientific information and the knowledge and views of interested parties into the decision-making process. This paper therefore serves as a context for the local studies that follow - Case Study 1 performed in National Park Tara and Case Study 2 – conducted in Nature Park Golija. The study was carried out within the Project TP-31070: “The development of technological methods in forestry in order to attain optimal forest cover”, financed by the Republic of Serbian Ministry of Education and Science, and within FOPER II, Research Project :„Governance assessment in the management of protected areas in the South Eastern European region“ .

Surveys were done by qualitative data collecting through in-depth interviews with all stakeholders’ representatives’ (scientists, forest enterprise employees, environmental non-governmental organizations (NGOs) and local communities’ members). Quantitative research was based on structured questionnaires and conducted by getting the feedback from completed forms sent and returned through postal service.

In a case study from Tara and Golija, investigation leads to the potential of applying forest ecosystem services as a common language for conservation-based management. The large investments needed if loss of biological diversity is to be stemmed will likely lead to increased public and political scrutiny of conservation strategies and the science underlying them. It is therefore crucial to understand the degree of consensus or divergence among different stakeholder’s perceptions and strategies most likely to achieve given objectives. With regard to conservation strategies, scientists, forest enterprise employees, environmental non-governmental organizations (NGOs) and local communities' members most often viewed and fully understand how people and nature interact in certain contexts and the role of biological diversity in maintaining ecosystem function as their priorities.

Estimating the provision of protected areas forest services under alternative management schemes offers a systematic way to incorporate bio ecological and socioeconomic information and the views of individuals and groups in the governance policy and management process. Employing ecosystem services as a common language to improve the process of ecosystem-based management presents both benefits and difficulties. Benefits include a transparent method for assessing trade-offs associated with management alternatives, a common set of facts and common currency on which to base negotiations, and improved communication among groups with competing interests or differing worldviews. Yet challenges to this approach remain, including predicting how human interventions will affect forests, how such changes will affect the provision of ecosystem services, and how changes in service provision will affect the welfare of different groups in society.

DISSCUSSION AND CONCLUSIONS

Main characteristics and scopes of governance in forests of protected areas are protection of biological diversity and its cultural and spiritual values. Unfortunately, its usefulness to humans has low priorities at the first site. Therefore it is common practice that many policy makers do not fully support the utilitarian concept of forest services. There are three primary elements of institutional theory: the nature of the institutional environment in which individuals operate, institutional incentives created by human and organizational behavior, and institutional change. There are three interrelated determinants of the institutional environment: formal institutions, informal institutions, and enforcement (Prato and Fagre, 2005). Many scientists expressed a willingness to consider conservation triage, NGO's members engage in active governance conservation interventions, considering reframing conservation goals and measures of success for conservation of biological diversity in an era of climate change. Local community members and forests enterprise employees defend attitude that nature conservation propositions often stay in discontinuity with economic benefit from forests, and that these two needs to be in a reasonable, but sustainable relations. Although some heterogeneity of opinion is evident, results of the survey show a clear consensus within the scientific and others stakeholder community on core issues of the extent and governance scope changes in a goal avoidance of forest coverless and biological diversity loss. There are many mutual attitude elements that may contribute to successful conservation strategies in the future.

One of the main transition consequences which consider environmental was actions such as the switch to a market economy. It has been considered generally advantageous for the environment because the region's resource endowment is not suited to heavy industry and market driven restructuring has increased the role of services which are generally less polluting. Democracy should require governments and entrepreneurs to give higher priority to environmental matters in the context of more intense and diverse development pressures when comes to any type of protected areas-exploitation's income (Pavlinek and Pickles, 2000).

The balancing of economic, social and environmental issues makes the politics of the region a fascinating study. It is often said that optimism in the early days gave way to disillusionment when it was realized how much there was to be done. However, there is strong external support and the present mood of realism is soundly based on the belief that steady progress can be achieved (common opinion of all parties).

Protected Areas Current Governments bodies should take significant initiatives, notably in identifying priority areas with severe pollution problems and its causers. The system could be based on the principle that polluters are legally responsible for the damage they cause and that payments will contribute to an effective system of environmental protection.

Typically work is divided between ministries which determine policy and environment commissions (scientific community, environment experts…) which are responsible for implementation. Further, they should be authorized and accredited for monitoring of PA nature ecosystems vitality condition and to constantly oversee protected areas coordinating activities relating to biodiversity and conservation of natural ecosystems.

Much responsibility for environmental control rests with local government. This is a helpful trend that local authorities in PA now have responsibilities for water, sewage and waste management. Effective local government means that environmental issues can be addressed in a more responsible and practical way because self-governments can directly assess the relative importance of different needs expressed by local populations', even if experience and expertise is lacking.

Sustainable development of local rural settlements requires: conventional balance between natural and built environment; retention of historic styles and traditional appearance; with national and community values.

The forestry programme on eroded land should be maintained in such areas for example by implementation of smaller hydropower projects which should be implemented to control flood hazards. In areas like Tara catchment-upper river flows fast the need for protection may restrict logging or even close down operations altogether. But attention to tourist pressure will also be needed as well as remedial action to rebuild forests ravaged by pollution and overcutting. In this way the protective role of woodland can be enhanced. At the same time forest management needs to be more mindful of ecological interests that wish to restrict clear-felling and safeguard old woodlands and virgin forests.

Modern Protected areas are recognized as nature expanses proclaimed to rebuild damaged environments which had gone hand in hand with recognition of the regions generally with high biodiversity value and the need to strengthen conservation activities. There is often a case that conventional reserves are inadequate and that larger networks are needed to conserve rare species. National parks and protected landscape areas connected by same governance principles and bodies could provide one model - including large biosphere reserves which cover clusters of nature reserves (Golija-Studenica).

Creating space for ‘Natura 2000’ (Google 1) postulates implementation should provide benefits of this comprehensive network of reserves through building existing areas into which should be a major contributor to safeguarding the region’s biodiversity.

NGOs usually tend to lose credibility through lack of their capacity to do no more than demonstration of results that could be secured quickly. Their main drawback is inability to impose in public as understandable and ‘constructive opposition’ and they could easily be seen as compromising economic progress through ‘unrealistic’ demands for strong environmental standards. Emphasis of existing NGOs could be placed on conservation and environmental education for young people organized through projects at local, regional and national levels.

Today management of nature protected areas in Serbia reliance on government, state enterprises and local population. All of these actors have own arguments in a way how to sustainable manage by protected areas. Government is driven by normative acts like Biodiversity and Water Policies, Habitats Directive, Natura 2000, etc. State enterprises retain market approach where the wood is still main and most frequent product. Local population e.g. rural population tent to achieve economic development through eco-tourism, bending of products as well utilization of own resource in protected areas. Rural population is close to ideas of economic development instead of conservation. Theoretically this triangle could be governance using communicative action shift from strategic to communicative reasoning requires specific conditions that are inspired by ‘ideal speech conditions’. This implies the possibility of questioning any proposal, expressing any new idea, need or wish, and ensuring that symmetrical distribution of opportunities and capacities of expression of all participants are given; this will make it possible to coordinate action determined by ‘good reasons’ and the ‘force of the better argument’ (Mitrovic, 1999).

Sustainable governance of natural resources could be understood as creating new room for a more communicative definition of the shared, inter-subjectively validated descriptions of the present situation and the goals and means required for transforming present norms, rules and power relations in view of achieving sustainable development (Rist *et al*. 2007) .

For sustainability-oriented research, this means that it is necessary to analyze the driving forces and conditions that enhance and hinder social learning and negotiation processes, with the aim of opening space for more communicative action allowing re-defining the norms, rules and power relations that impede a more sustainable use of natural resources.

General conclusion that Serbia's Case Studies confirmed, is that 'sustainable development cannot simply be 'delivered' by politicians and officials, and that it demands an active and creative input from all sectors of society' (Lafferty and Meadowcroft, 2000). Yet the culture has changed and a web of new institutions and procedures will make it increasingly difficult for abuses to go undetected for all resistant's to the gospel of sustainability. These in Serbia for now could be expected just for some main environmental targets, but which should be met at least in significant degree and substantial share in near future.

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STUDY RESULTS AND THE CONTRIBUTION OF THE INSTITUTE OF FORESTRY TO ENVIRONMENTAL PROTECTION AND IMPROVEMENT IN SERBIA

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Abstract: *The paper presents previous key activities of the scientific-research department 'Environmental Protection and Improvement' at the Institute of Forestry in Belgrade.*

Key terms: Institute of Forestry, research, environmental protection

INTRODUCTION

Since its establishment, throughout the entire period of activity, the Institute of Forestry has been committed to the improvement of the environment.

The final results of all scientific-research and other projects have been aimed at preserving and improving the quality and functions of the existing forest ecosystems and increasing forested areas in Serbia, in compliance with natural-geographic, climatic and other characteristics.

The encompassing the issues of urban forests and other categories of urban green areas, points to a conclusion that the principal aim of the Institute's entire activity is contribution to creation of ecologically, economically, aesthetically and functionally favourable living conditions in Serbia.

However, as a result of an intention to focus scientific-research departments on addressing particular, specialist scientific issues, a separate Department of Environmental Protection was established in 1999, in the framework of the last reorganisation of the institution.

All scientific-research departments and laboratories of the Institute of Forestry co-operate on accomplishing relevant tasks; additionally, researchers from several departments, if required, form teams that work on specific scientific-research and other projects.

From 1985 to 1999, the present members of the Department of Environmental Protection mainly worked at the scientific-research department 'Landscape Architecture', whereas from 1980 to 1985 they were engaged at the scientific-research department 'Forest cultures, plantations and nursery production'.

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PRIMARY FIELDS OF WORK OF THE DEPARTMENT OF ENVIRONMENTAL PROTECTION

The Department of Environmental Protection is involved in a broad range of studies. Among others, they include:

- Environmental protection and improvement;
- Biological re-cultivation of barren soil deposits of opencast mines;
- Afforestation of deposols (barren soil deposits) and other anthropogenically disturbed soils;
- Landscape design of areas degraded by opencast mines;
- A multi-functional post-exploitation use of areas degraded by opencast mines;
- Soil and water phytoremediation;
- Development of various categories of green areas;
- Urban forestry;
- Substitution of fossil fuels by renewable energy resources – biomass production and use;
- Sustainable development;
- Decorative dendrology;
- Nursery production;

RESEARCH PERSONNEL

The Department of Environmental Protection employs six full-time researchers, holding different scientific and research titles.

The researchers holding scientific titles are:

Dragana Dražić, PhD Principal Research Fellow

A Head of the Department. Obtained her Master Degree at the Faculty of Forestry in Belgrade in 1989. Defended her doctoral dissertation ’A study of the condition and functionality of the Kolubara basin barren soil deposits, re-cultivated by afforestation with a view to obtaining a more quality environment and their recreational use’ at the same faculty in 1998.

During the course of her scientific-research work, she has published 172 scientific papers in the field of environmental protection and improvement, sustainable development, biological re-cultivation of anthropogenically degraded stands, landscape design and multi-functional use of landscapes, urban forestry, decorative dendrology, nursery production.

Milorad Veselinović, PhD Senior Research Associate

Defended his master thesis ’Determining the optimum time of picking, collecting, preparation and sowing of silver lime *(Tilia tomentosa* Moench.) seeds in seedling nurseries’ in 1990, while he defended his doctoral dissertation ’Morphological, anatomical and cytological changes, effected by air pollution, of the species *Pseudotsuga menziesii* (Mirbel.) Franco in the cultures on the barren soil deposit of the Kolubara coal basin’ at the Faculty of Forestry in Belgrade in 2006.

During the course of his scientific-research work, he has published 160 scientific papers in the field of forestry, landscape architecture and environment protection.

The researchers holding the title Research Assistant are:

Ljiljana Brašanac – Bosanac MSc

Recognising the fact that a sustainable development policy indicates a new social approach to the environment, space and natural resources, which involves a relevant degree of responsibility for next generations, Ljijlana Brašanac-Bosanac’s master thesis ’Sustainable development of forest ecosystems and their role in environmental protection’ (Faculty of Geography, University of Belgrade, 2003) emphasised the need for the establishment of sustainable management of forest ecosystems; elaborated the most important functions of forests and forest ecosystems from the aspect of environmental protection; presented the condition and future prospects of the Serbian forests; pointed out to the need for implementation of assumed international obligations, arising from the adopted declarations and conventions; and proposed the basic principles and requirements that must be met in order to attain sustainable development of the Serbian forest ecosystems.

As forest ecosystems belong to a type of natural system estimated to be exposed to the adverse impact of climatic changes in all world regions and, therefore, in Serbia (which will call into question their sustainable development), a need has arisen for conducting a new study, the results of which will be presented in her doctoral dissertation ’The role of forest ecosystems in Serbia in protection of environment against adverse impact of climatic changes’. More specifically, a subject of the study of this doctoral dissertation is the interaction of climatic changes, forest ecosystems and the environment in Serbia, while the principal aim of the study is to emphasise the importance of forest ecosystem for the environment, particularly from the aspect of mitigation of adverse impact of climatic changes, and to stress the need for implementation of the ‘so-called’ adaptable forest management in practice. The results of this doctoral dissertation represent the continuation of her master thesis research, have an applicable character and can be used as a guide for pursuing various activities within Serbian state and privately-owned forests, aimed at attaining optimum multi-functional use of forest site and stand potentials and, in consequence, enhancing a positive impact of forest ecosystem on climatic changes and the environment in general, and realising the sustainable development of forest ecosystems in near future.

The results of previous studies have been exposed through 46 scientific and expert papers in international and domestic journals and presented at conferences and meetings in Serbia and abroad.

Milijana Cvejić MSc

Obtained her Master Degree at the Faculty of Forestry in Belgrade with the thesis: 'Valorisation of recreational potentials of the Belgrade urban forest 'Košutnjak'. She has begun work on her doctoral thesis 'The role and importance of urban forests in sustainable development of cities, the Belgrade example' at the same faculty.

During her previous scientific-research work, she has published 13 scientific papers in the field of environmental protection and improvement, landscape design and multi-functional use of landscapes and urban forestry.

Nevena Čule, graduated engineer

Obtained her Bachelor Degree at the Faculty of Forestry in Belgrade with the thesis: 'Constructed wetlands for treatment of domestic waste water'.

In the framework of her doctoral thesis, she examines the possibilities for use of Indian shot (*Canna indica* L.) for lead removal from polluted media. Based on the literature data and experiments in the framework of previous studies, it has been established that this decorative plant possesses an exceptional efficiency in the removal of heavy metals and other pollutants from contaminated waters. Additionally, this plant can be used for phytoremediation, since it has a potential for production of considerable quantities of biomass in a short time. In the framework of the initial research, Indian shot proved to be a plant tolerant to absence of nutrient matter in solution and planting and cultivation of which are easy. During these experiments, a total absence of pests and diseases that could threaten the plant has been established. For the purpose of determining *Canna indica* L.'s potential for phytoremediation of waters polluted by heavy metals, several trials have been established. For a trial purpose, adult Indian shot seedlings were individually transferred to containers with a 50% modified Hoagland solution. After a period of one week, lead, in three different concentrations in form of lead acetates ($Pb(CH_3COO)_2 \times 3H_2O$), was added to the nutrient solution. Following the collection of specimen, a plant division into a root, rhizome and the above-ground part, along with the specimen preparation, various analyses were performed. A lead concentration in plant tissues was determined by means of ICP-AES spectrometer; a plant potential to absorb lead from the planting medium, along with a plant potential to translocate the absorbed metal from the root to the above-ground parts were determined by means of histological and ultra-structural analyses of the individual parts of Indian shot. The obtained results will be statistically processed.

During her previous scientific-research work, she has published 50 scientific papers in the field of phytoremediation, environmental protection and improvement, sustainable development, biological re-cultivation, anthropogenically degraded stands, landscape design and multi-functional use of landscapes, urban forestry, biomass production, decorative dendrology and nursery production.

Suzana Mitrović, graduate engineer

Obtained her Bachelor Degree at the Faculty of Forestry in Belgrade with the thesis: ‘The system of mountain bike trails on the mountain Povlen’.

Working on her doctoral dissertation ’A phenotype stability of *Paulownia elongate* and *Paulownia fortunei* seedlings in different stands’ in the framework of the ’Seed production, nursery production an afforestation’ module at the Faculty of Forestry in Belgrade.

The increasing demand for wood, as a raw-material for different purposes, imposes a need for establishment of fast-growing tree plantations of different types. Numerous research studies are focused on fast-growing species of the *Paulownia* genus.

The study of fast-growing species potentials is of considerable importance for the efforts that are being made to resolve the global warming issue. The absorption of already emitted CO_2 by means of plants represents one of the methods where fast-growing species have a special role.

The above-stated facts justify the increasing interest for a study of successfulness of the adaptation of fast-growing species to domestic conditions. Species of the *Paulownia* genus are characterised by fast-growth, particularly in first 15-20 years of life. The growth rate mainly depends on stand conditions. In addition to the exceptionally rapid growth, the species of the *Paulownia* genus produce large quantities of leaf mass per year, which absorbs large amounts of carbon-dioxide.

Due to a large leaf mass, rich in nitrates, leaf waste of this species has a very pronounced ameliorative role in the improvement of soil quality. By a several-year long ploughing of the fallen leaves, of the cultures of 20 years of age, a suitable soil for establishment of vegetation is created, even in the areas previously covered by sand or in degraded areas.

A subject of the study of her doctoral dissertation is an investigation of a stand and nourishment impact on morphological characteristics of *Paulownia elongata* and *Paulownia fortunei* in different phases of their growth, with the aim of obtaining more quality plants. These investigations are conducted with a view to determining optimum methods of establishment of plantations, aimed at enabling successful introduction in Serbia of this exceptionally important fast-growing species.

During her scientific-research work, she has published 34 scientific papers in the field of environmental protection and improvement, sustainable development, biological re-cultivation of anthropogenically degraded stands, landscape design and multi-functional use of landscape, urban forestry, biomass production, decorative dendrology and nursery production.

As can be seen from the above, apart from Lj. Brašanac Bosanac MSc, who is a graduated landscape designer (Faculty of Natural Science and Mathematics), all other researchers graduated from the Faculty of Forestry in Belgrade, Department of Landscape Architecture, but are of different sub-specialties.

COLLABORATION WITH THE REPUBLIC OF SERBIA MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGICAL DEVELOPMENT – IMPORTANT SCIENTIFIC-RESEARCH PROJECTS

Before the establishment of the Department of Environmental Protection , its current researchers participated in numerous joint projects of the Institute, in the framework of which they had special sub-projects, themes and tasks, such as:

’A study of ecological basis for spatial organisation and improvement of the environment of the city of Belgrade area’, Belgrade Basic Community of Science (1985 - 1987), with special themes:

- ’A study of ecological basis aimed at determining optimum standards with respect to planting greenery and protection of living and working environment in the proximity of industrial facilities of REIK Kolubara’,
- ’A study of vitality, decorativeness and the health condition of park vegetation’,
- ’A study of functional and other values of green areas at primary schools in the Belgrade area, in the light of biological aspects’

’A study of the vegetation of the Belgrade area, as an environmental protection and improvement factor’ Belgrade Basic Community of Science (1986-1990) with special tasks:

- ’A study of the air pollution impact on green areas and dendroflora in the proximity and the broader zone of industrial facilities of REIK Kolubara’
- ’Determination of optimum standards for plantation of greenery in the proximity of industrial facilities’.

’Studies of condition and functionality of green areas in spas and schoolyards within industrial towns in north-west Serbia, aimed at improving and protecting the environment’ Belgrade Basic Community of Science

In the framework of this project, the following special themes were selected:

- ’A study of the condition of the existing park vegetation in spas in north-west Serbia, aimed at improvement of tourism development conditions’.
- ’A study of the condition and functionality of green areas in schoolyards in industrial towns of north-west Serbia’.
- ’A study of the optimum methods for vegetative and generative propagation of decorative trees and shrubbery’

’A study of development, productivity and functionality of newly-established forest ecosystems and the vegetation impact on ecological changes on barren soil deposits of REIK Kolubara, aimed at attaining optimum use of these anthropogenic landscapes’ Republic of Serbia Forest Fund (1993-1994).

Since its establishment as a separate scientific-research department, the Republic of Serbia Ministry of Education, Science and Technological Development (formerly the Ministry of Science and Environmental Protection, the Ministry of Science and Technological Development) with the participation of study result users, financed the following projects that involved the engagement of the department researchers. Only a part of them will be presented:

Technological Development Project (12M22): ’A study of endangered and degraded forest ecosystems, aimed at enhancement of their stability, multi-functionality and economic value’- sub-project IV: ’Determination of optimum methods for re-cultivation of barren soil deposits of opencast coal mines and ash disposal sites of thermal power plants;

Technological Development Project (BTR.5.06.0537.A): ’Multi-functional valorisation and improvement of anthropogenically degraded stands’, which involved engagement of 22 researchers from six institutions (2002-2004).

A large scale opencast exploitation of ore resources is becoming increasingly intensive in Serbia. The largest areas in which opencast exploitation is practised are the lignite mines, the exploitation of which severely threatens environment through use of lignite as an energy resource. The lignite processing releases vast amount of carbon-dioxide and other green-house gases, contributing to accelerated warming of the atmosphere, with catastrophic consequences on disturbance of climatic manifestations, adverse impact of which can be already felt today. In the course of opencast exploitation, natural vegetation and other ecosystems are destroyed.

Figure 1. Field ‘D’ in the Kolubara coal basin

In the technology employed in the opencast lignite exploitation in Serbia, overburdening of barren soil deposits is performed in a non-selective manner, which results in an occurrence of mixed or partially grouped layers of overburden from various geological periods on the surface of barren soil deposits, whose physical-chemical properties range from sterile inert sands of the Pontian geological period to heavy clay Pliocene substrata, of a very adverse hydrological and mineralogical composition. Thus deposited pedosubstrate, of degraded structure and water-air regime, is very unfavourable in terms of survival of plants established in the process of biological re-cultivation by means of afforestation.

Figure 2. Mixed overburden layers on the final slope at the barren soil deposit ’Tamnava istočno polje’

Following the trial studies on application of various methods, technology and selection of tree species intended for afforestation, based on the agreement with the Kolubara Mining Basin, the Institute performed afforestation of the post-exploitation area covering over 1,000 hectares, attaining a considerable success with respect to survival of established plants. Today, these areas are remarkable anthropogenic forest ecosystems with mixed forests.

Figure 3. A pond and forest cultures in the proximity of a seedling nursery in Baroševac

Following a long-term collaboration with the Kolubara Mining Basin, which was particularly intensive in the period 1975-1991, along with a performance of pedological research of physical-chemical and microbiological properties of barren soil deposits – non-selective overburden of barren soil deposits, disposed on post-exploitation areas of the mines ’A’, ’B’, ’D’ and ’Tamnava istočno polje’, the Institute was engaged to prepare numerous execution projects on forest-biological re-cultivation by afforestation, involving several species of broadleaves and conifers, in compliance with micro-ecological conditions of anthropogenically created stands characterised by different properties of pedosubstrate surface layer, along with development of post-exploitation landscapes.

Additionally, the Institute was engaged to conduct biological re-cultivation by means of afforestation of 1,000 hectares of post-exploitation areas, which was, in its most part, performed in the period 1976-1991, by means of plantation of seedlings produced at the Institute’s nursery that was established on the barren soil deposit, and on, for that purpose developed and ameliorated, areas of the post-exploitation mine in Baroševac.

Apart from the above-stated afforestations, numerous execution projects and works have been performed with respect to a landscape design of industrial and working facilities of the Kolubara mining basin, protection belts, schoolyards, children nurseries, hospitals, monument parks and other public facilities in the area of municipalities of Lazarevac, Lajkovac, Ub and Obrenovac.

The landscape design of free areas in the proximity of working and industrial facilities – coal processing plants, thermal power plants, equipment maintenance workshops, administrative buildings and other accompanying facilities, contributed to a large extent to the enhancement of the quality of the environment and the immediate surroundings. Newly-established forest ecosystems and all other green areas significantly contribute to mitigation of adverse impact of numerous pollutants.

Three doctoral dissertations and several master theses have been defended, two monographs have been designed, and numerous papers have been published in Serbia and abroad, on the subject of the study results of biological re-cultivation of opencast lignite mines.

The studies proved that opencast mines only temporarily destroy natural ecosystems located above the lignite deposits, while biological re-cultivation and landscape design of post-exploitation areas can create new anthropogenic vegetation and other ecosystems of richer biodiversity and biotope, suitable for spontaneous population by different plant and animal species. The entire landscape entity with altering forest, aquatic, grass-meadow and other ecosystems, becomes more versatile, valuable and multi-functional than it was prior to the exploitation.

It is an internationally recognised fact that the work on establishment of forest, agricultural, aquatic and other ecosystems on post-exploitation areas of the Kolubara-Tamnava lignite basin, is ranked along with large-scale contemporary mining systems, which pay great attention to restoration of devastated natural ecosystems and environmental improvement.

Project in the field of National Energy Efficiency Programme (NPEE 273015): ’A study on the possibility for biomass for energy production from forest short-rotation plantation in the areas degraded by opencast coal exploitation’ (2006-2009) and Technological Development Project (TR 18201A):’ A study on the possibility for biomass for energy production from short-rotation plantations in the framework of the Serbian electro-energy systems’ (2009-2010). Project leader: Institute of Forestry-Belgrade. Project collaborators: The Agricultural Faculty and the Institute for Multi-Disciplinary Research. Study result users: J.P. ‘Srbijašume’and P.K. ‘Kolubara’. Based on a timely recognition of the importance of a substitution of non-renewable fossil fuels by alternative renewable energy sources, studies on the possibility for biomass for energy production by establishment of short-rotation plantations of fast-growing woody species, were proposed and approved by the former Ministry of Science and Technological Development, in the framework of National Energy Efficiency Programme.

Given the previous several-year long experience, gained through studies and practical application of the obtained results in the field of biological re-cultivation by afforestation, the makeover of post-exploitation areas and determination of the possibility of their multi-functional use in the area of the Kolubara and the Kostolac lignite basins, the Ministry of Science, in the period 2006-2009, financed the studies on the project ’Possibilities of biomass for energy production from forest short-rotation plantations in the areas degraded by opencast coal exploitation’. These studies were extended to thermal power plant ash disposal sites and areas around long-distance power lines, which resulted in the integrated inclusion of Serbian electro-energy system potentials – lignite exploitation, biological re-cultivation of barren soil deposits (deposols), and establishment of energy plantations on post-exploitation areas, within thermal power plants and electric transmission systems. The continuation and extension of the scope of the study were carried out in the period 2009-2010, with a project ’A study on the possibility for biomass for energy production from short-rotation plantations in the framework of the Serbian electro-energy systems’.

The objective of the study was to determine the possibility for biomass for energy production from short-rotation plantations in the framework of the Serbian electro-energy systems.

Figure 4. Production cycle: establishment of short-rotation plantations- intensive tending, protection and nourishment- biomass harvest-biomass processing- storing and transport- use in the energy plant

The studies identified the potentials and the scope for biomass production in fast-growing dendroflora plantations and plantations of perennial herbaceous plants on barren soil deposits (deposols), opencast coal mine water areas, thermal power plant ash disposal sites and around the electric-transmission systems (long-distance power lines) in Serbia.

An additional objective of the study was to increase representation of biomass energy, thus, to facilitate a partial substitution of fossil fuels, pursuant to the provisions of the Kyoto Protocol and other international agreements.

Ecologically and economically most suitable tree species were determined for establishment of fast growing short-rotation plantations, and perennial herbaceous plants for plantation in degraded areas and in the proximity of newly-established water areas, at thermal power plant ash disposal sites and around long-distance power lines.

A technology of establishment of plantation was determined. A selection of optimum culture, tending, protection and nourishment measures, aimed at obtaining highest amounts of best quality biomass, was performed.

Possibilities were explored for use of waste sludge created in coal processing as a no-cost growth stimulus (fertiliser), along with possibilities for phytoremediation of contaminated substrata. The most cost-effective solutions were determined, along with a possibility of employing local workers and excessive labour force that was made redundant in the process of restructuring of energy field public enterprises.

Another topic of current interest that receives international attention, included in this study and studies of other projects, is phytoremediation. It is also a subject of Nevena Čule's doctoral dissertation. Alternative methods, using plants to remove pollutants from contaminated waters, soils and air, could be termed in one word: phytoremediation. This term relates to a versatile complex of technologies (phytoextraction, phytostabilisation, rhizofiltration, phyto-volatisation, phytodegradation, rhizodegradation, use of plants for removal of pollutants from air and other pollutants), based on use of plants, natural or genetically created, for the purpose of removal of pollutants from the environment or for their transformation into non-toxic forms, which do not represent a further threat.

In the framework of the initial studies on the possibility of application of phytoremediation in various cases in domestic climatic conditions, most attention within the Department has been paid to rhizofiltration (the project 'A study on the possibility for biomass for energy production from short-rotation plantations in the framework of the Serbian electro-energy systems' TR 18201A).

Figure 5. Initial trials in the field of phytoremediation performed by the Department of Environmental Protection

Rhizofiltration can be used for a treatment of surface and ground waters, industrial and municipal effluent, waste waters occurring as a result of washing away of particles from various surfaces, caused by atmospheric precipitation, diluted sludge and solutions contaminated by radionuclides. The process involves cultivation of plants in hydroponics and their replanting in waters contaminated by heavy metals, where they absorb and concentrate metals in the roots and shoots. The exudates of root and pH changes in rhizoshpere can even lead to precipitation of metal at the root surface. As they become saturated by metals, roots or entire plants are mowed and removed. The mowed parts of plant, rich in accumulated metals, are easily and safely dried, turned into ash by combustion, or composted. Some metals can be re-used, by means of an ash extraction process, which additionally reduces the amount of created harmful waste and leads to a more rapid recirculation.

Plants suitable for rhizofiltration efficiently remove heavy metals thanks to a fast growth of the root system. In addition to aquatic plants, edible plants, crops and vegetables, decorative and woody plants that can remove high amounts of Cu^{2+}, Cd^{2+}, Cr^{6+}, Ni^{2+}, Pb^{2+}, Zn^{2+} and other heavy metals from water solutions, are frequently used.

Figure 6. Phytoremediation of aquatic ecosystems and biomass production (*Phragmites communis* and *Canna indica* in the trial)

A realistic preliminary estimate indicates that the produced biomass from short-rotation plantation and plantations of perennial herbaceous plants will enable a partial substitution of fossil fuels, which is of considerable importance for our country from the ecological, economic and social aspect.

Figure 7. Considerable areas of barren soil deposits, ash disposal sites and areas around electric-transmission systems can be used for establishment of short-rotation plantations

Figure 8. Poplar, Douglas-fir and larch in trial short-rotation plantations

A part of the research team from the Department of Environmental Protection is currently engaged on the project **'Development of technological processes in forestry, with the aim of attaining optimum afforestation level'**, project filing number 31070 (2011 – 2014), led by Ljubinko Rakonjac PhD (Insitute of Forestry, Belgrade), whereas a part of researchers is engaged on the project **'A study of the impact of climatic changes on environment: monitoring impact, adaptation and**

mitigation', III 43007, led by Ratko Kadović PhD (Faculty of Forestry, University of Belgrade). Both projects are financed by the Republic of Serbia Ministry of Education and Science.

COLLABORATION WITH THE CITY OF BELGRADE SECRETARIAT FOR ENVIRONMENT PROTECTION

The capital city of Serbia, Belgrade, is facing numerous ecological problems caused by an intensive urbanisation and a rapid demographic increase, development of industry and transport, opencast mines located in its immediate proximity, numerous thermal power plants and heating plants.

In view of the necessity for addressing accumulated problems, while recognising the importance that forest ecosystems and various categories of urban green areas have not only for creation of healthier conditions for life of inhabitants, but the importance related to fulfilment of numerous ecological, economic, social, cultural and other needs, the following scientific-research projects, the results of which have a direct application in practice, have been jointly formulated.

'Integral valorisation of Belgrade forest resources' (2005-2009)

Through its three phases, the project included a study on condition, functionality and multi-functional valorisation of urban, suburban, protective forests, special purpose forests and anthropogenically established forests in the process of biological re-cultivation of degraded areas on the territory of all municipalities in the Belgrade area.

In the previous period, a sufficient attention has not been paid to forests, particularly to those in large and industrial Serbian cities, nor an adequate interest of a scientific or broader social community has been expressed for valorisation of their ecological functions.

Given the current environmental condition of Belgrade, a city of 2 million inhabitants, and proceeding from the fact that forest ecosystems are one of the most stable terrestrial ecosystems, it is essential that both forests in inner-city and in the broader city area assume far larger importance.

A common view of forests as a solely production facility must be altered, whereas new functional priorities for forest ecosystems in the proximity of large towns and villages should be determined, in compliance with the principles of sustainable development, environmental protection and improvement.

In Serbia, forests, as ecosystems, occupy an important position in the state Law on Environmental Protection and in numerous ratified international resolutions, and other legal acts that our country must observe.

In the past forest management plans, which prescribed a method of forest management, a priority was given to economic use of forests as a production-raw-material potential for wood production, while the generally-beneficial forest functions were only declaratively stated. The examination of current forest management plans for urban forests indicates that such attitudes have been significantly changed and that priority today is given to protective functions, primarily soil protection, but also to recreational functions of urban forests. The total forest surface area in the city of Belgrade (including suburban municipalities) amounts to 35,980 ha. Out of that number, state-owned forests cover 20,064ha, whereas privately-owned forests occupy 15,823ha. The afforestation level of the Belgrade region amounts to 11.2%, whereas the forest area per inhabitant is 0.025ha. 0.33ha per inhabitant of one region is considered a limit value, an optimum minimum that enables positive ecological forest functions to become effective in preservation of healthier environment. A forest surface area per inhabitant varies in different municipalities and ranges from 0.0ha in Savski Venac to 0.23ha in Barajevo and Sopot. The strategy for afforestation of eroded, agriculturally insufficiently productive areas on the territory of Belgrade with suburban municipalities aims at increasing present 11.2% afforestation level by 30%, i.e. to increase present 35,000 hectares of forest ecosystems to 90,000 hectares, which will contribute to protection and maintenance of healthier environment. Given the high population density per surface unit, the existence of considerable industrial capacities on the territory of the city and its immediate surroundings, where, in the perimeter of 60-80 km around Belgrade, there are seven thermal power plants and powerful chemical industry capacities, which are the major air pollutants, the existing forest complexes and other permanent green areas are not capable of protecting the environment.

Concurrently with the increase of forest ecosystem areas, a more intensive effort should be put in valorisation of generally-beneficial functions of the existing forest complexes. The most important functions of urban greenery are: ecological, sanitation and decorative-aesthetical. The efficiency of the city landscaping system depends on a mutual relation with its environment, in particular with free suburban forest areas and their greenery. For that reason, it is necessary to regard the city and its peri-urban zone as an integral spatial-planning and landscaping entity.

Numerous ecological and other beneficial functions of urban forests and greenery have been proved.

A wind protection role of greenery - Greenery reduces a wind velocity by 40-50%, whereas in a broader zone of thick plant greenery, wind can be completely stopped. Trees protect against wind not only up to the height they reach, but a dozen meters above, while the impact of trees is several times stronger above a wind protection belt.

A role of greenery in thermal protection is reflected in a fact that greenery can reduce summer temperatures and heats by 3-4^{0}C. Greenery improves microclimate of the city territory, creates more favourable conditions for an outdoor relaxation, protects soil, buildings and pavements from overheating. The preservation of a humidity regime is one of the greenery’s ecological roles, as in summer months greenery exudes, through evapotranspiration, a large amount of moisture. A forest has a 7-15% higher relative humidity as compared to the surrounding areas. Another exceptionally important role of urban greenery is protection against pollution, reflected, primarily, in the absorption of gas pollutants and dust. Greenery protects constructed areas from dust by reducing the wind power, upon which, as a consequence, dust is rapidly deposited on the ground.

Urban greenery also has an impact on noise reduction. The noise behind greenery, frontally positioned towards the street, is reduced by 30-39 dB. The studies proved that even narrow belts and plantations significantly reduce a noise level. It should be pointed out that thick plantations have a higher absorption capacity than the thin ones, whereas mixed plantations consisting of combination of trees and shrubs have better properties (particularly if their horizontal and vertical layout is carried out well).

A role of greenery in oxygen enrichment - Cities with developed industry are among largest oxygen consumers. Plants annually accumulate approximately 520 J of sun energy, in form of biomass. A tendency to produce as much biomass as possible (bio-reproduction) results in an increased role of the oxygen produced by plants.

A role of greenery in creating more comfortable urban living conditions - Urban forests and greenery are an important factor in creating comfortable microclimatic conditions. By creating shade and moisturising air, trees and shrubs exert an impact on a city microclimate. Plants possess certain transparency, that is, they allow a part of light rays to pass through, absorb one part, and reflect the remaining part. Leaf light reflection exceeds several times the amount of reflection of the above-stated construction materials. Plants in an infrared area have a very high albedo (about 90%). Shades created by trees and shrubs protect humans against the excess of a direct and reflected sun radiation. During summer, the surface temperature in the areas covered by greenery is by 12-14^{0}C lower than the temperature of walls, roads and buildings. A 5 meters wide greenery belt, placed between the pavement and the road, can 2.5 times reduce emission of sun energy on pedestrians. The total sun radiation under crowns of some tree species is as far as 9 times lower than in the open area. In the area covered by greenery, the sun radiation constitutes 1-39.8% of the amount of radiation in the open area.

A sanitation-hygienic role of greenery is reflected in a fact that it reduces heat radiation by as far as 5^{0}C. That is the reason why one feels more comfortable in the area covered by greenery than in an open area. The refreshing effect of one tree that grows in favourable conditions is an equivalent of the effect of ten household air-conditions. The increase of relative air humidity is perceived as a temperature decrease.

The studies indicated that relative air humidity depends, to a large extent, on the greenery surface area, but also on a time of measurement. The study of a suburban forest humidity, for instance, pointed to a conclusion that the mean forest air humidity, as compared to urban, is by 12-13% lower in the morning period, whereas it is by 7-9% higher during the day and in the evening. The mean monthly difference of relative air humidity between forests and urban areas reaches as far as 24%. In order to attain the effectiveness of a greenery's impact on microclimatic conditions in an urban area, it is necessary that it is at least 75-100m wide at every 400-500m of a city territory.

A fluctuation of atmospheric pressure in green plantations is less pronounced than in open areas.

Plants are ionisers of air. Green plantations improve electro-hygienic properties of the city air. The oxygen ionisation level of the forest air is 2-3 times higher than in the air above waters or meadows, and even 5-6 times higher than above an artificial urban territory. The studies indicated that green plantations remove part of radioactive matters from soil and, thanks to the photo-effect, ionise the air. It has also been established that a tree has its bio-electric potential, and that a forest exudes electricity through leaves and branches, which causes an increase in air ionisation.

The ability for improvement of air ionic composition is typical of most coniferous species, where the content of light ions is by 5-12% higher. The most significant improvement of the ionic regime of the atmospheric air is produced by mixed conifer-broadleaved plantations. The improvement of air ionisation and the increase in the amount of light ions are also attained by many flowering plants, which emit a floating organic matter in form of pollen into the air.

The city air contains a large amount of pathogenic bacteria and viruses. Some studies proved that many plants exude a floating matter that has antibacterial properties that either destroy or prevent development of pathogenic bacteria.

Aesthetic value of urban greenery is of considerable importance. A skilful mixing of plantations with local components of landscape – local climate, relief, water and already existing building facilities, increases the aesthetic dimension of an urban territory. By use of urban greenery, a pleasant urban texture and landscape-architectural complexes are created, but also individual city entities with agreeable living conditions. By a skilful use of decorative qualities of certain types of trees and shrubs, that is, their height, crown form and shadow, leaf colour and form, flowers and fruits, a higher aesthetic value of some inner city and suburban areas can be attained.

The health role of urban greenery is significant. Nature and greenery play a very important role in regeneration of ability for work and working capacities of city inhabitants. Relaxation in natural surrounding is accompanied by specific physiological and bio-chemical activities of an organism. Natural landscape actively ensures regeneration of power and establishment of a dynamic balance between organism and the environment, disturbed as a result of illness, stress, fatigue and insufficient stay in fresh air. Emotional effect of urban greenery is reflected in the feeling of stress-release and calmness.

Urban and suburban greenery have a positive impact on physiological functions of a man, therefore, it can be said that they have a health and tourism-recreational function.

With respect to tourism-recreational functions, the following can be singled out: urban and suburban recreation, outdoor sport, weekend tourism, outings, silent areas, safari etc.

Forest, urban and suburban greenery also represent a segment of spiritual life, a source of peace and calmness, a prerequisite for life and creative work, therefore, it is often said that they also have a spiritual function.

Design of a study on preservation of natural forest ecosystems and their restoration in the immediate riverside areas of the Sava and Danube watercourse on the Belgrade territory, aimed at valorisation of the ambient value and outing-recreational functions (2009-2012)

Studies in the framework of the project ‘Integral valorisation of Belgrade forest resources’ pointed to an exceptionally adverse state of the Sava and Danube riverside area, along with a fact that the economic, ecological, tourism and other potentials of this part of Belgrade are insufficiently utilised. Unlike other European cities located on the banks of the rivers Sava and Danube, which have extensively exploited the benefits of their highly favourable location, Belgrade has not realised its potentials until today.

In addition to adverse impact of numerous polluters (farms, slaughter houses), municipal and industrial waste landfills, illegal gravel pits on the banks, individual occupation and private-end use of the watercourse adjacent areas by placement of boathouses or weekend houses, natural forest communities have been largely devastated or destroyed, or substituted by a fast-growing plantations of Euro-American poplars, which all prevents effective use of riverside areas and the watercourses.

Despite its excellent strategic position on a water traverse of the Danube and the lower course of Sava, the advantages of favourable location have not been adequately exploited until today. The banks of the rivers Sava and Danube, immediately adjacent to the watercourse are, to a large extent, usurped by individuals. Building and fencing of weekend houses, located immediately adjacent to the watercourse, along with a continuous placement of boathouses on rivers, prevents other Belgrade citizens from using riverside areas and the watercourse.

Figure 9. The banks of the river Sava, occupied by boathouses

Figure 10. Poplar plantations substituted natural poplar and willow phytocoenosis

In the free foreland area, natural forest ecosystems consisting of perennial tree species (pedunculate oak, narrow-leaved ash, lime, hornbeam and other autochthonous tree species), are largely destroyed by clear cut and clearing. Additionally, natural forests of domestic black, grey and white poplar are, to a significant extent, substituted by plantations and intensive cultures of fast-growing poplar cultivars. Such fast-growing poplar plantations are relatively short-lived, since they are regenerated by means of clear cut after 15-20 years. The effects a complete degradation of forest biotope and drastic biodiversity depletion, which is in collision with the Ramsar Convention, as the destruction of natural plant communities also destroys bird and mammal habitats. In the aesthetical terms, these anthropogenic plantations create monotonous scenery and do not provide a pleasant ambient for stay of outing-goers.

This Study provided scientific evidence and pointed out to a necessity for restoration of perennial forest types with the above-stated autochthonous species that had existed prior to the destruction of forests. A restored forest belt with perennial species should penetrate at least 100m deep in the foreland, away from the river watercourses. For the purpose of enabling a more massive use of outing-recreational and sport-fishing potentials of the Sava and Danube riverside area, based on a detailed analysis of a field condition, analysis of ecological conditions of the environment and the condition of existing vegetation, the Study proposes technical-technological measures, along with a selection and spatial layout of tree species, subject and cost estimate of works and cartographic review of phase realisation of the riverside area makeover.

Valorisation of the above-stated functions, accompanied by the Belgrade’s importance as a metropolis with historical, cultural and natural values, will contribute to a richer tourism offer. That will create an opportunity to incite domestic and, particularly, foreign tourist, who are generally in transit and staying for no longer than one day, to prolong their stay in Belgrade for several days, and include and connect Belgrade tourism facilities to the overall Serbian offer. A precondition for that is to perform a transition, in the inner-city riverside zone along watercourses, from the existing anthropogenic, short-lived forest of depleted biodiversity into autochthonous perennial forests, of much higher ambient values, such as were those that once naturally existed in this area.

In that manner, a landscape will be created attractive for development of an outing-recreational, integrated aquatic-terrestrial complex, of high multi-functional value.

CONCLUSION

It is an undisputed fact that, in the future, the environmental issues will be in the focus of interest of the world and domestic public, while their solution will require multi-disciplinary approach by numerous experts from different fields.

The Institute of Forestry, as one of the leading domestic scientific-research institutions in this area, with its scientific-research Department of Environmental protection will, without doubt, have a significant role in their addressing.

The key concept of spatial development is based on preservation, protection and improvement of natural resources and values of a particular region.

The importance of forests as natural resources, a particularly distinctive part of nature, clearly points out to an obligation for understanding their condition, an aspect essential for planning and carrying out forest management, but also for the assessment of the impact of spatial planning and relevant projects on the environment. It is well-known that forest ecosystems are characterised by, among other things, a high degree of naturalness, broad distribution, specific structure, a distinct biological diversity, high biomass productivity, numerous resources and their versatile use, accumulation of large amounts of energy without use of supplemental energy, renewability, numerous functions and impacts, therefore, their role in environmental protection is of considerable importance, while the possibilities for research in this field are great.

The proposal of adequate measures and instruments aimed at environmental protection and improvement, valorisation of forest resources, selection of afforestation and amelioration species, rehabilitation and revitalisation programmes, presentation of various control mechanisms for rational use of space, both preserved areas, suitable for tourism, and the degraded areas, which require re-cultivation and development, are only some of the courses that future studies will take.

In addition, a participation in multi-disciplinary studies on local climatic changes and the impact of climatic changes on forestry, biodiversity and ecosystems, infrastructure, etc, determination of the effects of climatic changes on available natural resources, predominantly, forest ecosystems and biodiversity, use of biomass, a continuous updating of the existing and establishment of new databases on local and regional physical characteristics in the region of Serbian (databases on climatic elements, extreme occurrences and storms, vulnerability of certain areas, condition of forests and measures for their improvement, allocation of land, etc) have been planned for the purpose of their use in preparation of future spatial and urban development plans.

The course of investigations will be directed towards the analysis of an impact of development processes on condition of forest ecosystems and the land use in Serbia, as a part of creation of Spatial Plans and Development Strategies for certain regions.

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WOOD BIOMASS CHALLENGE AND OBLIGATION OF THE 21ST CENTURY

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Abstract: *Numerous resolutions, declarations and binding acts have been adopted by the United Nations and other international organisations, aimed at reducing the atmospheric emission of carbon-dioxide and, at the same time, decreasing the production of carbon-dioxide by developing 'clean' technologies.*

By the industry and rapidly developing transport combustion of the coal and oil fuels, large amounts of carbon-dioxide have been permanently emitted into the atmosphere. The required energy that is lacking should be supplied by a permanent increase of energy production from renewable sources, such as water, wind, solar energy, biomass, etc, as the use of the above-mentioned sources provides a healthier environment.

Serbia is a signatory of numerous international obligatory documents adopted as a form of combat for healthier environment, which prescribe limitations of the use of fossil fuels and focus on the use of renewable sources for production of electric and thermal energy. In Serbia, the legal and technical regulations with respect to optimum use of biomass for energy purposes are only being developed. A uniform Law on Energy Sector has been adopted, however, it has not been accompanied by regulations to a proper extent. Our regulations should be improved and harmonised with the regulations of the EU, where use of biomass for energy purposes is more represented and has a longer tradition. In the absence of domestic regulations, the EU regulations should be implemented.

Key Words: biomass, renewable sources, environment protection

INTRODUCTION

A rapid industrial development that took place in the second half of the 19th and during the course of 20th century, accompanied by an enormous increase of energy consumption that addressed the needs of industrial capacities, along with a fast development of transport, caused an ever-increasing consumption of fossil energy sources, coal and oil.

By the industry and rapidly developing transport combustion of the above-mentioned fuels, large amounts of carbon-dioxide have been permanently emitted into the atmosphere. They upset the natural balance between oxygen and carbon, while the adverse impact of this disturbance is manifested through an occurrence of so-called 'green-house effect'. This occurrence is causing an accelerated warming of the planet, accompanied by catastrophic consequences on living world; hence it is essential to reduce the emission of carbon-dioxide, along with other 'green-house gases', and

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restore the natural balance between oxygen and the above-mentioned gases in the atmosphere (Brown, 2008., Mac Cracken, 2008.).

Along with a positive impact of oceans, forest ecosystems represent the most important terrestrial ecosystems that affect the carbon and oxygen balance in the atmosphere, as they absorb enormous amounts of carbon through the assimilation processes. Subsequently, they deposit carbon in their tissues and release oxygen into the atmosphere, restoring the balance of the elemental structure of the air (Cannell, 2003.).

However, vast areas of forests had been cut down in the above-mentioned period of 19^{th} and 20^{th} century, particularly in so-called tropical rainforests of the African, Asian and South American continent. Peoples from these areas are economically underdeveloped and impoverished, and for that reason, base their economic prosperity on sale of wood from the rainforests to rich European and American countries.

According to the available data, clear cuts of the above-mentioned forests of Amazon and other regions have reached a massive scale. In these areas wood waste remains in forests, since traders take only the quality parts of logs. Through decay and mineralisation - by a decomposition of large amounts of waste, carbon-dioxide is released, the atmospheric amount of which exceeds the amount of oxygen released in assimilation processes of the remaining forest ecosystems and, as a result, rainforest areas cease to be ’the lungs of the Planet’.

For the above-mentioned reasons, numerous resolutions, declarations and binding acts have been adopted by the United Nations and other international organisations, aimed at reducing the atmospheric emission of carbon-dioxide and, at the same time, decreasing the production of carbon-dioxide by developing ’clean’ technologies.

By adopting the principle of sustainable development, the UN member states bound themselves to reduce, according a certain dynamics, the extent of use of fossil fuels for energy production and, consequently, to prolong their existence. The required energy that is lacking should be supplied by a permanent increase of energy production from renewable sources, such as water, wind, solar energy, biomass, etc, as the use of the above-mentioned sources provides a healthier environment.

Serbia is a signatory of numerous international obligatory documents adopted as a form of combat for healthier environment, which prescribe limitations of the use of fossil fuels and focus on the use of renewable sources for production of electric and thermal energy.

BIOMASS

Biomass, as a source of renewable energy, comprises a broad range of organic substance materials of plant or animal origin (wood, straw, bio-degradable residues from agricultural production, manure, organic segment of hard communal waste).

The economic reasoning excludes a high-value material, such as quality wood and large timber suitable for industrial processing, for which an active market exists. However, there are vast resources in forms of wood residue, co-products and waste, which could easily become available both in terms of quantity and relatively low price, or may even involve negative costs, in cases where it is required to pay for its disposal.

There are five basic categories of the materials:

- wood (originating from forestry activities, forest-silviculture works or wood processing)
- energy crops (specially cultivated high-yield crops for energy production)
- agricultural waste (harvest or agricultural crop processing residues)
- food industry waste (originating from production, preparation and processing of food and beverages, and after their consumption)
- industrial waste and co-products from production, processing and industrial processes.

Biomass is used in combustion processes or it is converted in systems for production of thermal energy, electric energy or both thermal and electric energy.

Biomass is mainly used for household heating. There are positive experiences in biomass utilisation in large plants, but the main obstacles are insufficient supply reliability and the costs. Some business entities use their own biomass (for instances, wood residues are used in forest and wood processing enterprises or agricultural residues are used on farms for production of thermal energy). There are also some instances of biomass trade, but they lack long-term supply contracts. Furthermore, the price of biomass is not clearly determined and it can vary significantly in various locations and time periods. At the same time, pellet producers sell their products mostly on foreign markets, due to a low presence of adequate devices for their combustion.

Additionally, biomass is used for production of liquid and gas fuels – bioethanol, biodiesel and biogas.

As a country with extensive areas of agricultural and forestry land, Serbia has a strong potential for biomass production.

Biomass represents 63% of the total renewable energy sources. Forests cover approximately 30% of the territory, whereas about 55% of the territory is the arable land. Apart from residues from crop husbandry for food production, there are large potentials for a special-purpose biomass cultivation, which would not compete with food production.

Most prospective potential biomass applications in Serbia are:

- heating households and building premises by use of pellets or biomass briquettes,

- co-heating or a complete substitution of use of mazut (heating oil) and coal in heating plants,
- electric energy production by use of agricultural and wood residues and
- production of biofuel for transport.

The Government of the Republic of Serbia has set up the aims with respect to the energy production from renewable energy sources (RES). One of the aims, in a short-term period, i.e., by the end of 2012, is to increase the share of electric energy produced from RES by 2.2% as compared to the total national consumption of electric energy in 2007, and to attain a minimum 2.2% market share of biofuel and other fuels from renewable sources, as compared to the total fuel consumption in transport, calculated on the basis of the energy content.

Pursuant to the Regulation on Amendments to the Regulation on Establishment of the Programme for Realisation of Energy Development Strategy of the Republic of Serbia by 2015, for the period from 2007 to 2012, the main programme objectives with respect to biomass are:

- effective use of available resources for energy production,
- reduction of emission of green house gases,
- reduction of dependency on import and
- creating new jobs

EU AND SERBIAN LEGISLATION

The Republic of Serbia ratified the Treaty Establishing the Energy Community in 2006, also known as the Energy Community Treaty of South East Europe or ECSEE (signed between the EU and the countries from the region of South East Europe. Pursuant to Article 20 of this Treaty, a year after its ratification, the Republic of Serbia is obligated to prepare a programme of implementation of the Directive 2001/77/EC on promotion of electricity produced from renewable sources on the internal electricity market and the Directive 2003/30/EC on promotion of use of biofuel or other fuels from renewable sources for transport. With the aim of fostering investments in RES, Serbia has adopted several legal and sub-legal documents concerning energy production.

In the White Book on renewable energy, as a first document published in 1997, stipulated a 12% share of renewable energy to be attained by 2010, and it was pointed out to several very important principles of use of RES:

- prevention of climatic changes,
- reduction of air pollution,

- safe supply of energy,
- development of competitiveness and
- fostering industrial and technological innovation.

Promotion of use of energy from renewable sources was established in the Directive 2009/28/EC established. This Directive amends, and, subsequently, repeals the Directives 2001/77/EC and 2003/30/EC, while establishing a common framework for promotion of energy from renewable sources. It sets up obligatory national objectives for the total share of energy from renewable sources in the final gross energy consumption and the share of renewable sources in transport:

- minimum 20% share of energy from renewable sources in the final gross energy consumption in the Community and
- 10% share of energy from renewable sources in transport energy consumption of each Member State by 2020.

Furthermore, the sustainability criteria for biofuel and liquid biofuels have been established.

The Biomass Action Plan (BAP) for Serbia has been designed in accordance with the obligations from the Treaty on Energy Community and in the spirit of the Directive 2009/28/EC. The implementation of the Directive 2009/28/EC on renewable energy in the Republic of Serbia and other countries signatories of the Treaty will be in future determined and harmonised within the community. Pursuant to the Directive 2009/28/EC, the Republic of Serbia will establish new objectives in 2012.

According to the assessment by the BAP, the available potential in Serbia is presently insufficiently exploited, due to the fact that the organised collection of biomass for energy needs, along with an adequate infrastructure, do not exist, (development of which would contribute to an increased use of biomass and improvement of the market), and due to the insufficient awareness of various possibilities of biomass utilisation. Use of biomass from agriculture, forestry and wood industry sources depends on the agreement of plant owners and multiple owners of agricultural land, forests and sawmills, a fact which diminishes reliability and creates difficulties in supply of fuel.

The importance of energy efficiency and the use of RES were emphasised in the Scientific and Technological Development Strategy of the Republic of Serbia for the period 2009-2014.

With a view to fostering investment in RES, Serbia has adopted a number of legal and sub-legal documents, related to the use of RES, hence, use of biomass as well.

The documents are the following:

- Law on the Kyoto Protocol Ratification (Off. Gazette of RS No 88/2007 and 38/2009) – formation of DNA, National Implementation Body; Serbia has a status of non-Annex I signatory and can develop CDM projects. The Law on Energy

(Off. Gazette of RS No 84/2004), which defines a legal framework for development of use of renewable sources of energy;

- Energy Sector Development Strategy of the Republic of Serbia by 2015 (Off. Gazette of RS No 44/2005), which emphasises the need for use of renewable energy sources for distributed production of thermal and electric energy;
- Amendments to the Programme of Realisation of Energy Sector Development Strategy by 2015 for the period 2007-2012 (Off. Gazette of RS No 99/2009). By these amendments, the strategy and use of renewable energy sources have been developed in more detail.
- The Regulation on requirements for acquiring the status of a preferred producer of electric energy and criteria for assessment with respect to compliance with those requirements (Off. Gazette of RS No 72/2009)
- The Regulation on fostering measures for production of electric energy by use of RES and combined production of electric and thermal energy (Off. Gazette of RS No 99/2009). It defines incentives (feed-in tariffs) for production of electric energy from renewable sources.
- By-law on technical and other requirements for liquid fuels of bio-origin (Off. Gazette of SCG No 23/06)
- The Law on Planning and Construction (Off. Gazette of RS No 24/2011).
- The Law on Environmental Protection (Off. Gazette of RS 72/2009)
- The Law on Strategic Environmental Impact Assessment (Off. Gazette of RS No 135/2004)
- The Law on Environmental Impact assessment (Off. Gazette of RS No 36/2009)
- The Law on Integrated Environmental Pollution Prevention and Control (Off. Gazette of RS No 135/2004), which defines IPPC licence for plants using biomass.
- The Law on Waste Management (Off. Gazette of RS No 88/2010). It defines the use of waste streams for energy production (biodiesel, biogas).
- The Law on Air Protection (Off. Gazette of RS No 36/2009). It defines the limit values of emissions for plants using biomass as fuel.
- The Law on Environmental Protection Fund (Off. Gazette of RS No 72/2009)
- National Strategy of Sustainable Development (Off. Gazette of RS No 57/2008)
- Strategy of Cleaner Production Implementation in the Republic of Serbia (Off. Gazette of RS No 17/2009).

BASIC DATA ON SERBIAN FORESTS

Total surface area of the Serbian territory, 29.1% (7.1% in Vojvodina, 37.6% in central Serbia 37.6%) represents the afforested area (National Forest Inventory, 2009.).

The forest coverage is similar to the global average, which accounts for 30%, but far lower than the European level, which reaches 46%.

Furthermore, according to the data from this document, the total forest surface area in Serbia amounts to 2,252,400 ha. 1.194.000 ha or 53.0% of the total forest area is state-owned, whereas 1,058,400 ha or 47.0% is in private ownership.

The most represented tree species is beech. Broadleaves are the most represented in the total forest fund (approximately 90%), while the most represented among them are beech forest, oak forest, followed by other hard broadleaves, poplars, etc, while conifers and mixed coniferous and broadleaved forests account for 10%. The most represented coniferous species are black pine and spruce.

Forest ecosystems represent the basis for healthy environment and the key factor of its preservation and improvement, given the importance generally-beneficial forest functions that are not related to production of wood as the main product. The region of Serbia is very rich in biological diversity, where forest areas have particular importance. Forestry, as an economic sector with a long tradition, developed structure, human resources and other potentials, acquired scientific and expert knowledge, represents an important segment of sustainable development of rural areas and the Republic of Serbia in its entirety.

The surface area of state-owned forests, managed by public enterprises, amounts to 1,375,553 ha, which accounts for 51.4% of the total forests and forest lands in Serbia. Other forest areas are managed by private owners, socially-owned enterprises and national parks.

Broadleaves account for 90.7% of the total forest fund, conifers account for 6.0%, whereas mixed broadleaved and coniferous forests account for 3.3%. Within broadleaved forests:

- beech forests account for 27.6%,
- oak forests account for 24.6%,
- other hard broadleaves account for 6.0%,
- poplars account for 1.9%,
- other soft broadleaves account for 0.6% and
- mixed broadleaved stands account for 30%.

Forests of seed origin account for 39.6%, coppice forests account for 34.6%, forest cultures account for 14.7%, thickets account for 5.6%, shrubs account for 5.5%, which means that coppice and degraded forests cover 45.7% of the total forest area.

The average volume is 101.7 m^3/ha, 153 m^3/ha in forests of seed origin, whereas in coppice forests it is 70m^3/ha.

The general condition of forests is unsatisfactory and it is characterised by a high proportion of forests of poor quality, inadequately tended artificially-established forests and an insufficient share of high quality and valuable tall natural forests. In addition to the above-mentioned, the present condition of the state-owned forests is characterised by: insufficient production fund, unfavourable age structure, unsatisfactory overgrowth and afforested area, unfavourable condition of stands – a high share of interrupted canopy stands and weedy areas and unsatisfactory health condition.

The total wood harvest in the Serbian forests amounts to 200 million m^3.

There is a large quantity of trees in Serbia, but the forest exploitation level, which is expressed as a ratio between forest harvest and increment, is lower than 50% in Serbia. The estimated wood mass increment in the Serbian forests amounts to 2.58 million m^3. Compared to the 75% exploitation level in developed countries, the Serbian forest exploitation level is low. Hence, there is a possibility to increase the wood harvest volume as compared to the present level. An important prerequisite for better exploitation of Serbian forests is the improvement of forest roads.

WOOD BIOMASS POTENTIALS FOR ENERGY SECTOR IN SERBIA

Serbia belongs to a group of medium-sized European countries, with the territory of 88 361 km^2 and, according to the 2011 census, the population of 7,120,666 (without the territory of Kosovo and Metohija)

Considered generally, the northern part of the Serbian territory consists of plains, it is mainly an agricultural region, whereas the southern part is a mountain region, rich in forests.

There are numerous studies and projects aimed at determining potentials and possibilities for biomass use in Serbia. According to those studies, technically utilisable biomass energy potential in the Republic of Serbia amounts to 2,7 Mtoe[3]. Forestry and wood industry (wood harvest and wood residues produced during primary and/or industrial wood processing) biomass energy potential is estimated at 1,0 Mtoe, while agricultural (agricultural waste and crop husbandry residues, including liquid manure) biomass energy potential is estimated at approximately 1,7 Mtoe.

[3] 1 toe = ton of oil equivalent = 41 868 MJ/t ; Mtoe= million ton of oil equivalent

Biomass has been traditionally used for production of thermal energy, and in 2008 it was estimated at 0.3 Mtoe.

DOCUMENTATIONAL BASIS FOR ESTIMATION OF FOREST BIOMASS POTENTIALS

State-owned regulated forests managed by J.P. „Srbijašume“ and JP “Vojvodinašume”

- Forest products – according to forestry methodology, defined in the forest management plans
- Product structure and quantities, ecologically and economically justified for use for energy purposes, included in the gross allowable cut in forest management plans

State-owned unregulated forests

- Documentation based on annual forest harvest plans

Forest owned by other owners – according to type of ownership

- Forest management plans for regulated forests
- Documentation based on annual forest harvest plans

Forests owned by other owners, refers to ownership of forest complexes by the following owners:

- Forest complexes owned by individual owners citizens – privately-owned forests
- Forests owned by the church and monastery forests
- Forests owned by the military
- Forests within National Parks

POTENTIAL SOURCES FOR BIOMASS PRODUCTION

Establishment of special-purpose short-rotation plantations

For the purpose of wood mass production for energy purposes, a long term strategy should be adopted with respect to establishment of short-rotation plantations with fast growing tree species such as selected poplars and willows, alder, empress tree and others, in the water adjacent areas of large rivers and their tributaries and on suitable areas on deposols of opencast mine post-exploitation localities. (Veselinovic, 2010., Mitrovic, 2011., Dražić, 2011.)

Other potentials

Other potentials for use of wood for energy purposes originate from the following non-forest categories:

- Shelter belts
- Tree lines in the proximity of roads
- Parks and tree lines in urban environments
- Waste in wood industry from primary and final wood processing

Forest wood potential in Serbia

From the aspect of regions, potentials are different. Out of 146 municipalities in Serbia, in 28 of them the afforested area exceeds 40% of the municipality territory.

Municipalities with high forest coverage of its territory are located in the eastern part of Serbia. That region consists of municipalities: Majdanpek (above 80%), Kučevo, Žagubica, Despotovac, Bor and Boljevac (all 41-60%). Another forest-rich region is located in the south-west part of Serbia and it consists of municipalities: Prijepolje (above 80%), Priboj and Kuršumlija (61-80%) and several neighbouring municipalities, with a share of afforested area between 41 and 60% of the municipality territory.

When analysing the data on municipalities, it can be observed that the richer a municipality is in forests, the lower the number of inhabitants and economic development is. This fact could be a hindrance to implementation of wood residue utilisation projects. For that purpose, wood waste should be transported to a more distant municipalities, where transport cost may have an important role with respect to cost-effectiveness of wood residue utilisation project.

In terms of ownership, approximately half of the forests are state-owned, whereas the other half is privately-owned. The most part of coniferous forests is state-owned.

With regard to Vojvodina, nearly all forests are state-owned and practically there are no coniferous forests. State-owned forests in Vojvodina are managed by the Public Enterprise Vojvodinašume. State-owned forests in other parts of Serbia are run by the Public Enterprise Srbijašume.

There are four national parks in Serbia. Seen from north-south direction, they are:

- Fruška Gora in Vojvodina (25,390 ha),
- Đerdap along the Danube (63,600 ha),

- mountain Tara in the proximity of the river Drina (19,710 ha) and
- mountain Kopaonik (11,810 ha).

Apart from the above-mentioned national parks, there are several zones of natural protected areas, which could also be a potential source of wood residue. They are:

- Golija,
- Stara Planina and
- the upper course of the river Ibar.

National parks are state-owned enterprises, whereas the zones of natural protected areas are generally of mixed ownership.

At present, there is no significant cultivation of energy plant cultures in Serbia, however, the research and analyses indicate that the soil that is not suitable for cultivation of conventional agricultural cultures could be suitable for cultivation of poplar woods, which grow fast and can be considered an energy culture.

It is estimated that large areas of land in plain regions in the proximity of rivers and canals, which is not suitable for agriculture, could be utilised for plantation of fast-growing poplar forests. The research of possibility of energy biomass production from short-rotation plantations of fast-growing tree species on deposols of opencast coal mines indicates that large potentials exist even in these areas, which all points out to a significant possibility of the increase of the wood energy potential in Serbia (Forest Development Strategy, 2006.).

As it has been mentioned above, countries with a developed forest infrastructure and well-managed forests, reach as far as the 75% utilisation of the annual wood increment in forests. The term good infrastructure primarily refers to a well-developed network of quality forest roads, which cover all parts of forest. By improving the forest infrastructure, Serbia could increase its potential for sustainable use of forest wood.

Serbia has a potential for an increase of afforested areas. According to the Republic of Serbia Spatial Plan from 1996, afforested areas should have been increased by 31.5% by 2010. Unfortunately, this goal had not been attained. The subsequent aim, according to the Spatial Plan, is to have 41% of the Serbian territory afforested by 2050, which is estimated as the Serbia's optimum afforested area. Even with the optimum afforested area of 41% of the Serbian territory, Serbia will not reach the scope of afforested areas on the territories of the countries in the region. The reason for that is the fact that Serbia has a large proportion of arable agricultural land.

In order to attain this aim, the afforested area should increase annually by 29,000 ha. During the period of intensive afforestation in the eighties, afforestation amounted to 20,000 ha. Afforestation conducted in Serbia in several recent years (2002 -2006) indicated that the afforestation intensity was lower than it was supposed to be, and amounted only to 5,300 ha per year. The above-mentioned increase should enable a proportionally higher volume of forest harvest for approximately 6900 m^3.

State-owned land and forests are generally entirely afforested , that is, occupied by forest trees. According to the estimates by JP Srbijašume, only 10% of the state-owned land remained to be afforested, that is, the state-owned forest can be increased only by 10%.

The most part of the land that should be afforested is privately owned. Private forests, on average, have the surface area of 0.5 ha and, for that reason, every individual forest owner cannot be expected to conduct wood harvesting, collection and transport by himself. Association of private forests owners or imposition of fees for non-utilised land might present a solution to this problem.

The consumption of wood fuel in Serbia accounts for slightly more than 50% of the total wood harvest. In other countries in the region, with a higher wood fuel consumption, the ratio between wood fuel consumption and total wood harvest is far lower and it is between 20% and 30%.

Wood production

A grown tree consists of a stem, thick branches, thin branches and a stump with a root.

Wood production in Serbia is expressed through a wood harvest volume. The term ’wood harvest’ in official statistical bulletins includes all commercial products, as well as wood residue. With regard to persons involved in harvesting, forest enterprises and citizens are the principal categories involved in wood harvesting in forests. Wood processing industry and other enterprises have a small share in wood harvesting.

With regard to tree species harvested in forests, beech tree from clear stands comprises the largest share of the total volume of wood harvesting in forests. Poplars constitute a significant share of the total wood harvesting volume in the total afforested area.

The following products represent the result of wood harvesting: saw logs and logs for production of various types of technical wood, wood for supporting columns for underground mines, wood for cellulose and paper production, wood fuel and other wood products including those for board production. The largest share (about 50%) of wood harvesting from the state-owned forests is used as fuel. The other half (about 50%) of wood harvesting from state-owned forests is intended for production of furniture, cellulose and paper industry, production of supporting columns and other purposes. The statistical records of wood harvesting in privately-owned forests is not as detailed.

Despite the fact that nearly half of the forests are privately-owned, the forest wood harvesting volume in privately-owned forests is three times lower than in the state-owned forests. A possible reason for this state is an insufficient demand for wood. As a result, private forest owners are not interested in establishing their association in order to improve management of their forests.

Wood waste in forestry

Within the total harvested wood volume, there are two principal types of products: technical round wood and spatial wood. Apart from these two main products, there is also wood residue, which generally remains in forests. Out of the total products obtained in wood harvesting, technical round wood and spatial wood constitute about 90%, whereas harvesting wood residue accounts for about 10%. In addition, stumps and thinner branches remain in forests.

Additionally, there are leaves and needles, which constitute about 2%, however, their share is disregarded in this analysis.

The volume of generally non-utilised parts of tree, which include bark, thin branches and stumps, constitutes approximately 42% of the total wood mass of a tree. That means that, at the present rate of wood harvesting in forests, usually approximately 1.1 million m^3 of wood residue, i.e., wood waste, remains after harvesting. These residues vary in size and shape and lay scattered in forests. With regard to the biomass quality, these residues can be used as a source of energy, while some of them can be used for production of wooden boards. Which part of residues will be utilised, generally depends on a type of terrain, forest infrastructure and a distance to a residue utilisation point.

In plain forests, where access to all parts of forest is easy, it is possible to utilise harvest residues nearly by 100%. However, in mountain forests, with very steep inclinations and forest infrastructure in poor condition, and where it is necessary to protect soil against erosion, a percentage of forest residues that can transported out of forests is lower. With better forest infrastructure and adequate price of forests residues, a far higher amount of forest residues would be utilised, than it is the case at present.

It is interesting that approximately 3% of the wood harvesting volume remains in forests, despite the fact that it consists mainly of large residues (branch forks), which could be relatively easily collected and transported.

If all forest wood residue were collected, that would amount to 1,1 million m^3. However, one part of wood residue has already been collected and sold as a wood waste. Additionally, stumps are not always pulled up from the ground. Poplar trees are usually young, with a relatively shallow root, and after a tree is cut down, a poplar stump is easily pulled up from the ground. However, beech and oak selected for harvesting are commonly older trees with a deeper root and, therefore, their roots usually remain in the ground.

Practically, approximately 600,000 m^3 of wood residue (not including stumps) per year remains in forests.

Wood residues in wood processing industry

As a result of wood processing, there are three main types of residues, according to the size:

- bark,
- large residues after a cut of round wood, and
- small residues (sawdust, chips, wood dust).

Out of the total amount of the wood processed in sawmills, a commercial product usually accounts for between 50 and 65%, whereas the remaining part is a waste. Depending on the quality of residues, for instance, whether the bark is removed or not, the remaining part can be used for production of wooden boards. Alternatively, residue can be used as fuel.

For different wood products, different processes are applied and the ratios between the amount of the main commercial product and the amount of residue are different. Generally, the amount of wood waste is approximately 50%. For example, in production of final wood products, furniture for instance, the amount of waste is above 50%.

In the final processing of wood, production of furniture, windows and doors, dried, saw wood is used. The amount of residue depends on the final product and applied technology.

However, other types of manufacturing of wood products, for instance wooden board production, can be suitable for utilisation of various types of wood residues.

The main raw-material for production of compressed chipboard is so-called spatial wood, i.e. cut-down tree, along with large residues created in the primary wood processing. The production of compressed chipboards in Serbia is based on a beech tree. Since the allowed amount of bark in the raw-material for compressed chip production is as far as 10%, bark is not removed from the beech tree. On account of that, the amount of residues in compressed chip productions is quite low, only 15% and the residue consists of wood dust and larger residues from the process of cutting boards into regular shapes. The main part of a large residue can be recycled, that is, returned and re-used for board production. In these enterprises, only a small part of residue remains non-utilised so that it can be used for other purposes, for instance biofuel production or in a direct combustion for energy production.

With regard to raw material for production of hard biofuels (pellets, wood chips), it depends on a market whether residues from various forms of wood processing will be used for board or pellet production.

In well-organised companies involved in production of boards or cellulose and paper, practically all by-products, including wood residue, can be used internally. Certain amounts of wood residue can be recycled or used as fuel. These production processes require a substantial amount of thermal energy, steam or hot water in addition to electric energy, which means that these companies should not be places where future wood pellet producers could obtain a raw-material for their production. This is how things should work in well-organised companies. However, Serbian companies producing cellulose and paper still have wood waste. Despite the current rate of wood waste in these companies, a future pellet producer should not base their production on wood residues from those companies.

In a well-organised economy, with well-organised enterprises, practically only sawmills represent a location where an excess of wood residue can be found. In sawmills, part of residue is used internally, but significant amounts of residue are available for other needs, such is pellet production, for instance, or direct combustion and energy production.

The largest part of wood residue as a raw material for pellet production originates from forest wood harvesting and sawmills. Other wood processing companies, particularly the small ones, also have wood residues available. Therefore, the total amount of wood residue for pellet production is estimated at 1 million m^3, and consists of wood residue from wood harvesting, which amounts to 0.6 million m^3, wood residue from sawmills amounting to 360,000 m^3 (as the mean value of the maximum value of 480,000 m^3 and the minimum available residue of 240,000 m^3) and the wood residue from other wood processing companies not exceeding 50,000 m^3,

Beech and oak harvesting account for approximately 65% of the total wood harvesting. Poplar occupies the third place. Given the fact that the density of a dry beech and oak tree is 0,58 t/m^3, whereas the density of a poplar tree is 0,38 t/m^3, and that pellets contain approximately 10% of moisture, it follows that 500,000t of pellets can be produced from the available amount of wood residue.

One of the main reason for non-utilisation of biomass as a fuel is the low price of electric energy, which is the reason why many households use it for heating.

On the domestic market, pellets can substitute fossil fuels for thermal production in various sectors: industrial, housing and agricultural. According to the Serbia Energy Balance, with respect to the final energy consumption, the industrial sector consumes far less coal than the housing and agricultural sector. The housing sector also includes public buildings. The industry consumption of liquid fuels is higher than in two other sectors jointly. The total industry consumption of wood fuel corresponds to the level of natural gas consumption in housing sector and agriculture.

With the production of 500,000t/p.a. and the energy value of 210,000 toe (ton of oil equivalent), wood pellets can substitute approximately a half of annual consumption of coal in housing and agricultural sector or the total consumption of liquid fuel in these two sectors or the total industry consumption of coal. The wood pellet production can substitute 35% of the final coal energy consumption or 35% of the final liquid energy consumption. It is clear that the energy potential of wood pellets has a significant value for the Serbian energy sector.

CONCLUSION

Use of biomass for energy, industrial, technological, ecological, agrochemical and other purposes is widespread in the EU, where it is accompanied by numerous legal and sub-legal regulations. In the EU countries, the price of thermal and electric energy obtained from biomass is subsidised, whereas a subsidy fund for this purpose is financed from the increased prices of traditional energy sources and the fees imposed on those companies and persons that pollute the environment.

In Serbia, the legal and technical regulations with respect to optimum use of biomass for energy purposes are only being developed. A uniform Law on Energy Sector has been adopted, however, it has not been accompanied by regulations to a proper extent. Our regulations should be improved and harmonised with the regulations of the EU, where use of biomass for energy purposes is more represented and has a longer tradition. In the absence of domestic regulations, the EU regulations should be implemented.

It is very important to bear in mind that use of biomass for energy purposes does not increase the content of CO2 in the atmosphere, does not create a green-house effect, which, consequently, cannot affect the global climate change. Unfortunately, the main problem in Serbia is that the energy efficiency of the existing biomass heating furnaces and boilers is still low and ranges between 50 and 70%. The thermal plants do not have the appropriate measurement, control and regulation equipment. They are charged manually, since there are no sufficient funds for the purchase of equipment for automatic charging. Consequently, the rate of their application in practice is slow.

As a country with large areas of arable and afforested land, Serbia has a strong potential for biomass production. Biomass accounts for 63% of the total potential of renewable energy sources (RES). Given the energy sector tendencies in the region, and recognising the fact that Serbia has significant biomass resources, biomass can be regarded as one of the most important energy sources for our country.

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STATE AND TRENDS OF THE HUNTING SECTOR IN SERBIA AS THE BASE FOR THE SUSTAINABLE GAME MANAGEMENT

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Abstract: *Serbia has a long-term tradition in organised hunting which, together with its natural potentials and favourable climate and orographic factors, represents a good-quality foundation for future sustainable development of the hunting sector. The favourable natural conditions and biological diversity in Serbia enable and support the successful management of the majority of principal European game species. However, despite the potentials available in Serbia, the abundance of the principal hunting species is not at the satisfactory level and the hunting potentials are not utilised to the maximum degree.*

Today, hunting in Serbia is faced with multiple risk factors. The scope of adverse effects ranges from traditional conflicts between hunting and modern forestry and agriculture, to modern risk factors, such as the adverse effect of climate factors, the presence of invasive species, habitat fragmentation and habitat modification, reduction in the number of hunters and the pressure of non-governmental conservationist organisations. The development of hunting in Serbia is also under the effect of the transformation of social order in harmony with the political processes of the accession to the European Union. The transformation process has an influence on all social sectors, including hunting, primarily by the change in legislation. At present, the hunting sector in Serbia is being modified by the changes in hunting legislation.

It is evident that the hunting sector in Serbia is developing in the direction of new trends, which can be correctly performed only if based on the adequate knowledge of the status of hunting and the hunting potentials in Serbia. This paper presents a survey of the actual status of hunting in Serbia, as well as the identified future trends of the sector development.

Key words: hunting, Serbia, transformation, treats

INTRODUCTION

Serbia has long tradition of organized hunting industry, that with natural potentials, suitable climatic and geographical characteristics make proper base for future sustainable development of the sector. Favourable natural conditions and biodiversity on Serbian territory allows successful wildlife management of most European game. Despite the advantages present in Serbia, the abundance of most valuable game species is not at the satisfactory level, while potentials of hunting industry are not fully utilized.

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Accession of the Republic of Serbia to the European Union (EU) was, according to article 45, paragraph 1 of the Law on Government, a high priority goal of every government in the past 12 years (www.srbija.gov.rs). The procedure of joining the EU causes transition processes that influence the whole industry, including the hunting sector.

The enforcement of the Law on hunting and game in 2010 started the changes in Serbian hunting industry, which was established by the Law on hunting from 1993. The changes are numerous, such as among others the transformation of hunting management system from two to three-level system, the decrease in the area of hunting grounds managed by the Hunting Association of Serbia and the increase in their number, change in the legal status of some game species, establishment of Hunting Chamber of Serbia, issuing professional licenses for hunting managers and the possibility of private sector to get involved in hunting industry.

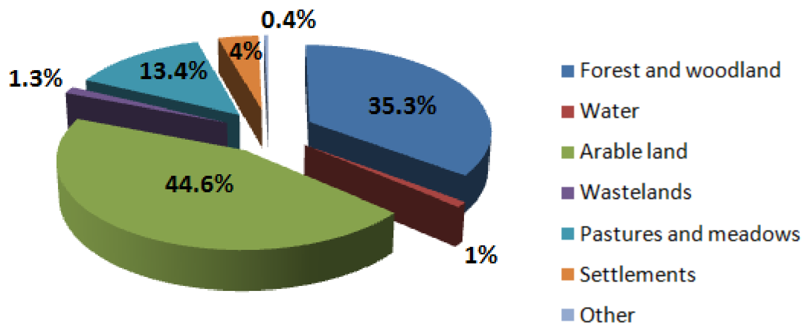
The aim of this paper is to analyze hunting sector in Serbia during the above mentioned transition processes and traditional treats in order to establish a proper base for future sector development. The priority in this paper is focused on basic elements of hunting industry in Serbia: habitat, game and hunters.

NATURAL CHARACTERISTICS OF SERBIA

The Republic of Serbia is a continental country situated in south-eastern Europe, in the central part of the Balkan Peninsula. Its total territory is 88,407 km^2 consisting of lowlands in the northern parts, while central and southern Serbia are dominated by hilly and mountainous regions (www.srbija.gov.rs). Serbia has three mountainous ranges – Carpathians, Rodophes and Dinarides. Due to diverse relief, from geographical point of view, Serbia belongs to central Europe, but also to the Mediterranean region (www.srbija.travel/). Serbia has very diverse water regime, where river belong to Black, Adriatic and Aegean Sea basins (www.srbija.gov.rs). Climate is temperate continental, with more or less local characteristics, average annual precipitation is 896 mm (www.srbija.travel/), but with increasingly dominating unpredictable weather extremes due to climate changes. According to National Forest Inventory (Banković *et al*., 2008), forests in Serbia cover 2,713,200.00 ha; woodlands cover 410,000.00 ha; arable land 3,937,200.00 ha; pastures and meadows cover 1,182,800.00 ha; wastelands 115,400.00 ha; water surface covers 89,800.00 ha; settlements cover 352,000.00 ha, while 35,100.00 ha is not classified (graph 1).

In Serbia most dominated forests are broadleaves, among which most common tree species are beech, oaks and hornbeam.

Serbia is characterized by high biodiversity that is conditioned by geographical variety, suitable climate and orographic factors. Therefore, Serbia has almost all European game species except those from the European far north and south (Šelmić *et al*., 2001).



Graph 1. Land use in Serbia (source: Banković *et al.*, 2008)

Beside small game and wild ungulates, Serbia has large carnivores such as wolf, whose abundance is stabile, and bear or lynx, whose populations are threatened.

HUNTING INDUSTRY IN SERBIA

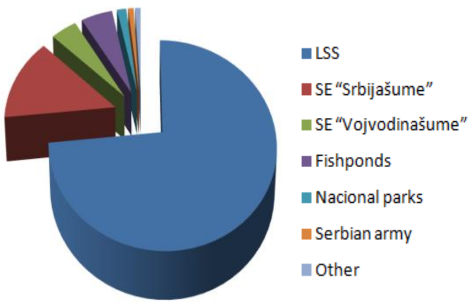
Serbia has regal hunting system; in which game belong to the State according to the Law on game and hunting from 2010. Hunting in the Republic of Serbia is in charge of the Ministry for Agriculture, Forestry and Water Management, while Autonomous Province Vojvodina has its local institutions. Organized hunting industry does not exist in Autonomous Province Kosovo and Metohija, due to conflict situation.

According to the “Program of hunting industry development in Serbia 2001-2010”, the Republic of Serbia has 321 hunting grounds with total area of 8,828,438.29 ha, which is almost 99% of its total territory (Popović *et al.*, 2012). Till 2012 this number oscillated a bit, afterward it started to grow because of the establishment of hunting regions. This process changes hunting grounds borders, dividing or merging old hunting grounds. After hunting regions are set, the final number of hunting grounds will be known. It is most likely that number of hunting grounds will increase in favour of the Hunting Association of Serbia.

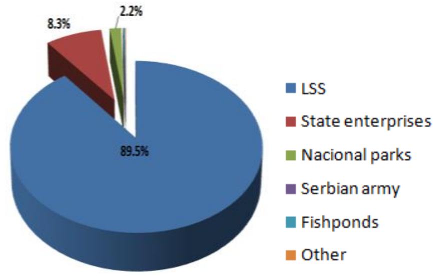
The most important hunting ground users in Serbia are the Hunting Association of Serbia (LSS), Forest State Enterprises “Srbijašume“ and “Vojvodinašume“. The distribution of hunting grounds per stakeholders is presented in graphs 2 and 3. Average size of hunting grounds in Serbia is 27,503.29 ha, less than average size of hunting grounds managed by LSS -34,763 ha. Size of hunting grounds is in the range from 117 to 124,000 ha (Grupa autora, 2001). According to the Law on game and hunting (2010), minimum size for fenced hunting ground is 300 ha, while for opened ones is 2,000 ha. Hunting grounds for special purpose are exempt from this provision. Out of total hunting ground territory, agricultural lands account for 46.5%, forest and woodland app. 28%, pastures and meadows app. 19%, while 0.62% area is on water.

The number of hunters in Serbia has been decreasing for the last 20 years due to financial situation, migrations from rural to urban environment, influence of anti-hunting organizations that consider hunting as human activity that should be banned, decreased birth-rate and diminished interest of youngsters in hunting. According to the latest study, Serbia has 77 128 hunters. The trend line of the number of hunters in the last 50 years is presented in graph 4.

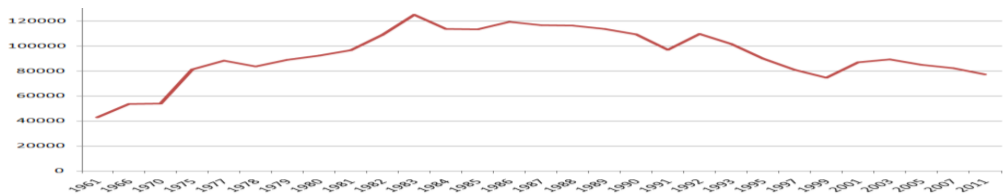
Hunters density is not uniform, hunters are most numerous in Šumadija and Bačka hunting districts, while the smallest number of hunters is "Južni Banat". Number of issued hunting licencses in 2009 and 2010 did not vary a lot, even in 2010 somewhat more licences were issued (graph 5).



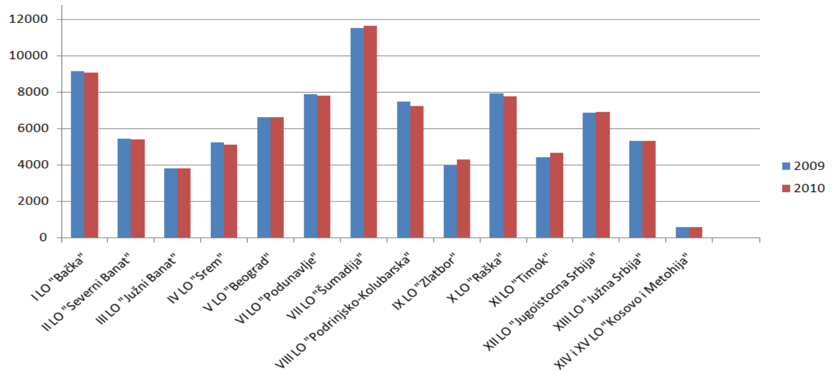
Graph 2. Distribution of hunting grounds per stakeholders



Graph 3. Total hunting ground surface per stakeholder



Graph 4. Trend line of hunters abundance in the last 50 years



Graph 5. Number of issued hunting licence per hunting districts in 2009. and 2010.

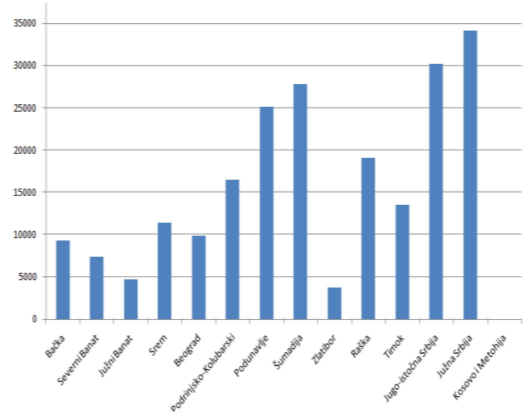
GAME STOCK

Although Serbia has rich biodiversity, suitable habitats and favourable natural conditions due to negative influence of biotic and abiotic factors, out of which anthropogenic influence can be stressed as one of most important, abundance of some game species is at the unsatisfactory level. Distribution and abundance of several wild ungulate species, such as red deer (*Cervus elaphus*, L) or chamois (*Rupicapra rupicapra*, L) are especially below biological carrying capacity of their natural habitats in Serbia, although they are major species from economical or touristic point of view. Abundance and hunters' bag of several game species for the whole territory of the Republic of Serbia are presented in Table 1 for the period between 2005 and 2009.

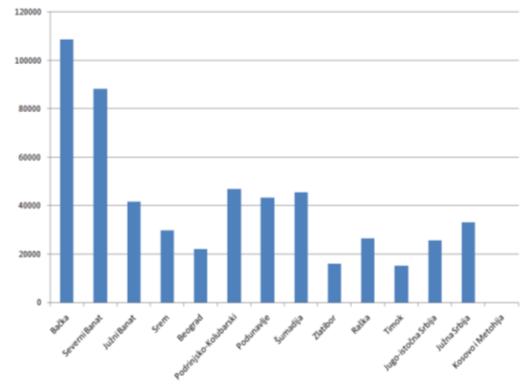
Table 1. Abundance and hunters' bag for several game species in Serbia (source: Statistical yearbook, 2010)

	Red deer	**Roe deer**	**Chamois**	**Wild boar**	**Brown hare**	**Partridge**	**Pheasant**
Game abundance							
2005	4869	106 000	110	17215	609 000	257 000	409 000
2007	4589	112 000	118	17436	611 000	246 000	406 000
2009	6216	111 000	832*	17475	606 000	194 000	403 000
Hunters' bag							
2005	884	5 000	20	3918	104 000	10 000	165 000
2007	615	7 000	-	5276	113 000	7 000	160 000
2009	757	8 000	35	5811	103 000	5 000	173 000

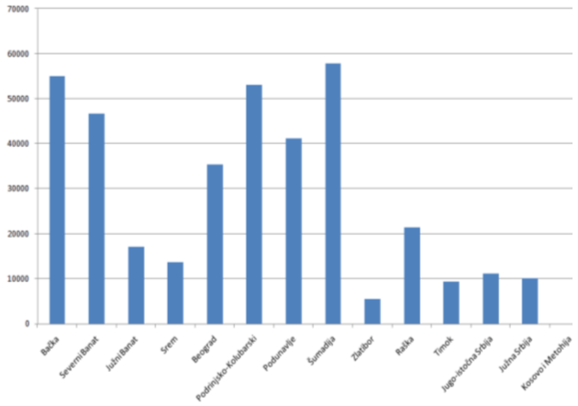
Except game stock on the whole territory of the Republic of Serbia, in this paper we also analyzed the abundance of several game species, important from economical perspective, in hunting grounds managed by the Hunting Association of Serbia, as the most important stakeholder in Serbian hunting industry. Game abundances have been analyzed by hunting districts. The results are shown in graphs 6-10 for hunting season 2006/2007.



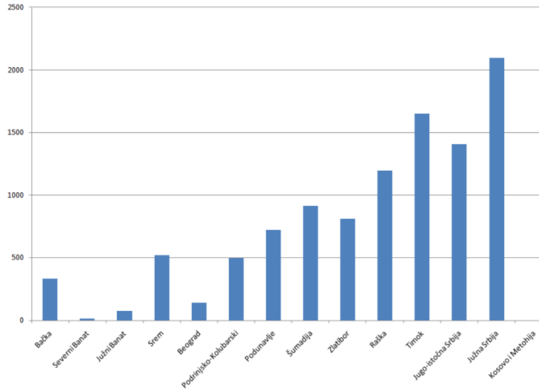
Graph 6. Partridge abundance per hunting districts in hunting grounds managed by LSS



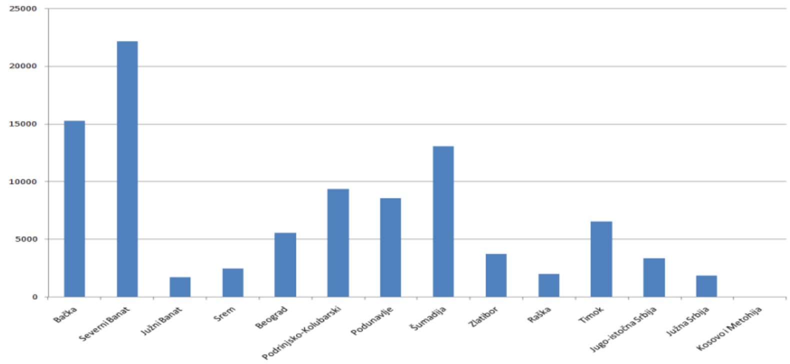
Graph 7. Brown hare abundance per hunting districts in hunting grounds managed by LSS



Graph 8. Pheasant abundance per hunting districts in hunting grounds managed by LSS

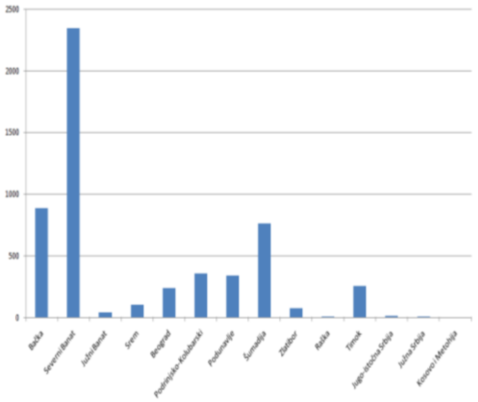


Graph 9. Wild boar abundance per hunting districts in hunting grounds managed by LSS

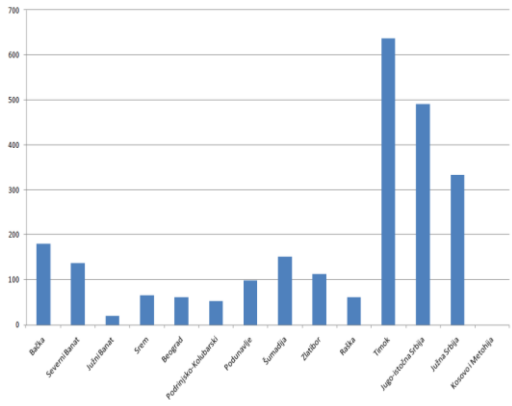


Graph 10. Roe deer abundance per hunting districts in hunting grounds managed by LSS

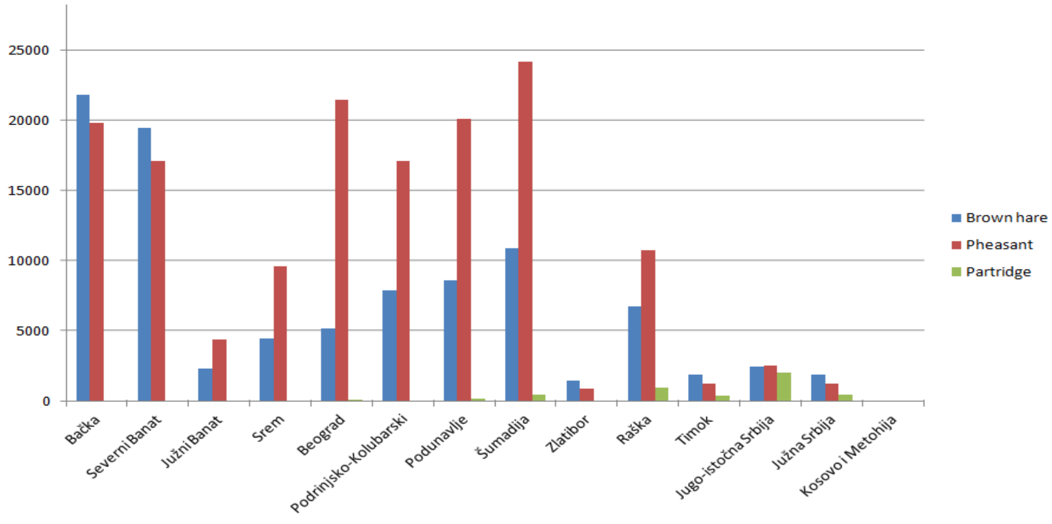
Except the abundance of these game species in hunting grounds managed by the Hunting Association of Serbia, we also analyzed hunters' bags. The results are shown in graphs 11, 12 and 13.



Graph 11. Roe deer shooting per hunting districts in hunting grounds managed by LSS



Graph 12. Wild boar shooting per hunting districts in hunting grounds managed by LSS



Graph 13. Shooting of brown hare, pheasant and partridge per hunting districts in hunting grounds managed by LSS

From the obtained results, it can be concluded that the abundance and density of the analysed game species per hunting districts are not uniform, and also that the extent of shot individuals is not harmonized with its number (Popović, 2006; Popović *et al.*, 2008; Beuković *et al.*, 2009; Popović *et al.*, 2012). This is one of the main factors that causes the unsatisfied game abundance in Serbia. The most abundant game species analyzed in this paper is brown hare, whose number is decreasing in last years (Popović *et al*., 2012) and it is below its number in sthe urrounding countries, such as Hungary or Austria (Popović *et al*., 2012; Hackländer, 2012).

DISCUSSION AND CONCLUSION

The Republic of Serbia is now going through the process of accession to the European Union, which has an impact on all the social sectors, and therefore also on the hunting sector. The transformation of the hunting sector in Serbia started by the entry into force of the Law on Hunting and Wildlife in 2010 and currently it is facing several challenges. Our paper is focused on three elements of the hunting sector – the habitat, game population abundance and the number of hunters. It is evident that natural conditions and suitable habitats are favourable to game management, but still game population density is at the unsatisfactory level, and it is characterised by varying distribution per hunting areas. This is proved by the analysis of the abundance of the most significant economic species of game in the hunting grounds of the Hunting Association of Serbia per hunting areas. This problem is all the more expressed thanks to the fact that the volume of game exploitation is not harmonised with the game population density in the field. This points to the fact that game population management has to be planned in the framework of individual regions, taking into account their specificities.

The number of hunters in Serbia is at present in the decreasing phase, and their number depends on the hunting areas. The reasons for the decrease in the number of hunters in Serbia is reflected in the difficult financial situation, increasing migrations village – town, poor interest of the young generations in hunting, reduced game density, and the pressure by the environmental conservation organisations on the hunting sector.

The study data analysis shows some inconsistencies in the official data, especially those referring to game density and shooting. This study points to the necessity that the statistical data in the hunting sector should be collected much more seriously at the state level, which will contribute to better monitoring of the trends and to the enhancement of the hunting sector.

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