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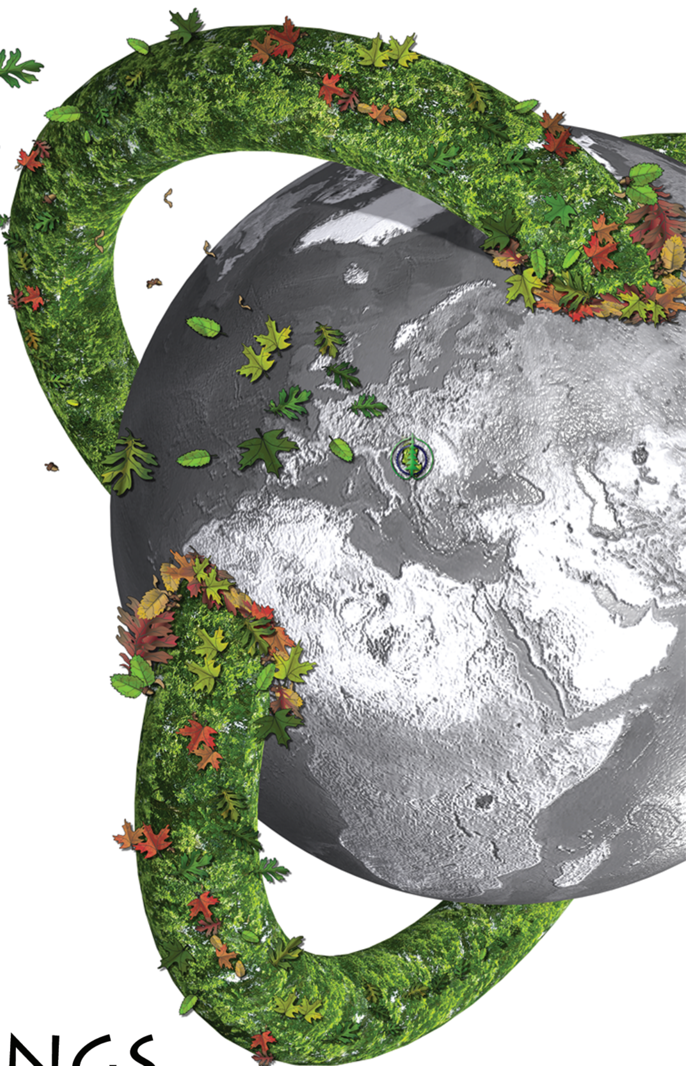

Forest ecosystems and climate changes

March 9-10th, 2010
Belgrade, Serbia

PROCEEDINGS
VOLUME 1

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FOREST ECOSYSTEMS AND CLIMATE CHANGES

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THE INVASIVE AND POTENTIALLY INVASIVE WOODY SPECIES IN THE FORESTS OF BELGRADE

Biljana NIKOLIĆ, Branislava BATOS, Dragana DRAŽIĆ, Milorad VESELINOVIĆ, Đorđe JOVIĆ, Vesna GOLUBOVIĆ-ĆURGUZ[1]

Abstract: *Forests and forest land cover an area of 26,000 hectares of Belgrade (10% of total city area). About 90 woody and over 200 herbaceous species from about 40 phytocenoses (mainly in alliance of white willow forests,* Salicion albae*), as well as natural and artifically established plantations of forest trees, cover an area of 15,000 hectares of city area. The degrees of invasiveness were determined for more than 80 of these species. Nine of them are principal invasive and also globally invasive (Acer platanoides, Ailanthus altissima, Clematis vitalba, Cotinus coggygria, Frangula alnus, Hedera helix, Ligustrum vulgare, Populus alba and Robinia pseudoacacia), while ten of them are also principal invasive (Acer pseudoplatanus, Aesculus hippocastanum, Amorpha fruticosa, Fraxinus americana, Fraxinus pennsylvanica, Gleditsia triacanthos, Populus x euramericana cv. I-214, Populus x robusta, Quercus cerris and Salix alba).*

Key words: aliens, principal invasive, moderate invasive, minor invasive, trees, shrubs, herbaceous species

INVAZIVNE I POTENCIJALNO INVAZIVNE DRVENASTE VRSTE U BEOGRADSKIM ŠUMAMA

Izvod: *Šume i šumsko zemljšte u Beogradu zauzimaju površinu od 26,000 ha (10% ukupne površine gradskog zemljišta). Preko 90 drvenastih i preko 200 zeljastih vrsta iz oko 40 fitocenoza (uglavnom u svezi šuma bele vrbe,* Salicion albae*) i prirodne i veštačke kulture šumskog drveća zauzimaju površinu od oko 15,000 ha gradskog područja. Za više od 80 vrsta utvrđen je stepen invazivnosti. Među njima ima 9 koje su jako invazivne a takođe i globalno invazivne (Acer platanoides, Ailanthus altissima, Clematis vitalba, Cotinus coggygria, Frangula alnus, Hedera helix, Ligustrum vulgare, Populus alba i Robinia pseudoacacia), dok je još 10 jako invazivno (Acer pseudoplatanus, Aesculus hippocastanum, Amorpha fruticosa, Fraxinus americana, Fraxinus pennsylvanica, Gleditsia triacanthos, Populus x euramericana cv. I-214, Populus x robusta, Quercus cerris i Salix alba).*

Key words: uljezi, jako invazivne, srednje invazivne, slabo invazivne, drveće, žbunje, zeljaste biljke

1. INTRODUCTION

Invasive species are considered such species which are introduced by man into habitats out of their natural environment, and have spread into these habitats on the scale beyond human control. It is a well-known fact that the introduction of some weed species began even in Palaeozoic and continued during the period of antiquity and the Middle-ages, while the largest waves of migration took place in the times after the discovery of America and the World War Two, simultaneously with more intensive human migrations (Trinajstić, 1976). Based on the findings of long-term world research, invasive species are considered a significant threat to biodiversity, and, consequently, they directly (in agriculture, forestry, wood industry, food

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industry, cattle breeding, etc.), or indirectly (in instances when the harm is not immediately recognisable, but it accumulates for years) disturb existing ecosystems and influence the economic development and the quality of all living beings on the planet. Detecting the trend of invasive alien species is one of the 2010 Biodiversity Targets of *Convention of Biological Diversity** which ought to be implemented as soon as possible (The Conference of the Parties, Decision VIII/15).

The invasion is most frequently caused by the favourable bio-ecological characteristics of the sites, climate changes and the lack of natural enemies, as well as the biological properties of the species which enable the fast spread of them (secretion of growth inhibitors, hairy or sticky seeds, small seeds, bird-dispersed edible seeds, ability to form adventitious root, etc.). Frequently, there is a significant number of the invasive species within the same family, which is attributed to the similar bio-ecological characteristics or phylogenetic relations. But, also relating species, and all other ones which show the tendency to invasiveness, should be treated as potentially invasive.

Man is the most invasive living being on the planet by far. The list of *One Hundred of the World's Worst Invasive Alien Species***, along with the House mouse (*Mus musculus*), originates from India, or Gypsy moth (*Lymanthria dispar*), of Eurasian-African origin, includes many sea species and microorganisms, algae, seashells, mushrooms, crayfish, amphibians, reptiles, fish, insects, birds, mammals and even 34 plant species, most of which are from the area of central and/or south America (15): *Cecropia peltata*, *Cinchona pubescens*, *Leucaena leucocephala*, *Miconia calvescens*, *Prosopis glandulosa*, *Schinus terebinthifolius* (trees), *Mimosa pigra*, *Clidemia hirta*, *Lantana camara*, *Opuntia stricta*, *Psidium cattleianum* (shrubs), *Mikania micrantha* (climber), *Chromolaena odorata*, *Sphagneticola trilobata* (herbaceous), *Eichhornia crassipes* (aquatic) and slightly fewer species from the area of Asia and Asia Minor (9): *Ardisia elliptica* (tree), *Hedychium gardnerianum*, *Hiptage benghalensis*, *Ligustrum robustum*, *Rubus ellipticus* (shrubs), *Pueraria montana var. lobata* (climber), *Arundo donax*, *Imperata cylindrica* (grasses), *Fallopia japonica* (herbaceous), but there are species originating from Euro-Asia (2): *Tamarix ramosissima* (shrub), *Euphorbia esula* (herbaceous), Africa (1): *Spathodea campanulata* (tree), Australia (1): *Melaleuca quinquenervia* (tree), and Europe (5): *Pinus pinaster* (tree), *Acacia mearnsii*, *Morella faya* and *Ulex europaeus* (shrubs) and *Lythrum salicaria* (herbaceous).

On the *Global Invasive Species Database**** (as a part of GISP, managed by ISSG/IUCN SSC, NBII, etc.), there are also seven species from Serbia, out of which two plants: one herbaceous, introduced, Himalayan balsam (*Impatiens glandulifera*) and one native, a bushy annual, Tumbleweed (*Salsola tragus*). The activities such as exchange of germplasm and establishing artificial plantations as a part of different introduction programmes, forest trees provenance trials in the second half of the 20th century, which were strongly imposed especially by the USA by the means of international co-operation, all contributed substantially to extending the invasive trees list in different continents or countries.

The stability of the plant community area of Belgrade and its surrounding (Gajić, 1952, 1954a,b; Borisavljević, 1955; Borisavljević *et al.*, 1955; Mišić, 1971; Dinić, 1975; Protić, 1976; Jovanović and Vukićević, 1977; Jovanović *et al.*, 1978, 1984, 1985; Topalović *et al.*, 1986; Vučković, 1991; Radulović *et al.* 2008) is constantly disturbed, not only by the effects of climate changes, but also by deliberate or indeliberate activites of man and his carelessness. The existence of 97 adventive species of weed on the territory of Serbia has been established, out of which every other is invasive (Vrbničanin *et al.*, 2004). Probably the highest number of introduced woody species in Serbia is located in the area of Belgrade and its outskirts, occupying, in the course of time, areas which were once covered by extinct species or species presently considered rare, very rare or facing extinction (Nikolić *et al.*, 2005), but also occupying degraded, uncultivated and damaged areas of forest, agricultural and urban land. Urban, suburban and country settlements, especially those in the proximity of large water currents, were recognized long ago as centres in which spreading of invasive species begins (Obratov-Petković *et al.* 2009, and literature cited therein).

2. OBJECT AND METHOD

The object of the research are woody species from urban and suburban Belgrade forests, belonging to the following management units (MU) from Public Enterprise "Srbijašume": MU "Ada Huja", MU "Avala", MU "Draž – Višnjik – Bojčin – Cerova Greda – Gibavac", MU "Dunav", MU "Gročanska Ada", MU "Guberevačke šume", MU "Kosmaj", MU "Košutnjak", MU "Košutnjačke šume", MU "Lipovica", MU "Makiš – Ada Ciganlija – šume uz autoput Beograd-Zagreb (do Surčina)", MU "Progarska Ada – Crni Lug – Zidine – Drenska", MU "Rit", MU "Stepin Lug", MU "Tamiš" and MU "Trešnja".

On the basis of cartographic documentation, literature on plant communities in the Belgrade area and outdoor research conducted, the representation, quantity, volume and volume increase of particular woody species in the area of Belgrade forests have been determined. From these data, as well as from the data concerning the invasiveness degree of particular woody species on global, continental or European level (from available sources), the following classification has been carried out: 1. Principal invasive and also globally invasive (+++++), 2. Principal invasive (++++), 3. Medium invasive (+++), 4. Minor invasive (++), and 5. Potentially invasive (+). Apart from that, the origin, beneficial characteristics and the area of representation have been determined for each species.

3. RESULTS AND DISCUSSION

Forests and forest land in Belgrade cover the area of 26,000 ha (10% of the total city area). Natural and artificially established plantations of Belgrade suburban forests cover approximately 15,000 ha, while 1,500 ha of forest land is ungrown. Among over 90 significantly represented woody species of trees from natural stands and artificial plantations, 30 deciduous tree species have a volume of 1,000 - 100,000 m^3, out of which the following seven species have a volume over 100,000 m^3: *Quercus cerris, Populus x euramericana* cv. I-214, *Quercus robur*, *Quercus petraea*, *Populus robusta*, *Fagus moesiaca* and *Fraxinus angustifolia*. Another 12 deciduous and 3 conifer species have a volume of over 10,000m^3, while most of them are invasive: Black locust, American ash, White poplar, White willow, Sessile oak, Large-leaved lime, Small-leaved lime, Europaean ash, Sycamore, Norway maple, Austrian pine and Douglas fir (Table 1.). Apart from woody species, state forests also include over 200 herbaceous species originating from about 40 phytocenoses (mainly in alliance of white willow forests, *Salicion albae*).

Among 663 globally invasive living organisms on the *Global Invasive Species Database**** list there are even 9 woody plant species frequently represented in urban and suburban Belgrade forests:

1. *Acer platanoides* (Norway maple), tree species native in Europe, which modifies its habitat by exuding authotonous species' growth and reproduction inhibiting toxins into the soil. Norway maple produces water-soluble antifungal chemicals which may alter the soil-borne mycorrhizae, pathogenic fungi, and decomposer fungi in ways that favour conspecific seedlings,

Table 1. *The list of invasive and potentially invasive woody species in the forests of Belgrade*

No.	Latin Name	English Name	Family	Order	Invasivity*	Origin**	Properties***	Significantly present in#
1	*Acer campestre* L.	Field maple	Sapinadecae	Sapindales	+++	AU	M, TO	U, SU
2	*Acer negundo* L.	American maple	Sapinadecae	Sapindales	+++	AL	M	U
3	*Acer platanoides* L.	Norway maple	Sapinadecae	Sapindales	+++++	AU	M	U, SU
4	*Acer pseudoplatanus* L.	Sycamore	Sapinadecae	Sapindales	++++	AU	M	U, SU
5	*Acer saccharinum* L.	Sugar maple	Sapinadecae	Sapindales	+++	AL	TO	U, SU
6	*Acer tataricum* L.	Tatar maple	Sapinadecae	Sapindales	+++	AU	M	U, SU
7	*Aesculus hippocastanum* L.	Common horse chestnut	Sapinadecae	Sapindales	++++	AL	C, M	U
8	*Ailanthus altissima* (Mill.) Sw.	Tree of haeven	Simaroubaceae	Sapindales	+++++	AL	RC	U, SU
9	*Alnus glutinosa* L.	Black alder	Betulaceae	Fagales	+++	AU	C, RC	U, SU
10	*Amorpha fruticosa* L.	Desert false indigo	Fabaceae	Fabales	++++	AL	E,C	U
11	*Berberis vulgaris* L.	European barberry	Berberidaceae	Ranunculales	+++	AU	E, C	U
12	*Betula pendula* Roth.	White birch	Betulaceae	Fagales	+++	AL	C, R, TO	U
13	*Betula verrucosa* Ehrh.	Birch	Betulaceae	Fagales	+++	AU	M, TO	U, SU
14	*Castanea sativa* Mill.	European chestnut	Fagaceae	Fagales	++	AL	E, C, M	U
15	*Clematis vitalba* L.	Evergreen clematis	Ranunculaceae	Ranunculales	+++++	AU	E, C, M	U, SU
16	*Cornus mas* L.	Cornelian cherry	Cornaceae	Cornales	++	AU	C, M	U, SU
17	*Cornus sanguinea* L.	Common dogwood	Cornaceae	Cornales	++	AU	E, M	U, SU
18	*Corylus avellana* L.	Common filbert	Betulaceae	Fagales	+++	AL	E, C, M	U
19	*Cotinus coggygria* (Scop.)	European smoketree	Anacardiaceae	Sapindales	+++++	AL	DT	SU
20	*Crataegus monogyna* L.	Common hawthorn	Rosaceae	Rosales	+++	AU	E, C, M	U, SU
21	*Crataegus nigra* Wald. et Kit.	Hungarian hawthorn	Rosaceae	Rosales	+	AU	E	SU
22	*Crataegus oxyacantha* L.	English hawthorn	Rosaceae	Rosales	+	AU	C	U, SU
23	*Frangula alnus* P. Mill.	Glossy buckthorn	Rhamnaceae	Rhamnales	+++++	AU	E, C, M	U, SU
24	*Fraxinus americana* L.	American ash	Oleaceae	Lamiales	++++	AL	C, M	U, SU
25	*Fraxinus angustifolia* Vahl.	Narrow-leafed ash	Oleaceae	Lamiales	++	AU	C, M	U, SU
26	*Fraxinus excelsior* L.	Europaean ash	Oleaceae	Lamiales	+++	AU	C, M	U, SU

* +++++ - Principal and also global invasive, ++++ - Principal invasive, +++ - Moderate invasive, ++ - Minor invasive, + - Potentially invasive;
** AL - alochtonous, AU - autochtonous, NAT - naturalised;
*** E - edible, C - curative, M - melliferous, DT - high tolerance to drought, R - high resistance to disease, RC - very often used in recultivation, TO - high tolerance to urban conditions;
# U - urban forests, SU - suburban forests.

No.	Latin Name	English Name	Family	Order	Invasivity*	Origin**	Properties***	Significantly present in#
27	*Fraxinus ornus* L.	Manna ash	Oleaceae	Lamiales	+++	AU	C, M	U, SU
28	*Fraxinus pennsylvanica* Marshall	Green ash	Oleaceae	Lamiales	++++	AL	C, R	U, SU
29	*Gleditsia triacanthos* L.	Honey locust	Fabaceae	Fabales	++++	AL	E, TO, DT	U
30	*Hedera helix* L.	Common ivy	Araliaceae	Apiales	+++++	AU	C, M	U, SU
31	*Juglans regia* L.	Common walnut	Juglandaceae	Fagales	++	NAT	E, C, M	U
32	*Larix decidua* Mill.	European larch	Pinaceae	Pinales	++	AL	M	U
33	*Ligustrum vulgare* L.	Common privet	Oleaceae	Lamiales	+++++	AU	M	U, SU
34	*Lonicera caprifolium* L	Italian honeysuckle	Caprifoliaceae	Dipsacales	++	AU	C, M	U, SU
35	*Morus alba* L.	White mulberry	Moraceae	Rosales	+++	NAT	E, C	U
36	*Morus nigra L.*	Black mulberry	Moraceae	Rosales	+++	NAT	E	U, SU
37	*Pinus nigra* L.	Austrian pine	Pinaceae	Pinales	+	AU	M	U, SU
38	*Pinus strobus* L.	Eastern white pine	Pinaceae	Pinales	+++	AL	C, M, U	U
39	*Platanus x acerifolia* (Aiton) Willd.	London plane	Platanaceae	Proteales	+++	AL	MT	U
40	*Populus alba* L.	White poplar	Salicaceae	Malpighiales	+++++	AU	C	U, SU
41	*Populus x euram.*(D) G. cv. I-214	Hybrid poplar	Salicaceae	Malpighiales	++++	AL	M	U
42	*Populus nigra* L.	Lombardy poplar	Salicaceae	Malpighiales	+++	AU	C	U, SU
43	*Populus x robusta* Schneid.	Robusta poplar	Salicaceae	Malpighiales	++++	AL	M	U, SU
44	*Populus tremula* L.	European aspen	Salicaceae	Malpighiales	++	AU	M	U, SU
45	*Prunus avium* L.	Sweet cherry	Rosaceae	Rosales	+++	AU	E, C, M	U, SU
46	*Prunus cerasifera* Ehrh.	Cherry plum	Rosaceae	Rosales	+++	AU	E, C, M	U
47	*Prunus spinosa* L.	Blackthorn	Rosaceae	Rosales	+++	AU	E, C, M	U, SU
48	*Pseudotsuga menziesii* (Mirb.) Fr.	Douglas fir	Pinaceae	Pinales	+++	AL	RC, TO	U
49	*Pyrus piraster* Burgst.	Pear	Rosaceae	Rosales	+++	AU	E, C, M	U, SU
50	*Quercus cerris* L.	European turkey oak	Fagaceae	Fagales	++++	AU	E, C, M	U, SU
51	*Quercus frainetto* Ten.	Italian oak	Fagaceae	Fagales	+++	AU	E, M	U, SU
52	*Quercus petraea* Liebl.	Sessile oak	Fagaceae	Fagales	+++	AU	E, C, M	U, SU
53	*Quercus pubescens* Willd.	Downy oak	Fagaceae	Fagales	+++	AU	M	SU
54	*Quercus robur* L.	English oak	Fagaceae	Fagales	+++	AU	E, C, M	U, SU
55	*Quercus rubra* Dur.	Northern red oak	Fagaceae	Fagales	+++	AL	E, M	U
56	*Robinia pseudoacacia* L.	Black locust	Fabaceae	Fagales	+++++	NAT	M, C	U
57	*Rosa arvensis* Huds.	Field-rose	Rosaceae	Rosales	+++	AU	E, C, M	SU
58	*Rosa canina* L.	Dog rose	Rosaceae	Rosales	+++	AU	E, C, M	U, SU
59	*Rosa dumetorum* Thuill.	Corymb rose	Rosaceae	Rosales	+++	AU	C	U

No.	Latin Name	English Name	Family	Order	Invasivity*	Origin**	Properties***	Significantly present in#
60	*Rosa gallica* L.	French rose	Rosaceae	Rosales	+++	AU	C	U, SU
61	*Rosa rubiginosa* L.	Sweet briar	Rosaceae	Rosales	+++	AU	C	U, SU
62	*Rhamnus cathartica* L.	European buckthorn	Rhamnaceae	Rhamnales	+++	AU	E, C	U, SU
63	*Rubus caesius* L.	Dewberry	Rosaceae	Rosales	+++	AU	E, C	U, SU
64	*Rubus fruticosus* L.	Shrubby blackberry	Rosaceae	Rosales	+++	AU	E, C, M	U
65	*Rubus hirtus* W. K.	Blackberry	Rosaceae	Rosales	++	AU	M	U, SU
66	*Rubus tomentosus* Borkh.	Wooly blackberry	Rosaceae	Rosales	++	AU	M	SU
67	*Salix alba* L.	White willow	Salicaceae	Malpighiales	++++	AU	C, M	U, SU
68	*Salix amygdalina* L.	Almond willow	Salicaceae	Malpighiales	++	AU	M	U
69	*Salix fragilis* L.	Crack willow	Salicaceae	Malpighiales	+++	AU	M	SU
70	*Sambucus nigra* L.	Black elderberry	Caprifoliaceae	Dipsacales	+++	AU	E, C, M	U, SU
71	*Styphnolobium japonicum* (L.) Sc.	Pagoda tree	Fabaceae	Fabales	++	AL	M	U
72	*Sorbus domestica* L.	Service tree	Rosaceae	Rosales	++	AU	E, C, M	U, SU
73	*Sorbus torminalis* (L.) Cr.	Wild service tree	Rosaceae	Rosales	+++	AU	E, C, M	U, SU
74	*Syringa vulgaris* L.	Common lilac	Oleaceae	Lamiales	+++	AU	M	SU
75	*Tilia cordata* Mill.	Small-leaved lime	Malvaceae	Malvales	++	AU	C, M	U, SU
76	*Tilia platyphyllos* Scop.	Large-leaved lime	Malvaceae	Malvales	+	AU	C, M	U, SU
77	*Tilia tomentosa* Moench.	Silver lime	Malvaceae	Malvales	+	AU	M	U, SU
78	*Ulmus campestris* L.	Elm	Ulmaceae	Rosales	+	AU	C	U, SU
79	*Ulmus glabra* Huds.	Scots elm	Ulmaceae	Rosales	+	AU	C	SU
80	*Viburnum lantana* L.	Wayfaring tree	Adoxaceae	Dipsacales	++	AU	E	SU
81	*Viburnum opulus* L.	European cranberrybush	Adoxaceae	Dipsacales	+	AU	E	U, SU
82	*Vinca minor* L.	Common periwinkle	Apocynaceae	Gentianales	+	AU	R, C, M	SU

too, (Templeton and Reinhardt, 2005). These trees also prevent the establishment of a herbaceous or shrub layer, leaving much of the soil bare and subject to erosion, which opens the way to gradual speding of other non-native species in the future.

2. *Ailanthus altissima* (Chinese sumac), tree species native to China and Taiwan, which occurs in agricultural areas, natural forests, ruderal/disturbed, urban areas. Spreads easily due to its rapid growth and prolific seed production.

3. *Clematis vitalba* (Evergreen clematis), vine and clumber, native in Europe, which occurs in agricultural areas, coastland, natural forests, planted forests, range/grasslands, riparian zones, ruderal/disturbed, scrub/shrublands, urban areas. Its vines can climb the tallest forest trees, forming a dense, light-absorbing canopy that suppresses all vegetation beneath it. Physical, chemical and mechanical measures are implemented in controlling the spread of these species.

4. *Cotinus coggygria* (European smoketree)**,** tree or shrub, native to Asia and southeastern Europe, natural forests, ruderal/disturbed, urban areas. It tolerates a broad range of soil types, from light sandy soils to heavy clays (Floridata, 2010).

5. *Frangula alnus* (Glossy buckthorn), shrub, native in North Africa, Asia and Europe. It occurs in agricultural areas, natural forests, planted forests, ruderal/disturbed, wetlands. *F. alnus* sometimes invades similar woodland habitats (Brue, 1980), but more often invades wetlands that are comparable to its European wetland habitats. *F. alnus* seeds are efficiently dispersed usually by starlings, blackbirds, woodducks, elk, mice (Ridley, 1930), cedar waxwings, robins and blue jays.

6. *Hedera helix* (English ivy), native to Europe, western Asia, and northern Africa is a vine or climber which occurs in coastland, estuarine habitats, natural forests, planted forests, riparian zones, urban areas, wetlands. Vines climbing up tree trunks spread, surround and cover branches and twigs, preventing most of the sunlight from reaching the leaves of the host tree thus reducing photosynthesis. *H. helix* reproduces vegetatively and by seed, which is dispersed to new areas primarily by birds. New plants grow easily from cuttings or from stems making contact with the soil (Diedrich and Swearingen, 2000). Chemical and non-chemical methods of control are frequently necessary.

7. *Ligustrum vulgare* (Common privet), shrub native to Europe and northern Africa Occurs in ruderal/disturbed, scrub/shrublands, on sandy, loamy and clay soils. Digging plants out when they are young or using herbicides are the most effective measures of controlling the invasion of this species.

8. *Populus alba* (White poplar), tree native to Eurasia. Occurs in agricultural areas, natural forests, range/grasslands, riparian zones, urban areas. It outcompetes many native tree and shrub species in mostly sunny areas and interferes with the normal progress of natural community succession, because it can grow in a variety of soils and produce large seed crops. A measures of physical and chemical control are implemented against unrestrained spread of these species.

9. *Robinia pseudoacacia* (Black locust), naturalised tree, native to southeastern United States which occurs in agricultural areas, natural forests, planted forests, range/grasslands, ruderal/disturbed. Once introduced, *R. pseudoacacia* expands readily into areas where their shade reduces competition from other (sun-loving) plants. It is an early successional plant, preferring full sun, well drained soils, and little competition.

Another three principal invasive species in Belgrade forests are recorded on the European list (*List of Invasive Species in Europe*****):

1. *Acer pseudoplatanus* (Sycamore), Euro-Asian tree species (yet considered as environmental weed in some parts of Australia),

2. *Amorpha fruticosa* (Desert false indigo), shrub, native in Canada, Mexico and United States, and

3. *Gleditsia triacanthos* (Honey locust), tree, native to eastern North America.

It could be said for all enumerated species that they are invasive on the territory of Belgrade. Among them, a significant volume and volume increase are reached by *R. pseudoacacia* (99327,5 m^3 and 4053,6 m^3, respectively) and *A. pseudoplatanus* (15059,1 m^3 and 415,1 m^3, respectively). Black locust is, following different cultivars of *Populus* sp., the most strongly represented alien deciduous species in the Belgrade area (area: 230 ha; volume: 27,172.6 m^3; volume increase: 3.1m^3/ha). *G. triacanthos* has reached volume of 995,1 m^3 among forest cultures and volume increase of 37,2 m^3. *Ailanthus altissima* and *Amorpha fruticosa*, weeds widely spread at Belgrade river islands (Jovanović *et al.*, 1984, 1985; Radulović *et al.*, 2008), are regularly destroyed and, therefore, the data on invasivness are only an indicator of (un) successfulness in maintaining green areas. These two species are also placed on the EPPO list (*European and Mediterranean Plant Protection Organization******, 50 countries) list. A real picture of the degree of invasiveness of *A. altissima* and *A. fruticosa,* as well as many other exotic plants, is possible to obtain only on the basis of the condition in protected areas (such is, for instance, Veliko Ratno ostrvo), since care measures are not implemented there and therefore invasive species spread unhindered. *A. fruticosa* covers even 36.8% of the area at Veliko Ratno ostrvo (Šinžar-Sekulić *et al.,* 2007).

Apart from *A. pseudoplatanus*, there are two other species from Belgrade forests on the NOBANIS list of 59 most invasive species from 17 European countries (*North European and Baltic Network on Invasive Alien Species Database*[#]): Manitoba maple (*Acer negundo*) and Elder (*Sambucus nigra*).

There are even 243 tree species and 290 shrub species, some of them also to a large extent introduced into Serbia, among 862 invasive plant species in the Atlas of invasive species of the United States (*Invasive Plants Atlas*[##]: Common horse chestnut (*Aesculus hippocastanum*), Eastern white pine (*Pinus strobus*) and Douglas-fir (*Pseudotsuga menziesii*). And many our autochthonous or adapted species proved invasive on the American continent (mainly in the United States), such as, e.g.: Black alder (*Alnus glutinosa*), Common privet (*Ligustrum vulgare*), Crack willow (*Salix fragilis*), English ivy (*Hedera helix*), European aspen (*Populus tremula*), Europaean barberry (*Berberis vulgaris*), English oak (*Quercus robur*), Europaean birch (*Betula pendula*), Glossy buckthorn (*Frangula alnus*), Hedge maple (*Acer campestre*), Lilac (*Syringa vulgaris*), Lombardy poplar (*Populus nigra*), Norway maple (*Acer platanoides*), Scots pine (*Pinus sylvestris*)*,* White mulberry (*Morus alba*), White poplar (*Populus alba*) and White willow (*Salix alba*). Some parts of the continents or countries also have their own invasive species lists (there are more than 200 of them, linked to different biodiversity protection projects), such as, e.g.: ARAF, BIOLFLOR, CBCN, CIPM, CONABIO, FISNA, GCW, GIST, IAS, IABIN, NAISD, NCBI, NeoFlora, WWD, itd. Other species from Table 1 are on at least one of the the above-mentioned lists.

High category invasiveness (++++) in Belgrade forests is assigned to some other species which do not show particular invasiveness, but it can be assumed, on the basis of their high percentual representation and taxonomic closeness with invasive species (*Populus x euramericana*, cv. I-214 and *Populus x robusta*).

Most mentioned species are not considered particularly invasive in Belgrade state forests, but it can be noticed that many of them, particularly pioneer and fast growing species, to a considerable extent populate forest gaps, forest edges and fallows, and often uncultivated agricultural areas near the forest edge. Sometimes even autochthonous species can become invasive, as e.g. Red osier dogwood (*Cornus sericea*) in Canada (Charles-Dominique *et al.*, 2010). That is the reason why the tabular survey (Table 1), apart from the above-mentioned species, includes many other species as a potentially major or minor threat to stability of autochthonous phytocenoses in altered habitats or climatic conditions. Above all, it refers to the species taxonomically or phylogenetically close to the invasive species. The most numerous species on the list belong to the species of the order Rosales (21 species, most of which from

Rosaceae family), Fagales (13 species, families: Betulaceae and Fagaceae) and Sapindales (21 species, most of which from Sapinadecae family) nevertheless, strong invasiveness is typical of representatives of some other orders and families: order Malphigiales, fam. Salicaceae (4 species), order Lamiales, fam. Oleaceae (4 species), order Fabales, fam. Fabaceae (2 species), order Ranunculales, fam. Ranunculaceae (1 species), order Rhamnales, fam. Rhamnaceae (1 species), and order Apiales, fam. Araliaceae (1 species) (Table 1). It is interesting that Common periwinkle (*Vinca minor*) is placed on the list of invasive species in Canada, while it is considered a rare species in Belgrade forests (Nikolić *et al.*, 2005), and the literature cited therein). However, alien tree species pose a more serious threat, among them particularly hybrid poplar trees, which present strong competition to autochthonous vegetation in blue city zones. A particular attention should be also paid to adapted species, since some of them, in accordance with climatic changes, and even 150 years after the introduction, can manifest strong invasiveness, as it is the case, for instance, in the USA (Willis *et al.*, 2010). Biological diversity of a certain area can be disturbed by spontaneous hybrids of autochthonous and alochtonous plant species. For instance, a list of globally most invasive plants also includes a hybrid (tetraploid) marsh grass (*Spartina anglica)*, which appeared in England as a product of crossbreeding of a native species (*S. maritima)* with an introduced American species (*S. alterniflora*).

The list of alien and potentially invasive woody species in the area of Belgrade and its outskirts would be certainly much longer if numerous decorative and fast growing species in city parks, arboretums, forest and horticultural seedling nurseries, gardens and other private properties, which by its appearance and function (attractive flower colours, decorative leaves and crowns, melliferousness, healthiness and nutritiousness) often conceal aggressiveness, until now manifested most frequently in the form of allergenic effect on people, were taken into account.

4. CONCLUSSIONS

Numerous engeneering methods increase trends in global changes which are in strong positive correlation with number of invasive species (Kolar and Lodge, 2000). Man very frequently encourages invasiveness of alien vegetation, for instance by clear-felling of stands, thinning of stands and poor forest management, in particular of those artificially planted, or by neglecting agricultural areas and degradation of forest habitats. Habitats under certain degree of protection also help spreading of exotic plants, since classical measures of protection against undergrowth and weed (Cvejić *et al.*, 1996) are not implemented in them. However, regardless the protection measures implemented, the influence of man and other factors, (birds and other animals disseminating seeds, change of level of underground waters, climate change), is unavoidable an it can disturb the quality of phytocenosis.

Invasive species are also the indicators of the degradation of: site, gene pool of autochthonous species, plant communities, climate changes and of the environment degradation, in general.With the exception of weeds, there are no clearly defined methods for control of many species, and their degree of invasiveness has not been defined. In regard to woody species, it can refer to the autochthonous species which spread in an uncontrolled way due to leaving of the arable areas, but also owning to the altered site conditions (by drainage, deforestation, wildfires, creation of waste disposal sites, etc.). These plants are often competitive with allochthonous (exotic) trees and bush, which were introduced in the aim of reforestation or establishment of green areas in the inhabited places. Sometimes arbuscular mycorrhiza fungus (AMF) plays an important role in process of invasion, as it is the case with a well-known seed species *Ambrosia artemisiifolia* (Fumanal et al. 2005), which was introduced in Europe from North America about one century ago.

Climate change may exacerbate species invasions across communities if non-native species are better able to respond to climate changes than native species. In particular, invasives track seasonal temperature variation better than natives and non-native non-invasives. It is usually manifested in plants by, compared to native species, early blooming, fruiting and seed dissemination. So, climate changes play an important role in facilitating non-native species naturalisation and invasion at the community level (Willis *et al.*, 2010).

Although several invasive woody species from the European list have been detected in the Belgrade area, and a certain number of fast growing species is considered potentially invasive, the situation is still not alarming, since none of the above-mentioned woody invasive species belong to a category of those which require quarantine supervision and their further spreading can be restrained by a timely reaction in form of mechanical clearing (Stilinović, 1991) or implementation of certain arboricides (Janjić, 1977). Ungrown forest land, but also uncultivated agricultural area and other, differently damaged land (including protected forests), certainly pose the greatest challenge concerning populating and further spreading of invasive woody species and herbaceous weeds and, therefore, a proper planning of the intention and care of these area is a necessary and urgent task.

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**Convention of Biological Diversity*, COP VIII/15 (*http://www.cbd.int/decisions/cop/?m=cop-08*)

***One Hundred of the World's Worst Invasive Alien Species,* Global Invasive Species Database, ISSG, (http://en.wikipedia.org/wiki/List_of_invasive_species; *http://www.k-state.edu/withlab/consbiol*)

****Global Invasive Species Database* (*http://www.issg.org/database/species/search.asp?st=100ss*)

*****List of Invasive Species in Europe* (*http://en.wikipedia.org/wiki/List_of_invasive_species_in_Europe*)

******European and Mediterranean Plant Protection Organization*, EPPO (*http://www.eppo.org/QUARANTINE/Alert_List/alert_list.htm*)

[#]*North European and Baltic Network on Invasive Alien Species*, NOBANIS (*http://www.nobanis.org/Search.asp*)

[##]*Invasive Plants Atlas of the United States*, The University of Georgia - Center for Invasive Species and Ecosystem Health and the National Park Service, etc. (*http://www.invasive.org/weedus/index.html*)

THE INVASIVE AND POTENTIALLY INVASIVE WOODY SPECIES IN THE FORESTS OF BELGRADE

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Summary

On the list of one hundred globally principal invasive species (*The list of One Hundred of the World's Worst Invasive Alien Species*, Global Invasive Species Database, ISSG), there are even 34 plant species (most of which are from America). Five of them originated from Europe: *Pinus pinaster* (tree), *Acacia mearnsii***,** *Morella faya* and *Ulex europaeus* (shrubs) and *Lythrum salicaria* (herbaceous). On the whole ISSG list, there are seven species also present in Serbia, out of which two plants: *Impatiens glandulifera* (herbaceous) and *Salsola tragus* (annual). Forests and forest land cover an area of 26,000 hectares of Belgrade (10% of total city area). About 90 woody and over 200 herbaceous species from about 40 phytocenoses (mainly in alliance of white willow forests, *Salicion albae*), as well as natural and artifically established plantations of forest trees, cover an area of 15,000 hectares of city area. The degrees of invasiveness were determined for more than 80 of these species. Nine of them are principal invasive and also globally invasive (*Acer platanoides*, *Ailanthus altissima*, *Clematis vitalba*, *Cotinus coggygria*, *Frangula alnus*, *Hedera helix*, *Ligustrum vulgare*, *Populus alba* and *Robinia pseudoacacia*), while ten of them are also principal invasive (*Acer pseudoplatanus*, *Aesculus hippocastanum*, *Amorpha fruticosa*, *Fraxinus americana*, *Fraxinus pennsylvanica*, *Gleditsia triacanthos*, *Populus x euramericana* cv. I-214, *Populus x robusta*, *Quercus cerris* and *Salix alba*). The most numerous on the list of invasive species are from order Rosales (21 species, mostly from Rosaceae family), Fagales (13 species, families: Betulaceae and Fagaceae) and Sapindales (21 species, mostly from Sapinadecae family). The list of alien and potentially invasive woody species in the area of Belgrade and its outskirts would be certainly much longer if numerous decorative and fast growing species in city parks, arboretums, forest and horticultural seedling nurseries, gardens and other private properties. Ungrown forest land, but also uncultivated agricultural area and other, differently damaged land (including protected forests), certainly pose the greatest challenge concerning populating and further spreading of invasive woody species and herbaceous weeds and, therefore, a proper planning of the intention and care of these area is a necessary and urgent task.

INVAZIVNE I POTENCIJALNO INVAZIVNE DRVENASTE VRSTE U ŠUMAMA BEOGRADA

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Rezime

Na listi od 100 globalno najinvazivnijih vrsta (*The list of One Hundred of the World's Worst Invasive Alien Species*, Global Invasive Species Database, ISSG), nalaze se čak 34 biljne vrste (većina je iz Amerike). Pet od njih je poreklom iz Evrope: *Pinus pinaster* (drvo), *Acacia mearnsii*, *Morella faya* i *Ulex europaeus* (žbunovi) and *Lythrum salicaria* (zeljasta). Na celoj ISSG listi nalazi se sedam vrsta iz Srbije, od toga dve biljke: **Impatiens glandulifera** (zeljasta) and *Salsola tragus* (jednogodišnja biljka). Šume i šumsko zemljšte u Beogradu zauzimaju površinu od 26,000 ha (10% ukupne površine gradskog zemljišta). Preko 90 drvenastih i preko 200 zeljastih vrsta iz oko 40 fitocenoza (uglavnom u svezi šuma bele vrbe, *Salicion albae*) i prirodne i veštačke kulture šumskog drveća zauzimaju površinu od oko 15,000 ha gradskog područja. Za više od 80 vrsta utvrđen je stepen invazivnosti. Među njima ima devet koje su jako invazivne a takođe i globalno invazivne (*Acer platanoides*, *Ailanthus altissima*, *Clematis vitalba*, *Cotinus coggygria*, *Frangula alnus*, *Hedera helix*, *Ligustrum vulgare*, *Populus alba* i *Robinia pseudoacacia*), dok je još deset jako invazivno (*Acer pseudoplatanus*, *Aesculus hippocastanum*, *Amorpha fruticosa*, *Fraxinus americana*, *Fraxinus pennsylvanica*, *Gleditsia triacanthos*, *Populus x euramericana* cv. I-214, *Populus x robusta*, *Quercus cerris* i *Salix alba*). Najbrojnije na listi invazivnih vrsta su iz reda Rosales (21 vrsta, uglavnom iz familije Rosaceae), Fagales (13 vrsta, familije: Betulaceae and Fagaceae) i Sapindales (21 vrsta, uglavnom iz familije Sapinadecae). Spisak alohtonih i potencijalno invazivnih drvenastih vrsta na području Beograda i okoline bio bi svakako mnogo duži da su u obzir uzete i brojne dekorativne i brzorastuće vrste koje se nalaze u gradskim parkovima, arboretumima, šumskim i hortikulturnim rasadnicima, baštama i drugim privatnim posedima. Neobraslo šumsko zemljiste, ali i neobradjeno poljoprivredno zemljište i druga, na razne načine oštećena zemljišta (ali i zaštićene šume) svakako su najveći izazovi za nastanjivanje i dalje širenje invazivnih drvenastih vrsta ali i zeljastih korova, pa je pravilno planiranje namene i nege ovih površina neophodan i hitan posao.

CLIMATE CHANGE IMPACT ON FOREST VEGETATION IN REPUBLIC OF SRPSKA

Zoran STANIVUKOVIĆ[1], Zoran GOVEDAR[1], Marijana KAPOVIĆ[1], Zorana HRKIĆ[1]

Abstract: *Aim of this paper is to determine and evaluate the impact of climate change on forest vegetation in Republic of Srpska, based on the analyzed data. There were analyzed air temperature and precipitation amount in the reference period 1961-1991 years for the area of Doboj, Sokolac and Trebinje. Obtained results were compared with the previous reference period, and based on estimates is predicted increase or decrease of the average values of temperature and precipitation by the end of 21 century. Climate change (which is manifested inter alia by increasing or decreasing of air temperature and precipitation amount) indisputable affects on altitude belts shifting, and thus zones of forest vegetation. On the basis of the obtained results, it is defined shifting of forest vegetation spreading zones in the analyzed reference areas (Doboj, Sokolac and Trebinje), which will occur as a result of climate change.*

Key words: climate change, forest vegetation, Doboj, Sokolac, Trebinje.

UTICAJ PROMJENE KLIME NA ŠUMSKU VEGETACIJU U REPUBLICI SRPSKOJ

Izvod: *Cilj rada je da se na bazi analiziranih podataka utvrdi i procjeni uticaj promjene klime na šumsku vegetaciju u Republici Srpskoj. Analizirani su temperatura vazduha i količina padavina u referentnom periodu 1961 – 1991 godina za područje Doboja, Sokoca i Trebinja. Dobijeni rezultati su upoređivani sa prethodnim referentnim periodom, te na bazi procjene predviđen je porast odnosno smanjenje prosječnih vrijednosti temperatura i padavina do kraja 21 vijeka. Promjena klime (koja se manifestuje između ostalog povećanjem ili smanjenjem temperature vazduha i količine padavina) neosporno utiče na pomjeranje visinskih pojaseva, a time i zonalnost šumske vegetacije. Na bazi dobijenih rezultata definisano je pomjeranje zona rasprostranjenja šumske vegetacije u analiziranim referentnim područjima (Doboj, Sokolac i Trebinje), koje će se javiti kao posljedica klimatskih promjena.*

Ključne riječi: promjena klime, šumska vegetacija, Doboj, Sokolac, Trebinje.

1. INTRODUCTION

Global climate changes are largely a result of the negative anthropogenic influence on different planet's ecosystems, especially in forest ecosystems. Climate changes have only recently recognized as one of the most important global challenges, which operates on ecosystems and society (Gračan, 2008). Climate through its elements influence on the intensity of photosynthesis and respiration, as well as other processes in forest owergrown. In addition, climate has a large impact on the stability of forest ecosystems, by its hesitation leads to creation of favorable conditions for the emergence of certain phenomena (storms, fires, etc.) that are able to for a very short period cause destabilization, and often degradation of forest ecosystems.

As the global climate change, forest ecosystems will change as the boundaries of physiological tolerance of species may exceed and the rates of forest biophysical processes will change (Thompson et al., 2009). According to Houghton et. al., 2001, there is strong scientific consensus that in this and next century will come to serious climate change at the global level, in response to increased emissions of carbon dioxide in the atmosphere. The way we managed and how we manage our forests will play a key role in reducing the climate change impact on forests

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and forest ability to adapt to changed climate conditions (Gitay et al., 2001). Anticipated climate changes will reflect on the precipitation amount as on the sum and on the intensity of their appearance, depending on the geographic area and its exposure to climate changes. It can change the environmental conditions in forest ecosystems, and to expose their members to harmful effects of various factors such as abiotic and biotic nature.

With increasing temperature, the biological function of forests also changes, because the faster biological processes (metabolism, respiration, litter decomposition, mineralization and nitrification of forest land) (Thompson et al., 2009).

Global climate change will be particularly affected developing countries, one of which is, Republic of Srpska (BiH). In the context of global climate changes and sustainable development, forest management activities play a key role in reducing (slowing down) climate change (B. Metz, et al, 2007). According to the Cadastre of forests and forest land in the Republic of Srpska has a total of 1,287,970 ha of forests and forest land, or about 50% of the total territory of RS, of which 50% are high forests, 27% low forests and 23% other forest lands and other barren lands.

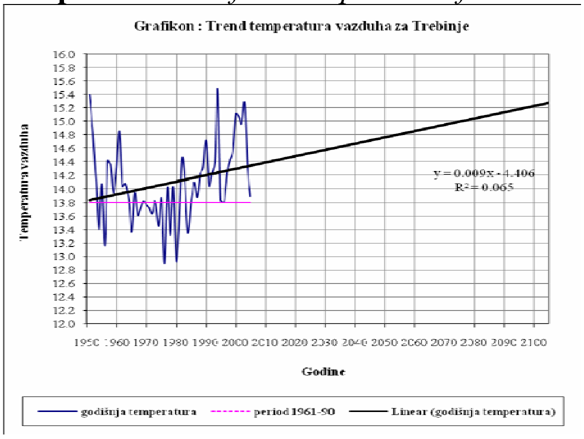
2. MATERIAL AND METHODS

In this paper were analyzed the basic climatic elements, the amount of precipitation, air temperature, for the reference period 1961 - 1990. year. The analysis was conducted for the area of Doboj, Sokolac and Trebinje and is based on meteorological data obtained from meteorological yearbooks I and II, and the Hydrometeorological Institute of Republic of Srpska. Obtained average values of air temperature and precipitation amount have served as the basis for calculating trend function on which basis assessment of this climatic elements was carried out to the end of 21 century and the 2100-s years. Characteristics of climate in the Republic of Srpska change if we start from the south (the area of Trebinje - Mediterranean, amended - continental climate) to the north (Doboj - moderate – continental, Sokolac - mountain climate). By analysis of these areas, we have tried to include a variety of climate and to determine to what extent will the global climate change affect the forest vegetation of the analyzed area.

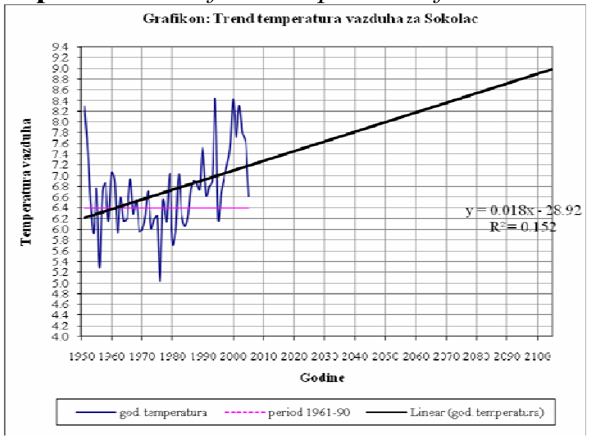
3. RESULTS AND DISCUSSION

The research results of the average air temperature and precipitation amount for the analyzed periods, alert us to come up increasing of air temperature (Graph 1 - 3), and predictions by the end of 21st ages based on trends analysis (Graph 4) are not optimistic. The average annual temperature in 2005. year for the Doboj area was 11.2ºC (according to the trend line), and in year 2100th will amount to 12.8ºC, which is about temperature increasing by 1.6ºC. For the Sokolac area the temperature increase in the analyzed period will amount to 1.8ºC (2005. year and 7.2ºC, and 2100. year 9.0ºC), while for the area of Trebinje, that difference is 1.0ºC. The temperature increasing is in correlation with the change of the average precipitation amount among other things reflects on the change of vertical zoning of forest vegetation. Namely, any (even minimal) increase in average air temperature, results in spreading of forest vegetation zones upward. Forest trees represent a very divergent organisms that to present are passed through more climate change and adjusting to a greater or lesser extent. Each climate change has created new challenges in the forests management, especially when talking about biodiversity. Research by Schoene, 1983. show that the forests are very sensitive when it comes to differences in temperature and moisture regime, respectively they react to any change.

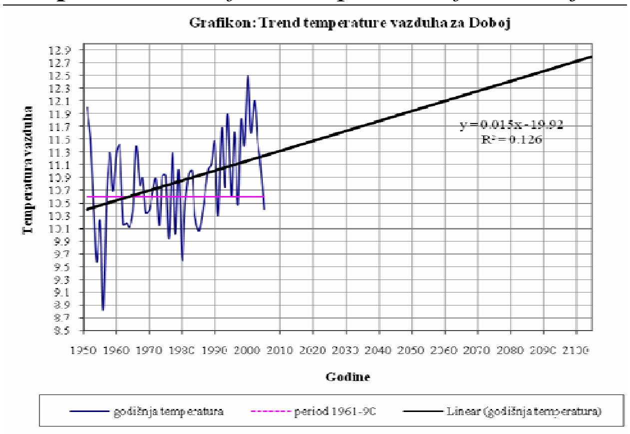
Graph 1. *Trend of air temperature for Trebinje*



Graph 2. *Trend of air temperature for Sokolac*



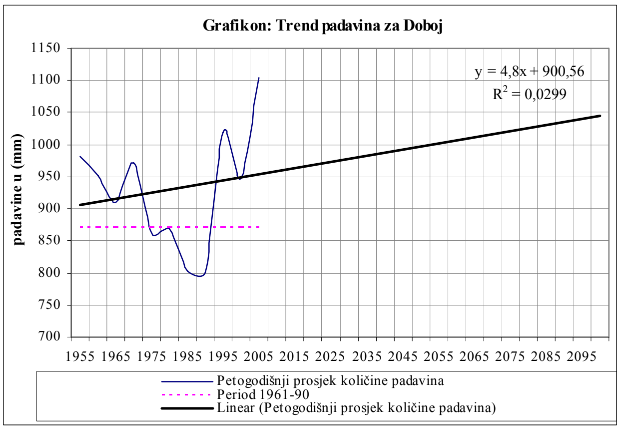
Graph 3. *Trend of air temperature for Doboj*



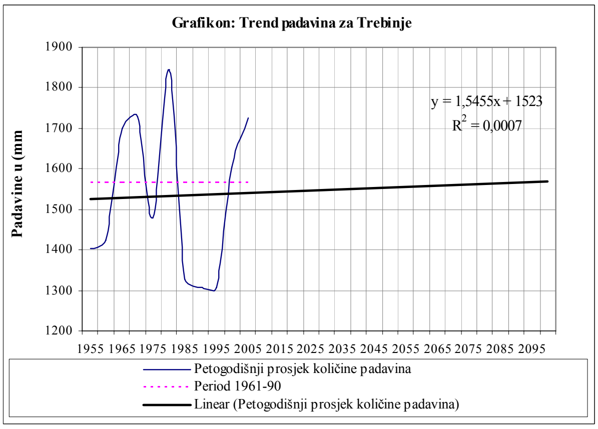
Charts 1, 2 and 3 show the trend of temperature changes by the end of 21st century. Areas of research differ both in average annual temperatures, and in their change in the future. Increasing in average annual temperature is evident in all three areas. Trebinje is located in the southern part of the Republic of Srpska and is largely influenced by Mediterranean (amended continental) climate. Climate of Trebinje, in addition to the large number of sunny days, is characterized by low relative humidity and cloudiness, increased air currents, heavy rain in the colder part of the year and rarely of snow and very warm and dry summers. Based on analysis of air temperature existing trends in Trebinje, it can be seen that the expected increase in air temperature of 1.0 Celsius by the end of this vijeka. Such air temperature changes can lead to shifting in vegetation belts of forest for about 200 m to more.

The air temperature increasing of 1.6°C predicted for the area of Doboj and for Sokolac 1.8°C. Analyzing the air temperature flow for the meteorological station Bjelave (Sarajevo) for the period (1901-2000.), Majstorović (2006, 2008.) concludes that there has been an increase in mean annual air temperature by 0.6°C. Thus, comparing the air temperature increase for the periods (1901-2000. and 1951-2005) it can be expect a slightly higher warming intensity in relation to 20th century. According to the BiH first national report on climate change, in the northeastern part of the Republic of Srpska (BiH), particularly in the area around Doboj and Sokolac, there is an increase in the rain amounts (up to 13%). The Mediterranean region represents the most vulnerable areas in terms of climate change in Europe. The amount of precipitation depending on the region in BiH shows minimal changes in the last 100 years most of the +/- 5%, with what is in the central mountain belt is present trend of increasing rainfall amount, while in the southwestern and northern and northeastern part of the country's present downward trend , but there are different trends for the seasons. The largest part of BiH, shows a negative trend during the spring and summer, while is recorded increase in rainfall during the winter half year (Majstorović et al, 2005). The last decade shows a significant deficit in summer rainfall in the Republic of Srpska (Trebinje 18.4%), especially in Herzegovina. Mountain station Sokolac past 10 years has a surplus rainfall during all seasons, especially in the winter half of the year. At the annual level of surplus rainfall is 12.2% (first BiH national report on climate change).

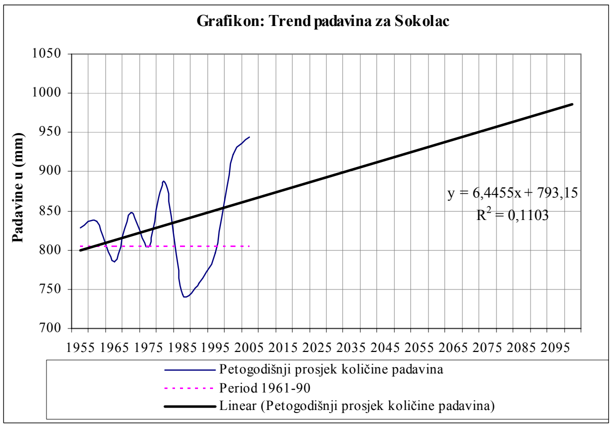
Graph 4. *Precipitation trend for Doboj*



Graph 5. *Precipitation trend for Trebinje*



Graph 6. *Precipitation trend for Sokolac*



Charts 4, 5 and 6 show the precipitation amount trend by the end of 21st century. Explored areas differ in the average amount of precipitation calculated for the five-year period (starting from the period 1951-1955), as well as to change the above parameters in the future. On the basis of the trend, increasing amounts of precipitations to the end of the 21st century is predicted for all analyzed areas, and most for Sokolac area (where the average annual amount of precipitation to increase by 13.9%). For Doboj area provided annual increase amount of precipitation is 10%, and for Trebinje, about 3%.

Taking into account mentioned changes in temperature and precipitation amount by the end of the period, for explored area, it can be concluded that the negative trend is most pronounced for the region of Herzegovina (pronounced temperature increasing and a slight increase in the precipitation amount), which can cause a risk of drought, fires, plant diseases and lead to the disappearance of the already endangered and rare vegetation in the specified area.

4. CONCLUSIONS

In recent decades, weather variability is marked which includes faster changes of very short periods of cold and warm weather conditions, and periods with high amounts of precipitation and drought. These changes are often accompanied by strong winds, though it must be noted that the values of wind speed is still less than in other parts of the world, as well as damage that it caused. The results of previous research suggests the effects of climate change on forest ecosystems in the area of Republic of Srpska:

- ✓ Shifting of vegetation zones (belts) in the horizontal and vertical view,
- ✓ There was nalyzed the data related to air temperature and amount of precipitation for the three meteorological stations (Doboj, Sokolac and Trebinje) which are located in different regions of the Republic of Srpska;
- ✓ The lowest air temperature increase of 1.0 º C is predicted for Trebinje, and maximum of 1.8ºC for Sokolac;

- ✓ The predicted increase of air temperature will lead to shifting of vegetation belts of forest vegetation belts upward within the boundaries of (200-350m).
- ✓ In all analyzed meteorological station is predicted increase of precipitation amount to the end of the 21st century (mostly in the Sokolac area, 13.9%).

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INFLUENCE OF HETEROGENEOUS LIGHT CONDITIONS ON REGENERATION DYNAMICS IN THE SILVER FIR – NORWAY SPRUCE FOREST AT DNOLUČKA PLANINA, BiH

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Abstract: *This article presents results of the research relating to the influence of light regime on seedling regeneration in the mixed silver fir – Norway spruce forest at Dnolucka planina, Bosnia and Herzegovina. For the purpose of assessing the influence of heterogeneous light environments on density and ADR (apical dominance ratio) of fir and spruce seedlings, our study was conducted in experimental canopy gaps ranging from 50 m^2 to 300 m^2 in size. Microsite suitability for seedling establishment under dense crown canopy was assessed, as well as the survival ability of seedlings up to 2 m in height. Processing of the hemispherical photographs was performed by using the software application Gap Light Analyzer 2.0 in order to evaluate light regime on the chosen sample plots. The results suggest that ADR for both species changes with gap size, that is, with different levels of shading. Seedling density was correlated with gap size and canopy structure. It was determined that very small gaps (up to 50 m^2 in size) have on average about 12,9 % light transmission and provide fourfold higher density of fir seedlings in relation to spruce (1,12:0,31 N/m^2); in small gaps ranging from 50 m^2 to 150 m^2 in size, light transmission reaches 19,5 % and these microsites provide slightly higher density of fir seedlings than that of spruce (0,52:0,43 N/m^2); on the other hand, middle-sized gaps ranging from 150 m^2 to 300 m^2 in size, transmit about 34,1 % of full light and enable threefold higher density of spruce seedlings compared to silver fir (0,62:0,22 N/m^2). The results obtained from the field have applicable character in forestry business practice since drawn models representing statistical dependence of seedling density and ADR on forest canopy cover and light regime provide specific ecological implications.*

Key words: mixed fir-spruce forest, canopy gaps, light regime, hemispherical photographs, seedling regeneration

1. INTRODUCTION

It is known that solar radiation plays a complex role in forest regeneration. Light intensity that reaches forest floor or existing new crop can be regulated by different size and shape of canopy gaps, which enables forest managers to provide the optimal light conditions for regeneration development. For that reason proper understanding of spatial and temporal dynamics of tree regeneration under different light conditions is of the essence for practical silviculture.

Regeneration renewal of different tree species in a forest stand depends on several factors including size and shape of canopy gaps, frequency of initial gap formation, subsequent extension chronology, etc. Light measurements in forest stands result in key information on growth conditions of woody and herbaceous plants that occupy stand understory. Even slight changes in structure of dense canopy bring about changes in light transmission that have an effect on stand microclimate to some extent, which eventually influences seed germination, and growth and survival of seedlings (Bunuševac, 1951; Krstić, 1989; Whitmore et al., 1993; Brown, 2000; Hale and Brown, 2005).

Forest vegetation is subject to management and shadows are the best tool we have to affect direct solar radiation (Halverson and Smith 1979). Harvesting models can be designed to regulate light intensity and so the renewal of tree species with different demand for light can be

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successfully managed. Regarding differences in light demand between silver fir and Norway spruce there is an issue what size of a gap in the canopy should be in order to positively influence the development of one species or the other. In connection with this subject, apical dominance ratio (ADR = ratio between the length of the leader and the mean length of the lateral branches at the first node) can serve as a very practical indicator of light environments in which tree regeneration develops.

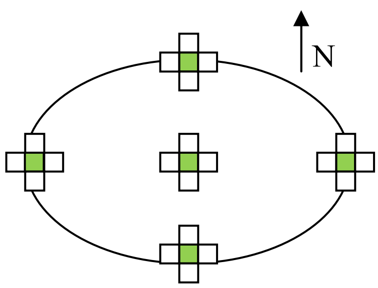
In recent times applied forest ecology emphasizes light regime studies in relation to tree regeneration dynamics in the canopy gaps. In the wave of technical improvements, especially in the last two decades, the digital hemispherical photography was devised for the purpose of light regime estimating in forest stands.

According to what has been said, the goal of this article is to give a contribution to applied forest ecology on the subject of influence of heterogeneous light conditions on regeneration dynamics in silver fir – Norway spruce forest.

2. STUDY SITE AND METHOD

The research was conducted in three fir-spruce forest stands on deep brown soils and luvisols on limestone, which are situated at the elevation 1150 to 1250 m within management unit »Dnoluka«, forest managemnt area »Srednjevrbasko«. They are exposed to north and northeast and have topography that is mostly in form of slight slopes (inclination 5° do 15°) with numerous depressions. Climate characteristics were determined by employing the method of Thornthwaite – Mather (1956), and thereby the data from meteorological station in Jajce were used. Annual climate index for the research area indicates moderate humid climate, while in the vegetation period subhumid wet climate predominates in the area. In terms of phytocoenology all three stands belong to forest community Abieti – Piceetum illyricum, and according to eco-vegetation regionalization (Stefanović et al. 1983) they are situated in the region of inner Dinaric massifs of central Bosnia.

In each of the stands by one square-shaped sample area (0,25 ha) has been set where inventory data were obtained by following standard inventory procedure for permanent sample plots. The influence of light regime on regeneration dynamics in the canopy gaps was studied. Nine gaps altogether were selected (three in each stand) for analysis and in each gap 25 bio-indicating plots were set. From these square-shaped plots (1x1m) hemispherical photographs were taken and characteristics of silver fir and Norway spruce were measured. In the center of a gap 5 plots i.e. 5 m^2 were established, and by 5 plots also toward each cardinal point, that is, at the intersections of the basic axes of a gap and vertical crown projections of surrounding trees (Scheme 1). Therefore, the total number of sample plots that were established in each canopy gap is 25.



Scheme 1. Sample plots in a canopy gap

In addition to total number of 225 plots that were established and analyzed in nine gaps, 25 plots under dense canopy were established in order to obtain the results that could be suggestive of 1 year-old seedling density, as well as of the light conditions that affect older seedlings survival. Three another plots were established in the centers of three different gaps that are featured with dense ground vegetation. Light conditions were estimated indirectly by using software application *Gap Light Analyzer 2.0*. Light regime was analyzed in relation to gap size, and for that reason all canopy gaps were categorized by size:

- very small gaps up to 50 m^2,
- small gaps ranging from 50 to 150 m^2,
- middle-sized gaps ranging from 150 to 300 m^2.

Seedling density and apical dominance ratio (ADR) of silver fir and Norway spruce regeneration were examined in gaps of different size, which consequently have different light transmission.

3. RESULTS AND DISCUSSION

3.1. Size and shape of canopy gaps

Studied canopy gaps, for the most part, have shape of irregular ellipse whose size depends on the lengths of its two basic axes (the longest axis and the wide axis that is perpendicular to the longest), while the shape of a gap can be adequately defined by direction of the longest axis (Table 1). Although shape of a gap has certain importance for tree regeneration, we emphasized gap size since it mostly influences light transmission in forest stands. Besides, it is easier for forest practitioners to regulate size than shape of canopy gaps.

Table 1. *Basic features of investigated canopy gaps*

sampling area 1	gap axes	direction of long axis	m	area m^2
gap 1	long axis	E - W	14,2	78,03
	short axis	N - S	7,0	
gap 2	long axis	N - S	10,0	62,80
	short axis	E - W	8,0	
gap 3	long axis	E - W	23,5	258,27
	short axis	N - S	14,0	
sampling area 2	gap axes	orientation of long axis	m	area m^2
gap 1	long axis	E - W	28,0	257,17
	short axis	N - S	11,7	
gap 2	long axis	N - S	14,6	105,44
	short axis	E - W	9,2	
gap 3	long axis	N - S	8,0	25,12
	short axis	E - W	4,0	
sampling area 3	gap axes	orientation of long axis	m	area m^2
gap 1	long axis	N - S	12,5	112,84
	short axis	E - W	11,5	
gap 2	long axis	E - W	9,5	33,56
	short axis	N - S	4,5	
gap 3	long axis	E - W	14,0	102,21
	short axis	N - S	9,3	

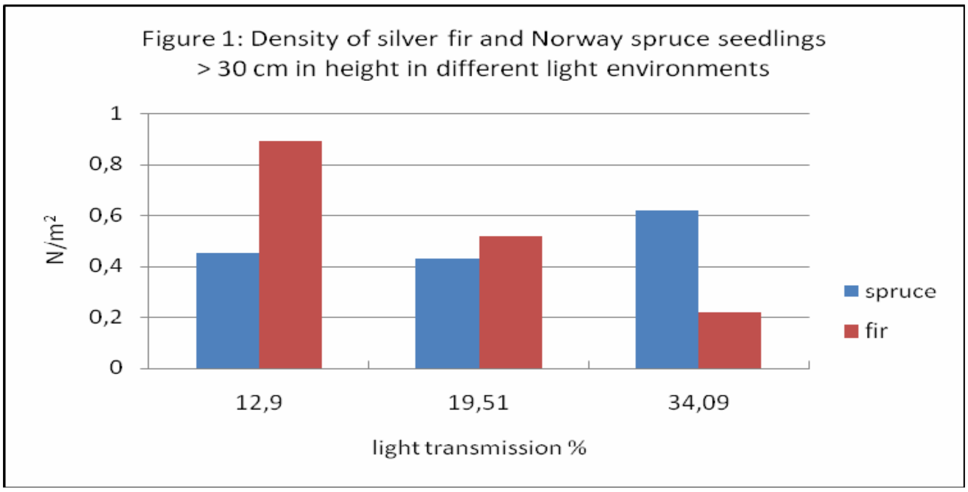
3.2. Light regime and seedling density in canopy gaps

Seedling density is influenced by many ecological factors, and influence intensity of particular factors is changeable through time. Microsite conditions suitable for the establishment of fir and spruce germinants are not identical to those conditions suitable for growth of immature (10 – 30 cm) and grown regeneration (over 30 cm in height). They particularly change their demand for light in the course of their development. Such shifts can be relevant for silvicultural decisions (Brang, 1998). Light influence on density and composition ratio of tree species increases with the height of seedlings that compete for living space and therefore we decided to analyze density of seedlings ranging from 30 to 220 cm in height.

It was determined that very small gaps (up to 50 m^2 in size) have on average about 12,9% light transmission and provide fourfold higher density of fir seedlings in relation to spruce (1,12:0,31 N/m^2); in small gaps ranging from 50 m^2 to 150 m^2 in size, light transmission reaches 19,5% and these microsites provide slightly higher density of fir seedlings than that of spruce (0,52:0,43 N/m^2); on the other hand, middle-sized gaps ranging from 150 m^2 to 300 m^2 in size, transmit about 34,1% of full light and enable threefold higher density of spruce seedlings compared to silver fir (0,62:0,22 N/m^2) (Table 2, Fig. 1).

Table 2. *Seedling density in different light environments*

gap size category	gap area m^2	light transmission (%)	seedlings/m^2	
			spruce	fir
very small	up to 50 m^2	12,9	3,1	1,12
small	50–150 m^2	19,5	0,43	0,52
middle-sized	150–300 m^2	34,1	0,62	0,22



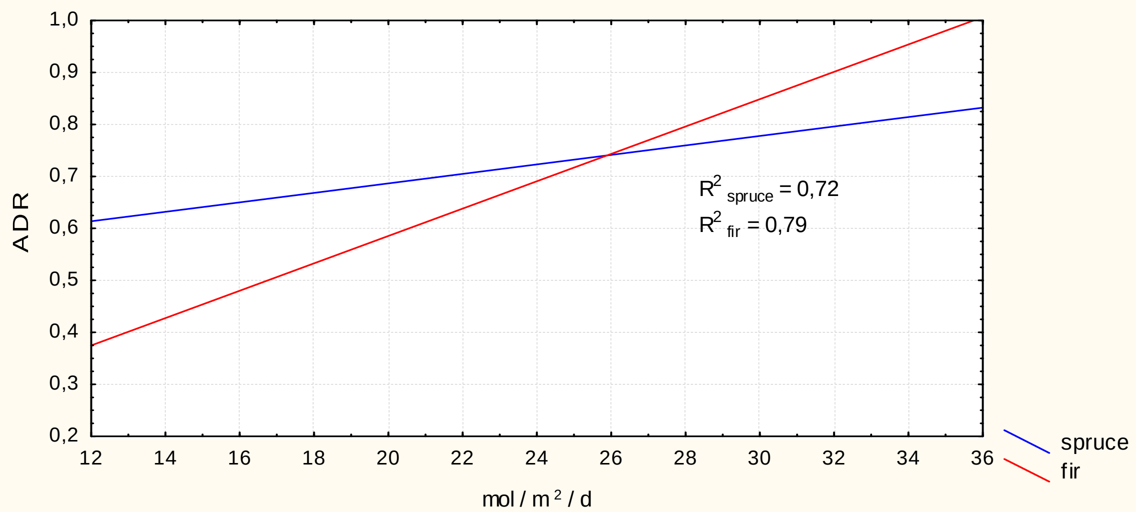
Three middle-sized gaps (one in each stand) featured with dense ground vegetation (Rubus spp., Sambucus racemosa) instead of tree regeneration were selected for analysis. Their longest axes have E – W direction, and their size ranges from 209 m^2 and 238 m^2 to 288 m^2. Common attribute of these gaps is absence of rocky outcrops. Total light transmission in their central parts is 47–51% of full sunlight, which is similar to values that were obtained for gaps with abundant regeneration of silver fir and Norway spruce.

Explanation, most likely, can be found in the fact that tree regeneration depends not only on size and shape of canopy gaps but also on chronology of their formation and extension as well. This article actually presents results from one-time sampling of fir and spruce regeneration dynamics including some hurdles for their occurrence; so, only the results of long-term observations could provide thorough answer to above-mentioned phenomenon. However, on the basis what has been determined from our one-time research it is reasonable to deduce that middle-sized gaps with dense ground vegetation were created following single harvesting operations, while the gaps of similar size and shape with abundant regeneration (primarily of spruce) have been gradually extended to the present size (after initial formation).

3.3. Influence of solar radiation on apical dominance ratio of seedlings

Norway spruce has better ADR compared with silver fir, which is expected because of the fact that lateral branches of fir grow more intensively than that of spruce when the light levels are low (Govedar, 2005). For instance, seedlings of fir and spruce up to 30 cm in height that mostly occupy very small gaps next relations have next features: average length of the leader of fir is 3,33 cm/y, and of spruce 1,25 cm/y; the mean length of the lateral branches at the first node of fir is on average 7,33 cm/y, and of spruce only 2,67 cm/y. For silvicultural practice it is of special importance to estimate the influence of different light levels in canopy gaps of different size on apical dominance ratio of seedlings, and for this purpose we used regression analysis. Linear regression was determined between mentioned elements, which is statistically significant at $p<0,05$ (Fig. 2).

Figure 2: Influence of total light transmission on ADR of fir and spruce regeneration 10 - 130 cm in height



Average ADR of both species is unsatisfactory in very small gaps and is equal to 0,59 and 0,32 for spruce and fir, respectively; likewise, in small gaps ADR values are 0,72 and 0,68 for spruce and fir respectively. In middle-sized gaps average ADR value is still under 1,0 for both species. However, fir and spruce can have ADR over 1,0 on northern gap margins of very small gaps if the longest axis has E – W direction, and in central parts and northern (somewhere also eastern) margins of small gaps. In middle-sized gaps ADR is regularly under 1,0 only on southern gap margins.

3.4. Regeneration under canopy cover

Under dense canopy cover 10 plots of 1x1 m in size were randomly established in order to investigate density of fir and spruce germinants in such conditions. At light transmission 9 – 11% of full sunlight, it was determined that germinant density amounts to $50/m^2$ and $35/m^2$ of spruce and fir, respectively. Besides, 25 plots were established under dense canopy in order to examine light conditions that affect regeneration survival. On these plots we registered that Norway spruce can reach almost 2 m in height at light regime 5 – 9% of full sunlight, but then unsuitable light conditions lead to crown mortality. On ten plots it was found out that silver fir regeneration can reach 2 m in height if light transmission is about 3% of full sunlight. However, crowns of the fir regeneration in such light environments die at some point if initial gap formation is not opportune.

Figure 3. *Dead crowns of spruce regeneration in unsuitable light climate*

4. CONCLUSIONS

On the basis of presented results concerning the influence of heterogeneous light conditions on regeneration dynamics in the silver fir – Norway spruce forest type on deep brown soils and luvisols on limestone we can draw next conclusions:

- silver fir regeneration is most numerous in canopy gaps up to 1,5 are (light transmission up to 19,5%),
- Norway spruce regeneration is most abundant in canopy gaps about 2,5 are in size (light transmission about 34,1%),
- ADR values of fir and spruce imply that central parts and northern margins of middle-sized gaps from 2 to 3 ares in size provide most suitable light environments for regeneration development,
- if silver fir is to be favored then size of initial gaps should be 1 – 1,5 are in size; on the other hand, if the management goal is to favor Norway spruce regeneration then initial size of canopy gaps should not exceed 3 ares, and thereby it is desirable that the longest axis of a gap has N – S direction.

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CONTRIBUTION TO THE STUDY OF LIGHT REGIME IN SESSILE OAK STANDS ON FRUŠKA GORA

Violeta BABIĆ[1]

Abstract: *Results of light regime research in pure sessile oak stands located in the area of National park "Fruška Gora", are shown in this paper. Pure sessile oak stands in this area cover 3960.73 ha, i.e. 17.6%. Reserched stands belong to the most frequent sessile oak forest type (Quercetum montanum typicum Čer. et Jov. 1953) on acidic brown soils and ilimerised acidic brown soils. Stands are even aged, origin is vegetative, between 100 and 105 years of age. Data collecting was done in the summer of 2008, on two different aspects. The stand on southeastern aspect is located at 350 m a.s.l, inclination is 25°, canopy is sparse to complete (0.6 to 0.7). The stand on northwestern exposure is located at 345 m a.s.l, inclination is 15°, canopy is sparse (0.5 to 0.6). The Stationary isohel method is used for the ascertaining of stands light regime. Isohel maps were drawn, the average light intensity and light permeability indices were calculated for the areas between isohels, based on average light intensity values on monitoring spots. Significant differences in light regime were established in researched stands which have different canopy and aspects.*

Key words: Fruška Gora, sessile oak, canopy, light regime

1. INTRODUCTION

Total forest area in Serbia amounts to 2,412,940 *ha*. The dominant species in the growing stock is beech (60 *%* of the area), and the percentage of sessile oak is also considerable 7,28 *%*.

Sessile oak forests owned by the state are characterised by a relatively wide ecological amplitude of horizontal and vertical distribution, so sessile oak is more or less present in all forest areas in Serbia, and also on the low mountains in Vojvodina.

In the area of the National Park Fruška Gora, sessile oak forests occupy the area of 4660,80 ha or 4,79 *%* of the total area of sessile oak forests in Serbia. Pure sessile oak stands in this region occupy 3960,73 *ha*, i.e. 17,6 *%*. These forests are predominantly formed by anthropogenic interventions, through the conversion of high forests into coppice forests. Light regime is of essential significance for sessile oak, as a heliophytic tree species, as well as the degree of stand canopy closure. However, light regime, in addition to a series of other factors, is especially affected by the aspect, or the direction toward which a slope faces. Therefore, this paper will analyse the light regime on the slopes that are exposed to southeast and northwest, which represent the two extreme points in this respect. Between these two aspects, there are differences regarding the light regime and air temperature, and as a result, also in the soil moisture and temperature and in the non-uniformity in the speed and method of decomposition of dead forest litter. According to Lambert Law, the intensity of thermal energy received by an area from the sun changes proportionally with the sine of the angle of the sun rays falling on the horizontal surface. For this reason, the slopes facing south and west are warmer than those facing north and east (B u n u š e v a c, 1951).

The light regime was measured in the study stands in the aim of identifying the effect of the degree of stand canopy closure and the exposure to different cardinal points on the light intensity and coefficient of light transmission in the study stands.

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2. STUDY AREA, MATERIAL AND METHOD

Fruška Gora, being an island mountain, extends in the Northern part of Srem lowland between two rivers: the Sava and the Danube. Numerous transverse and longitudinal directions traverse this area and connect it to Bačka, Slavonia and other parts of Srem. Its length is about 80 *km*, and the maximal width is 15 *km*. The relief has a specific lenticular form, and the main ridge in the direction east-west clearly divides this mountain into two principal drainage basins: the Sava and the Danube Basins.

By the designation of the National Park, with the spatial definition of the Park boundaries, the designated spatial area amounted to 25.548 *ha*, of which 24.391 *ha* in state ownership, and 1.156 *ha* in private ownership enclaved within the National Park. The geographic position, the size of the mountain and a very much developed relief, geological-petrographical and soil diversity, as well as the macroclimate and microclimate diversity, with a rich paleobotanic and syndynamic past, made Fruška Gora a very complex system from the aspect of ecology and vegetation.

Climate conditions in the area of the National Park are presented based on the data of the meteorological measurements (mean annual and mean monthly temperatures, precipitation and cloudiness) at the weather stations: Iriški Venac, Sr. Kamenica, Sr. Karlovci, Gladnoš, Šid and Sr. Mitrovica over the period 1948-1967. The entire area of Vojvodina, and also the area of Fruška Gora, is characterised by temperate continental climate with clear seasonal alterations. Mean annual air temperature is 11,2 ^{0} C and in vegetation period 17,9 ^{0} *C.* Mean annual precipitation quantity is 663 *mm*, of which about 55 *%* falls during the growing season. In this area, cloudiness is considerable (Table 1). It varies from 3,4 to 7,1 tenths of the sky covered by clouds, with the annual average of 5,3 tenths of the sky covered by clouds, so it has a significant effect on the mitigation of the daily fluctuation of air temperature, especially in winter.

Table 1. *Mean monthly cloudiness (Nm), mean number of clear days (Dv) and mean number of cloudy days (Dt)*

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	**Year**.
Nm	6.8	6.4	5.9	5.5	5.3	4.8	4.0	3.4	3.7	4.5	6.8	7.1	5.3
Dv	3.7	3.8	5.9	5.1	5.2	5.9	10.2	12.5	10.8	9.1	3.0	2.9	78.1
Dt	13.5	10.4	9.4	7.5	6.9	4.7	3.4	2.7	3.5	5.8	13.1	15.0	95.9

The month with the greatest number of clear days is August, and the month with the greatest cloudiness is December. Insolation is inversely proportional to cloudiness.

The research was performed in pure sessile oak stands in the area of the National Park, Forest Administration Beočin, FMU 3805 Beočin-Manastir-Katanske Livade-Osovlje in the compartments 21, section f and 22 section c. The study stands are classified as the most represented sessile oak forest type (*Quercetum montanum typicum* Čer. et Jov. 1953) on acid brown soil and leached acid brown soil. The stands are even-aged, of vegetative origin, aged between 100 and 105 years. The data was collected in summer 2008 on permanent sample plots on two different aspects. The stand on the south-eastern aspect (I) is located at the altitude of 350 *m*, slope 25^{o}, it is insufficiently stocked to fully stocked, from 0,6 to 0,7. The study stand on the north-western aspect (II) is at the altitude of 345 *m*, slope 15^{o} and it is insufficiently stocked from 0,5 to 0,6.

Aiming at the identification of light regime, spatial distribution of trees and crown coverage, one sample plot was established on each investigated aspect. The sample plot area was 400 m^2 (20 x 20 *m*), and it was divided into 25 identical squares (side 4 *m*) with total 36 measuring points.

Light regime in the stands was determined by the stationary isohel method (K o l i ć, 1975).

Light intensity was measured in July during three completely clear days, at 7 measuring terms by local time, starting from 6 a.m. to 6 p.m. with two hour measurement intervals. The applied Light Meter was *LUTRON LX-107* facing the light source in a horizontal position of the instrument 1.0 *m* above ground level.

The position of all trees within the sample plots was determined and their horizontal crown projection were surveyed and characterised by a number of radiuses. The position of trees was plotted on millimetre paper, scale 1:100, and the horizontal crown projection was obtained by connecting the marked points.

The data was processed by the usual method for this type of research: the isohel maps were produced based on the average values of light intensity at measuring points and, for the area between the isohels, the average light intensity and the coefficient of light transmission - by isohel method.

The spatial distribution of trees and crown projections on sample plots was presented using AutoCAD 2007 programme. We calculated the total crown area on sample plots, the average distance between trees, and the average crown area per one tree .

3. RESULTS

Light regime in the stand depends on orographic factors, especially on the aspect, canopy closure, total crown area, the sun's height above the horizon, time of the day, etc. Table 2 presents the main data on the canopy characteristics and light intensity on sample plots. There are different coefficients of light transmission, which is conditioned by the degree of canopy closure and the effect of the aspect.

Light transmission in the conditions of insufficient canopy on the cooler northwestern aspect is substantially higher than in the conditions of insufficient to complete canopy on the sout-heastern aspect. Also, it can be seen that the degree of canopy closure has a higher effect on the coefficient of light transmission compared to the aspect. With the increase in the average distance between the trees, the average crown area of a tree also increases.

The previous similar results (K r s t i ć, 1984. and 1989; S t o j a n o v i ć a n d K o l i ć, 1985; S t o j a n o v i ć, 1995; G o v e d a r, 2006) point out the decrease in light intensity with the increase in the degree of canopy closure, but the dependence differs depending on the stand composition. If the stand consists of heliophytes, the increase in light transmission is higher and faster with the decrease in the degree of canopy closure.

Picture 1. *The stand on the south-eastern aspect (I)*

Picture 2. *The stand on the north-western aspect (II)*

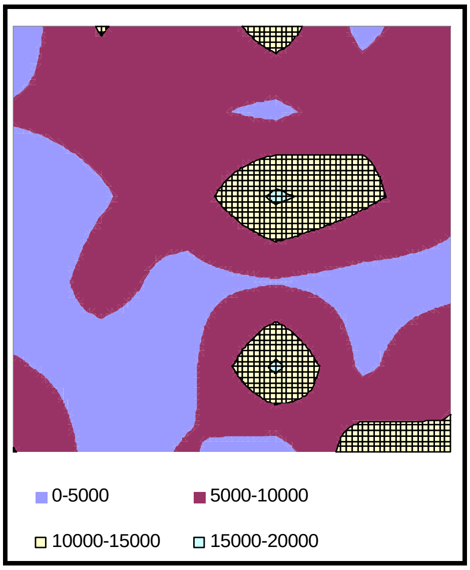
Table 2: *Basic data for the sample plot 20 x 20 m, canopy and light*

Sample plot 20x20*m*	Alti-tude (*m*)	Aspect	Slope (%)	Canopy closure (SS)	Total crown area (m^2)	Average crown area per one tree (m^2)	Average distance between trees (*m*)	lo (Lx/m^2)	Kp (%)
I	350	SE	25	0.6-0.7	298.26	30.21	9.01	6.722.6	15.45
II	345	NW	15	0.5-0.6	214.55	32.02	10.95	9.882.1	22.72

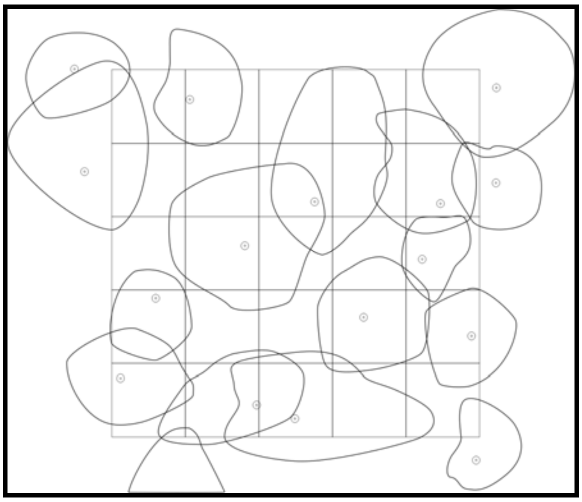
Isohel Map 1 presents the spatial dist ribution of light intensity on sample plot (I), and Scheme 1 presents the spatial distribution of trees and horizontal crown projection. The sample plot is illuminated with the average light intensity lo = 6.722,6 Lx/m^2 i.e. the coefficient of light transmission Kp = 15,45 %. The greatest part of the area is illuminated by the average light intensity of 5.000 to 10.000 *Lx*. In sessile oak stands in the area of Debeli Lug, K o l i ć a n d J o v a n o v i ć (1969) reported also a very close value Kp = 16,2 %, also, G o v e d a r (2006) found almost identical Kp = 15,2 % in pure sessile oak stands in the area of Čelinac in the Republic of Srpska in very similar orographic conditions and the same stand canopy closure.

Total crown coverage in the sample plot was about 3/4 of the area (300 m^2), and crown area of individual trees was about 30 m^2. The average distance between trees was 9 *m*.

Date: 26th to 28th July 2008.
lo = 6.722,60 Lx/m^2 Kp = 15,45%

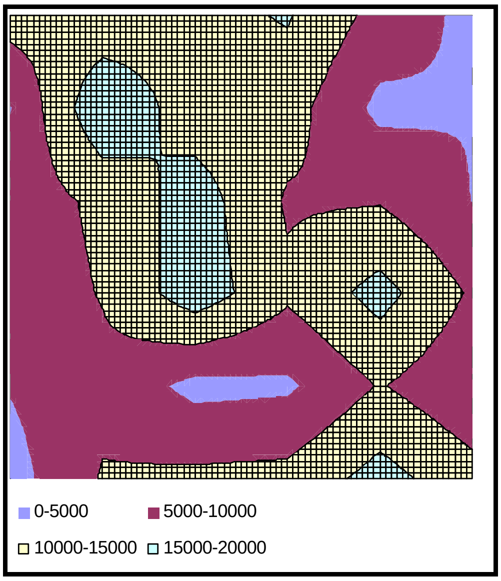


Isohel Map 1 (I)

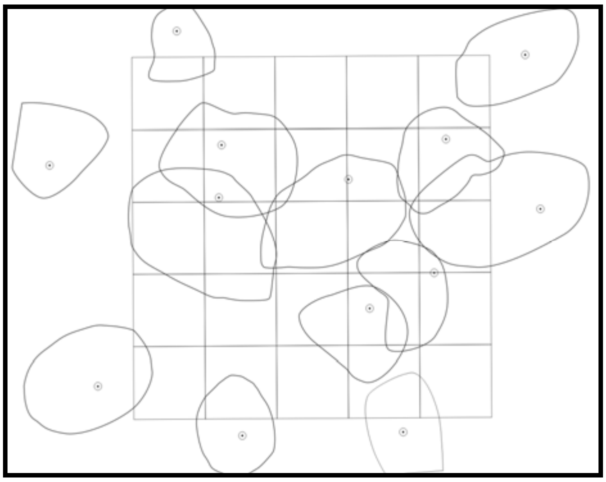


Scheme 1: Spatial distribution of trees (I)

Date: 26th to 28th July 2008.
lo = 9.882,10 Lx/m^2 Kp = 22,72 %



Isohel Map 2 (II)


Scheme 2: Spatial distribution of trees (II)

Isohel Map 2 presents the isohel distribution, and Scheme 2 presents the spatial distribution of trees and the horizontal crown projections on the sample plot (II). Average light intensity is 9.882,1 Lx/m^2, and Kp = 22,72 %. Sample plot (II) consists of two almost identical areas with light intensities from 10.000 to 15.000 *Lx* and from 5.000 to 10.000 Lx/m^2, whereas the areas with lower light intensities to 5.000 *Lx* and the highest light intensities to 20.000 *Lx* are almost identically represented on the sample plot. The stand on northwestern aspect has by about 1/3 lower total crown coverage. The average distance between trees and the average sizes of tree crowns are greater.

Based on the investigated light regime and the degree of canopy closure in both study stands, it is seen that the light intensity is higher in the stand with a lower degree of canopy closure and a cooler aspect. Also, it is evident that the effect of the degree of canopy closure on the coefficient of light transmission is greater than that of the aspect. This indicates that in this case, the stand canopy has a decisive impact on light intensity and the coefficient of light transmission.

4. CONCLUSIONS

The study stands are classified as the most represented sessile oak forest type (*Quercetum montanum typicum Čer. et Jov. 1953*) on acid brown soil and leached acid brown soil. The stands are even-aged, of vegetative origin, aged between 100 and 105 years. They are located on two different aspects (southeastern and northwestern). The stand on the southeastern aspect (I) is located at the altitude of 350 *m*, slope 25°, it is insufficiently stocked to fully stocked, from 0,6 to 0,7. The study stand on the northwestern aspect (II) is at the altitude of 345 *m*, slope 15° and it is insufficiently stocked from 0,5 to 0,6.

Average light intensity (lo) in the stand on southeastern aspect is 6.722,6 Lx/m^2 and the coefficient of light transmission is Kp =15,45 %.

In the stand on northwestern aspect, the average light intensity is 9.882,1 Lx/m^2, and the coefficient of light transmission is 23 %.

In the study stand, with insufficient to complete canopy on southeastern aspect, light intensity in the greatest part of the area is 5.000 – 10.000 Lx/m^2, and on northwestern aspect with insufficient canopy it is 10.000 – 15.000 Lx/m^2.

Light transmission in the conditions of insufficient canopy on the cooler northwestern aspect is substantially higher than in the conditions of insufficient to complete canopy on the warmer (more sunny) south-eastern aspect. Also, it can be seen that the degree of canopy closure has a higher effect on the coefficient of light transmission compared to the aspect, whish indicates clearly that in this case, the stand canopy has a decisive impact on light intensity and the coefficient of light transmission.

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CONTRIBUTION TO THE STUDY OF LIGHT REGIME IN SESSILE OAK STANDS ON FRUŠKA GORA

Violeta Babić

Summary

Results of light regime research in pure sessile oak stands located in the area of National park "Fruška Gora", are shown in this paper. Pure sessile oak stands in this area cover 3960.73 *ha*, i.e. 17.6*%*. Reserched stands belong to the most frequent sessile oak forest type (*Quercetum montanum typicum* Čer. et Jov. 1953) on acidic brown soils and ilimerised acidic brown soils. Stands are even aged, origin is vegetative, between 100 and 105 years of age. Data collecting was done in the summer of 2008, on two different aspects. The stand on southeastern aspect is located at 350 *m* a.s.l, inclination is 25 °, canopy is sparse to complete (0.6 to 0.7). The stand on northwestern exposure is located at 345 m a.s.l, inclination is 15 °, canopy is sparse (0.5 to 0.6). The Stationary isohel method is

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In the stand on northwestern aspect, the average light intensity is 9.882,1 *Lx/m²*, and the coefficient of light transmission is 23 *%*.

In the study stand, with insufficient to complete canopy on southeastern aspect, light intensity in the greatest part of the area is 5.000 – 10.000 *Lx/m²*, and on northwestern aspect with insufficient canopy it is 10.000 – 15.000 *Lx/m²*.

Light transmission in the conditions of insufficient canopy on the cooler northwestern aspect is substantially higher than in the conditions of insufficient to complete canopy on the warmer (more sunny) south-eastern aspect. Also, it can be seen that the degree of canopy closure has a higher effect on the coefficient of light transmission compared to the aspect, whish indicates clearly that in this case, the stand canopy has a decisive impact on light intensity and the coefficient of light transmission.

SCOTS PINE (*PINUS SYLVESTRIS* L.) ECOTYPES OF THE ILLYRIAN REGION IN THE AFFORESTATION OF SITES IN SOUTH-WESTERN SERBIA

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Abstract:*The methodological approach to Scots pine ecotype differentiation was studied. It was presented that the specific site conditions of the wider ecological range of Scots pine in Bosnia could have affected the processes of the reproductive isolation of this species, despite the small geographic distance of the study populations. The study of Scots pine ecotype differentiation shows that there is a regular interdependence between Scots pine morphological-anatomical and eco-physiological properties and the characters of the sites. It is the defined regularities of the distribution of the researched elements by the study groups that actually represent the adopted parameters of Scots pine ecotype differentiation. Based on the analysis of all differential characters, the populations are grouped into 5 Scots pine ecotypes.The planting stock applied in the afforestation with Scots pine in the conditions of south-eastern Serbia should originate from the phenogroup B1 (after Tošić's classification of the sites very close to Scots pine natural sites – regarding the altitude).*

Key words: Scots pine, ecotype, afforestation, different sites.

EKOTIPOVI BELOG BORA (PINUS SILVESTRIS L.) ILIRKOG PODRUČJA U POŠUMLJAVANJU STANIŠTA JUGOZAPADNE SRBIJE

Izvod: *U radu se govori o metodološkom pristupu ekotipskoj diferencijaciji belog bora. Izneto je da su specifični stanišni uslovi šireg ekološkog dijapazona belog bora u Bosni mogli uticati na procese reproduktivne izolacije ove vrste, bez obzira na slabo izraženu geografsku udaljenost proučavanih populacija. Rezultati istraživanja diferencijacije ekotipova belog bora pokazali su da postoji zakonita međuzavisnost morfološko-anatomskih i ekofizioloških svojtava belog bora sa karakterom njihovih staništa. Upravo određene zakonitosti u distribuciji ispitivanih elemenata po oblastima istraživanja su, u stvari i usvojeni parametri u ekotipskoj diferencijaciji belog bora. Analizom svih diferencijalnih karaktera grupisane su populacije u 5 ekotipova belog bora.Kod pošumljavanja belim borom u uslovima jugozapadne Srbije treba koristiti sadni materijal koji vodi poreklo od fenogrupe B1 (prema klasifikaciji Tošića za staništa vrlo bliska prirodnim staništima belog bora – u pogledu madmorske visine).*

Ključne reči: beli bor, ekotip, pošumljavanje, različita staništa.

1. INTRODUCTION

Scots pine communities *Pinetum sylvestris* s.l. in Southwest Serbia are :

–**Asociation *Erico-Pinetum silvestris serpentinicum* Stef 1963**

– **Asociation *Pinetum illyricum calcicolum* Stef. 1960**

According to Vidaković (1982), Scots pine, belonging to the Subboreal-Eurasian floral element, is distributed in Europe from Scotland and Scandinavia to southern Spain and northern Greece. Its range includes the Central massif, Vogezen, the Alps, and the Rhodopes. In Asia it ranges from northern Manchuria and the Okhot Sea to the Caucasus and central Turkey.

According to "Flora of Serbia", Scots pine is distributed in Serbia primarily in the western and south-western parts: Povlen, Maljen, Tara, Mokra Gora, Radočelo, Kopaonik, Zlatar, Šar-Planina

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and other massifs. Based on our research, these complexes of Scots pine forests also include the Scots pine forests of Pešterska Visoravan.

In Serbia, Scots pine forests were researched by Pavlović, Z. (1953), who described the community of Scots pine and Austrian pine on Zlatibor peridotites and serpentinites. Also, a similar forest was described by Gajić et al.. on Maljen in 1954, only at gentler slopes and at the altitudes of 950 - 1030 m (after Tomić, Z., 1992).

2. METHOD

The method of work is based on the theoretical assumptions – that the peculiar site conditions of the wider ecological range of Scots pine might have affected the processes of reproductive isolation of the populations of this species, regardless of the relatively ill-expressed geographical distance of the observed populations. In order to confirm these hypotheses, it is needed to study the chorological conditions, phytocoenologic characteristics, forest silvicultural and taxative elements. In addition, the populations, which are typical on dolomite, limestone, peridotite, and acid siliceous rocks, were researched. Based on their ecotype characteristics, this paper will suggest the sites which can be afforested by certain ecotypes.

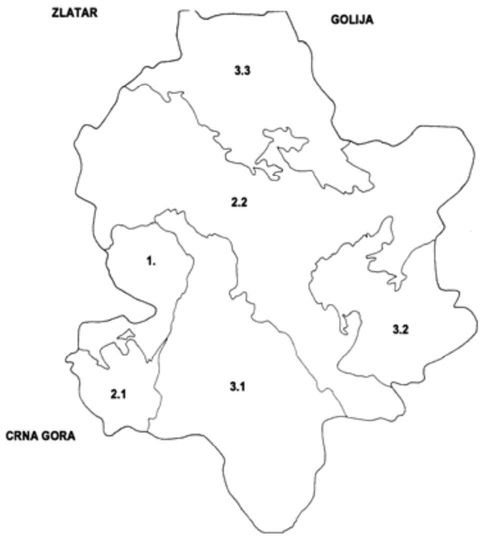
3 RESULTS

Biological spectre. A very high presence of hemicryptophytes reaches 62%. The percentage of phanerophytes of 12% is considerably lower than that in the Austrian pine forest, which is the consequence of a considerably lower percentage of true phanerophytes and also of nano-phanerophytes (5% phanerophytes and 7% nano-phanerophytes), i.e. the higher percentage of frigoriphilous elements. The percentage of chamaephytes is significant, 5% herbaceous chamaephytes and 5% woody chamaephytes. The share of geophytes (8%) is lower than it could be expected, considering the moister conditions in which the Scots pine stands develop, but these are mostly rankers, which are although deep, highly skeletal. Terrophytes and terrophytes/chamaephytes account for 4% respectively. Based on the biological spectre, this Scots pine community is a hemicryptophyte-phanerophyte community.

Figure 1: *Pinus silvestris*

Figure 2: *Pinus silvestris*

Mesophilous plants (Central European and Subatlantic floral elements) account for 23.5%. The percentage of the xerophilous plants (Pontic, Submediterranean, Balkan and desert floral elements) is 37.5%, and the plants of a wide ecological amplitude (Eurasian and Cosmopolitan floral elements) account for 21.5%. The percentage of frigoriphilous plants (floral elements of Boreal and Circumpolar regions) is 12.5%. According to the spectre of floral elements, this community is Submediterranean-Pontic-Central Asian-Central European. Scots pine community shows such a range of floral elements on Tara.



Graph 1: *Study area*

In the afforestation of treeless forest areas, the selection of tree and shrub taxa should be taken into account for several reasons:

– to ensure a satisfactory percentage of seedling survival – success of afforestation,

– to achieve a satisfactorily high and good-quality production, with the safe health conditions of the stands and sites of the afforested areas,

– to prevent further degradation of the soils and sites, i.e. to improve their condition,

– to transform the treeless areas into economic forests in the most economic way and as soon as possible,

– to sustain the positive effect on biodiversity conservation.

In this aim, some characteristics of the soil should be observed, that can present the limiting factors both in the selection of species and the lower taxa, and in the afforestation technology and technique.

In serpentinite-peridotite soils, the specificity of their chemical composition (magnesium and heavy metals) should be taken into account, so it is necessary to select the species for afforestation that can tolerate such a chemical composition (serpentinophytes).

Isajev (Isajev, V. *et al.*, 2000) reports that in the afforestation of rich, undegraded sites, immediately after felling, a suitable model is the seedling production from the local seed sources. If a sufficient quantity of local planting material is not available in the domestic market, the material from the region with general climatic conditions should be applied. Seed material is usually transferred from the north towards the south (maximal distance 300 km) and from the higher to the lower altitudes (maximum 150 m). In addition to seed and planting material from the local seed stands at the population level, a mixture of planting material from several selected seed trees is desirable.

Stefanović and Milanović (Stefanović, V., Milanović, S., 1979), dealing with the methodological approach to Scots pine ecotype differentiation, report that the specific site conditions of the wider ecological range of Scots pine in Bosnia could have affected the processes of reproductive isolation of this species, regardless of the minor geographical distance of the researched populations. The study of Scots pine ecotype differentiation shows that there is an inter-relationship between Scots pine morphological-anatomical and ecophysiological characters and its site characteristics. The regularities in the distribution of the analysed elements are actually the adopted parameters in Scots pine ecotype differentiation. Based on the analysis of all differential characters, the populations are grouped into 5 Scots pine ecotypes:

Ecotype A - Scots pine on deep moist soils,
Ecotype B - Scots pine on deep fresh soils,
Ecotype C - Scots pine on medium deep to shallow soils,
Ecotype D - Scots pine on shallow extremely dry soils,
Ecotype E - Scots pine on extremely moist soils.

Afforestation of the site of the potential vegetation community

***Abieti-Fagetum moesiacae* s. l. on the soil series (ranker-eutric cambisol) on serpentinites and feldspar peridotites**

On eutric brown soils in the openings, on the aspects that are less exposed to the sun, afforestation should be done with Scots pine (*Pinus silvestris*) **ecotype B,**
On the more denuded southern and south-western slopes on the right side of the Dubočica, mostly over eutric rankers on feldspar peridotites, afforestation in the lower parts should be carried out with the Goč Austrian pine (*Pinus nigra ssp. gočensis*), and in the upper parts of the belt above 1200 m, with Scots pine (*Pinus silvestris*) **ecotype C**.

Afforestation of the sites of the potential vegetation communities *Abieti-Fagetum moesiacae* s.l. on the soil series (ranker-eutric cambisol) on serpentinised harzburgites

On deeper eutric brown soils along the streams, afforestation should be carried out with sycamore maple (*Acer pseudoplatanus*). In the upper parts, about 1300 m, on the peaks, afforestation should be carried out with Scots pine (*Pinus silvestris*) **ecotype C**.

Afforestation of the sites of the potential vegetation communities *Piceo-Fago-Abietetum* s.l. on the soil series (ranker-eutric cambisol) on ultramafics

The altitudes of the ultramafic complex from 1250 m to the peak of 1354 m, as a potential site of the three-dominant communities of beech, fir and spruce (*Piceo-Fago-Abetetum),* due to cooler conditions compared to the previous altitudinal belt, requires also some additional species which can have a successful development in this altitudinal belt. The predominant soil series consists of the shallower soils/the soils on serpentinite harzburgite. Afforestation should be performed with Scots pine (*Pinus silvestris*), **ecotype C.**

Afforestation of the site of the potential forest community *Piceo-Fago-Abietetum* on the soil series (dystric cambisol-luvisol) on acid siliceous rocks

The afforestation of forest sites occupied with the grass communities should be carried out with spruce (*Picea abies*), Scots pine (*Pinus silvestris*) **ecotype B** and Balkan maple (*Acer heldreichii*).

Afforestation of the site of the potential vegetation community *Piceo-Fago-Abietetum* s.l. on the soil series (black soil-leached soil) on limestones

The dominant species for afforestation should be Scots pine (*Pinus silvestris*), **ecotype D,** on calcareous black soils and **ecotype C** on brown calcareous soils. In the sheltered positions with the deeper calcareous soils, afforestation should be done with spruce (*Picea abies*) – ecotype on limestones. In the higher limestone belt between 1200 and 1468 m, above the belt of montane beech (*Fagetum moesiacae montanum calcicolum*), afforestation should be done with the pioneer species, such as Scots pine (*Pinus silvestris*), **ecotype D**.

4. CONCLUSION

Based on the results of our research, we recommend the following taxa for afforestation:

Scots pine (*Pinus sylvestris*) should be applied in all more intensively degraded sites in the potential beech-fir forests and beech-fir-spruce forests, i.e. above the altitude of 1200 m. In the purchase of the planting material, it is necessary to select the adequate ecotypes, defined by Stefanović, V. and Milanović, S. in Bosnia. The following ecotypes are recommended: in the ultramafic complex (medium deep to shallow soils) - primarily ecotype C; in the complex of acid siliceous rocks (deep and fresh soils) - ecotype B, in the limestone complex (shallow and dry soils) - ecotype D.

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SCOTS PINE (*PINUS SYLVESTRIS* L.) ECOTYPES OF THE ILLYRIAN REGION IN THE AFFORESTATION OF SITES IN SOUTH-WESTERN SERBIA

Ljubinko RAKONJAC; Vasilije ISAJEV; Vera LAVADINOVIĆ; Mihailo RATKNIĆ; Aleksandar LUČIĆ

Summary

The methodological approach to Scots pine ecotype differentiation was studied. It was presented that the specific site conditions of the wider ecological range of Scots pine in Bosnia could have affected the processes of the reproductive isolation of this species, despite the small geographic distance of the study populations. The study of Scots pine ecotype differentiation shows that there is a regular interdependence between Scots pine morphological-anatomical and eco-physiological properties and the characters of the sites. It is the defined regularities of the distribution of the researched elements by the study groups that actually represent the adopted parameters of Scots pine ecotype differentiation. Based on the analysis of all differential characters, the populations are grouped into 5 Scots pine ecotypes.The planting stock applied in the afforestation with Scots pine in the conditions of south-eastern Serbia should originate from the phenogroup B1 (after Tošić's classification of the sites very close to Scots pine natural sites – regarding the altitude).

EKOTIPOVI BELOG BORA (PINUS SILVESTRIS L.) ILIRKOG PODRUČJA U POŠUMLJAVANJU STANIŠTA JUGOZAPADNE SRBIJE

Ljubinko RAKONJAC; Vasilije ISAJEV; Vera LAVADINOVIĆ; Mihailo RATKNIĆ; Aleksandar LUČIĆ

Rezime

U radu se govori o metodološkom pristupu ekotipskoj diferencijaciji belog bora. Izneto je da su specifični stanišni uslovi šireg ekološkog dijapazona belog bora u Bosni mogli uticati na procese reproduktivne izolacije ove vrste, bez obzira na slabo izraženu geografsku udaljenost proučavanih populacija. Rezultati istraživanja diferencijacije ekotipova belog bora pokazali su da postoji zakonita međuzavisnost morfološko-anatomskih i ekofizioloških svojtava belog bora sa karakterom njihovih staništa. Upravo određene zakonitosti u distribuciji ispitivanih elemenata po oblastima istraživanja su, u stvari i usvojeni parametri u ekotipskoj diferencijaciji belog bora. Analizom svih diferencijalnih karaktera grupisane su populacije u 5 ekotipova belog bora.Kod pošumljavanja belim borom u uslovima jugozapadne Srbije treba koristiti sadni materijal koji vodi poreklo od fenogrupe B1 (prema klasifikaciji Tošića za staništa vrlo bliska prirodnim staništima belog bora – u pogledu madmorske visine).

THE IMPORTANCE OF GENETIC MELIORATION OF OAK SEED STANDS (*QUERCUS PETRAEA / MATT / LIEBL*) IN THE LIGHT OF CLIMATE CHANGES

Milan MATARUGA[1], Vasilije ISAJEV[2], Bojan ILIĆ[3], Branislav CVJETKOVIĆ[1]

Abstract: *Climate changes that occur are obvious, and the consequences of their effects are already present in different ecosystems and human everyday life. Particularly affected are forest ecosystems where, for several decades, the attention of the forestry science and profession has been focused on the oak forests, especially on the Sessile oak forest (Quercus petraea /Mat/Liebl). Maintaining high-quality stands of this type has multiple significance. Besides the economic and ecological importance of the oak forests, the need for improving the seed and nursery production is particularly important. Technological procedures in the production of seeds and seedlings should be focused on the production of seedlings with morpho-physiological characteristics which will correspond to the climate conditions predicted for the next 50-100 years.*

The paper presents the results of activities conducted in genetic-meliorations in seed stands of a 100-year-old oak in the area of Forest Enterprise "Banja Luka"-B&H. We have analyzed the works done in the previous period, conducted the first thinning with the aim of genetic melioration, collected data in the field, tested the quality of fructification and proposed the measures which will be used in the future. Starting from the bio-ecological characteristics of the analyzed species, complexity of oak stands, as well as their sensitivity and response to climate change, the implementation of genetic melioration in seed stands aims at improving the production of the seeds of this species through the targeted use of the genetic potential of seed stands.

Key words: *Quercus petraea*, seed stands, genetic melioration, climate change

1. INTRODUCTION

In the last few decades, stands, groups and individual oak trees (*Quercus petraea* /Matt/ Liebl.), are declining in almost the entire area – they die as a result of, until now, still insufficiently studied and systematized causes. The phenomenon is probably conditioned by the influence of complex factors whose effect is cumulative (Marinković, P., et al., 1990).

Based on the results achieved so far in research related to the occurrence of oak death, it can be considered a consequence of:

-Global climate change (a decrease of rainfall during the vegetation period and the increase of air temperature).

-Changes in population structure of sessile oak forests (reduction of the number of trees in the stand reduces their gene pool).

-Air pollution, plant diseases, insects gradation, etc.

That is why their present state is a consequence of intense negative effects of climate factors. The impact of climate changes is registered in all forests, but they are most prominent in the "most sensitive" ecosystems. The appearance of oak forests death was also noted at the end of the nineteenth century and the last great wave of dying (which has lasted until today) began in 1980 year (Karadžić, D., et al., 2007) and was recorded on almost the entire territory of Europe. One general conclusion would be that the most important role in oak decline are climate changes, defoliators and pathogenic organisms (Oszako, T., 2000).

Today, high sessile oak forests in this region are characterized by prominent abnormality in relation to their age accompanied by the lack of stands area in the youngest age groups, noticeable excess of the surfaces of midle-aged stands and almost normal surfaces of maturing

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and mature stands (Medarević, et. al., 2007). Most sessile oak forests have a protective character because they can be found on the extreme habitats, which are often characterized by shallow or very shallow, flushed, dry land. According to the above mentioned and among the objectives and the management, thinning takes particular place (from releasing young seedlings, cleaning, thinning of different intensity, to clear cutting on bigger area) when we can significantly amend the composition and the unfavorable situation of the stands, depending on the functional requirements.

According to Stojanović, Lj. and Krstić, M., (1990) changes in selection and the dynamic of the implementation of artificial regeneration of sessile oak forests are caused by the global phenomenon, known as "dying forests", as well as omissions from the past caused by the bad management of sessile oak forests. In the process of the successful regeneration of forests in places where it is not possible in a natural way, first you need to ensure sufficient quantities of high quality forest seeds. Scientists and forestry experts are faced with a growing demand for artificial restoration of sessile oak forests.

When it comes to the management of sessile oak forests for special purposes (including seed stands), the management of these forests in terms of planning must be in accordance with the objectives of management legislation (Medarević, et al. 2007). Also, we are witnessing the fact that the abundance and frequency of the full production of seeds of sessile oak has been rare lately as a consequence of the action of various unfavorable factors. The success of the planted forests, their further growth and the quality and quantity of the mass which will be available later, depends, among other things, on the quality of seeds. This emphasises the need to apply modern silvicultures activities, that involve a number of complex procedures in production of seeds. Of course, in these activities genetic melioration in the registered seed stands takes significant place.

In most cases in literature, genetic meliorations were described as thinning of different intensities, which mainly depended on the age of stands (Mikic, T., 2002; Mataruga, M., et al. 2005; Isajev, V et al., 2001). Often we can find the definition of genetic meliorations which assume thinning and thus favoring the selected genotypes, and removing spam, taking into account not only the properties such as diameter and the height of growth, but also sterility of trees with disabilities in the formation of flower and fruit. Having considered the above mentioned and evolutionary processes that occur in a population, as well as all the interventions that have resulted in direct or indirect influence on the gene pool of the population, the notion of genetic melioration could be viewed in the broader context of words. In this sense, **genetic meliorations** would represent all the works in seed stand which have a result in a genetic improvement of seed quality. The implementation of genetic melioration in seed stands aims at permanently improving the hereditary characteristics of forest trees and forest stands in general (Mataruga, M., et al. 2005). They must be carried out so that the next generations stay permanently better than the previous ones, which refers to the offspring produced from seeds collected in seed objects. Genetic melioration of seed stands include activities such as: directed selection of seed trees-following the principles of individual selection, thinning (which is usually considered genetic melioration), activities to increase the abundance of fruit (such as lighting trees, using fertilizers, etc..), as well as activities that provide easier collection and handling of seed in the seed objects (removal of weeds, etc.). However, in this work, the emphasis of the research and the implementation of genetic melioration is put on the thinning of oak stands.

With all the above mentioned we should keep in mind that through genetic melioration in each seed stand we directly affect the gene pool, which directly affects the level of genetic diversity, diversity and heterozygote which are a necessary prerequisite for the protection and adaptation of forest trees, populations and ecosystems. Genetically richer populations adapt better to the changing conditions in the environment, ie. populations that are more heterozygous will develop greater resistance to various stress factors.

2. OBJECT OF RESEARCH

There are 56 registered seed objects in the area of the Republic of Srpska. All registered objects are arranged in three ecological areas (Internal Dinars, Transit Illyrian-Moesian area and Pripanonic area) (Mataruga, M., et al 2005). Out of the total number of registered seed objects, there are five oak seed stands, the total area 83 ha, two of which are located in the territory of Forest Enterprise Unit “Banja Luka”.

The object of research and the analyzed seed stand belongs to the Pripanonic area (Stefanović, et al.1983), ŠPP “Donjevrbasko”, Forest Unit, “Banja Luka”, Administrative Unit "Banja Luka, Management Unit “Crni Vrh”, Section 59b. The stand is located in the forest complex “Crni Vrh”, which includes three municipalities: Banja Luka, Čelinac and Laktaši.

The total surface of the seed stand is 20.10 ha and the reduced area is 16.22 ha. Latitude: 44°46'17.5", longitude: 17°17'32.7", altitude: 350-400 m, slope: 20 °, exposure: all exposures, Climate: moderately continental, the percentage share of species: *Quercus petraea*-94%, *Fagus silvatica*-5%, *Acer pseudoplatanus*-1%. Canopy is quite rare with an average 0.6, but often occurs in two classes (0.4-0.5) and (0.8-0.9), which indicates that the surface is differentiated and heterogeneous. This distribution of canopy has an impact on the abundance of fruit in the stand, ie. area where the canopy is more open as a rule yield is higher and vice versa.

The stand wood stem volume at the time of the implementation of genetic melioration was 245 $m^3 \cdot ha^{-1}$, the prevailing height of the trees about 29 m (the largest part 25-35m) and average breast height diameter is 40 cm. Current annual increment for sessile oak is 4.49 $m^3 \cdot ha^{-1} \cdot year^{-1}$ and for all species 5.69 $m^3 \cdot ha^{-1} \cdot year^{-1}$.

Most of the geological background is serpentine and serpentine-peridotite. Soil: 71% is luvisol; 13% dystric cambisol; 6% eutric coluvium; 6% ranker and 5% stagnosol. In the stand itself diferent types of soils are laid in the form of a mosaic (Brujić, J., and Travar, J., 2001).

During activities to proclaim the seed stands Brujić, J., and Travar, J. (2001) found 14 different communities were found, where the existence of 153 species of plants was found (of which: 14 species of trees, 15 species of shrubs and 4 types of semi-shrubs), 7 species of moss, 7 species of fern. Also, the following communities were diagnosed: *Fangulo-Quercetum petraeae, Potentillo albae-Quercetum petraea, Calluno-Quercetum petraea, Molinio-Quercetum petraeae, Querco-Sorbo-Fagetum sepentinicum.*

3. METHOD OF RESEARCH

Immediately after the registration of seed stand during the preparation for the implementation of the first genetic melioration, elimination and marking of seed trees has been done. All seed trees were marked with four yellow dots placed on the four sides of the trunk. Superior trees were marked with a yellow circle around the tree on the breast height. Criteria which were evaluated during marking these trees were: above-average growth, how straight there are, decrease of diameter per height, the length of crown, branch insertion, branch thickness, trees with or without two or more tops, clean trunk, the structure of the bark, vitality, health and others. Besides all these criteria we should not forget the abundance and frequency of fructification of these trees, which was followed and recorded during the period 2006-2009.

In terms of quantitative parameters, marking trees as one way of individual seed selection was done following the objective mathematical and statistical methods so that the trees that meet the criteria are picked out:

$$\text{Average}_{\text{(seed tree)}} = \text{Average}_{\text{(stands)}} + \text{Stdev} = \text{Average}_{\text{(stands)}} + 2\text{Stdev}$$

Selected seed trees had the function of “trees of the future” in common thinning as a form of nourishing mature oak stands (Krstić, M., and Stojanović, Lj., 2007).

After selecting the seed trees and several years of observations and the occurrence of blossom and seed production, the first thinning in seed stand was made in order to highlight genetic meliorations and removal of undesirable trees. The description of the structural elements of the stand at the moment of works is given in the form of classical forest project.

Based on detailed analysis of the collected data and biological characteristics of the stand, the following are the proposed activities that could be done in the future, both in this and in other oak seed stands.

4. RESULTS OF RESEARCH AND DISCUSSION

From the aspect of geological base, peridotites and serpentinites are not ideal substrates for sessile oak. The analysis of soil types in the stand suggests that it's on the five types of soil which are mosaic spread, and the productivity of the stand directly depends on the type of soil. Canopy varies from 0.4 to 0.9 and is also distributed mosaic through the stand, which had a significant impact on the intensity of thinning. All the above mentioned shows that stand conditions are very complex, and in carrying out any action multiple factors must be taken into account, from which follows the conclusion that the genetic melioration in the stand is far more complex than in some other homogenous stands.

This stand is registered as seed stand several decades ago, but no serious work on the issue of genetic melioration has been performed. The determined age of the stands (100 years) indicates that it is at the end of harvesting time, which would be 120-140 years in sessile oak forests (assuming that it is a stand for the production of saw technical wood) (Medarević, et al. 2007). This indicates the need and necessity of preparing for the final regeneration cutting, which, considering the purpose of the stand, is not the primary goal. At the same time, the age of the stand with previously defined canopy (0.4-0.5) and (0.8-0.9) leaves little room for the implementation of genetic melioration through the thinning.

Seed trees

By selecting and marking the seed trees performed by using the previously defined methodology and based on earlier literature (Mikić, T., 1987, Marić, B., and Jovanović, M., 1961; Isajev, V., et al. 1998, Mataruga, M., et al. 2005), we found a total of 271 seed trees in the stand. If this number is divided by the area we have 16 trees per hectare which is practically the lowest number of seed trees and far from the necessary number of trees of the future. According to Krstić, M., and Stojanović, Lj. (2007) number of trees for the future middle-aged stands should be 150-200 per hectare. The reason for this significantly small number of marked seed trees in relation to the recommended number of “trees of the future”, is the fact that the selection criteria for selecting seed trees are considerably stricter. Besides the quantitative and qualitative traits important for the production of wood biomass, they should also include the abundance of blossom and seed production. The number of trees which have been selected is not enough for actually possible more intensive interventions in seed stand aimed at the implementation of genetic melioration. This confirms the necessity of registration of younger oak stands as seed objects and gradual abandoning the existing ones (Poštenjak, K., et al. 2007).

Besides the fact that the organization of the collecting of oak seeds should be implemented at the level of seed stands, regions or provenances, seed orchards (if there are any), the number of seed trees is very important. This is because of the encompassing the real genetic diversity through the actual number of seed objects (distributed in all regions of provenances) and the number of trees from which seed is collected in one seed object. By increasing the sample the likelihood is higher /greater that in this way rare haplotypes in the population will be included (Isajev, V., et al. 2007). Using a mixture of collected seeds from as many trees as possible, which are evenly distributed in the population, reduces the possibility of adverse effects of "inbreeding" that may occur as a consequence of an insufficient number of trees that have pollinated in the year when the fruit was harvested.

Additional difficulties arise from the fact that the thinning was not made on time in the previous period. Failing to implement these works, caused a slightly greater number of patients and phenotypic bad trees, so after the removal of these trees a not enough room remains for the selection of trees which interfere with the development of seed trees and trees of the future. During tree selection we must be very careful because 100 year old trees suggest that it is no more as "plastic" as the younger stands, and that it will react much more slowly to the action of thinning. Each mistake during the selection is unlikely to be corrected (Ilić, B., 2009).

Health condition

Through the analysis of the health condition of trees (the result of previous and several-year observations) the following was stated in this stand: 14% diseased trees; rot of the lower part of the trunk as a consequence of injury (mostly from earlier works on the tree cuts in the stand) occurs in 4% of total number of the trees, (intensive) dying of the tops of the trees (to a high degree) of 2%, simultaneous dying of branches and tops of crowns to a high degree 2%, any kind of damage of 50% of the total number of trees, of which to a high degree 10%, the third considerably or moderately and the remaining 20% to a low degree.

Having in mind the above mentioned health conditions in the seed stand, there is a large number of damaged trees in various stages of dying. For this reason, the option was that the activities in the implementation of genetic melioration could be mostly carried out through the sanitary thinning and partly through the "classical" thinning. Works at the time of logging and export on the truck road were conducted under strict supervision.

Thinning

The analysis of the situation regarding the overall layout of the stand stem wood volume supplies in seed stand is shown in Table 1. Stand stem wood volume is displayed, by default, under breast height diameter classes, separately for oak, while all other species are put in one category (other species). Stand stem wood volume is displayed in cubic meters per hectare, and the total stand area can easily be calculated (total area of seed stand is 20.10 ha). Comparisons were made in relation to the stand wood volume of “management class 1414” (High forests of sessile oak on deep soils mainly on serpentine and peridotite), “normal stand stem volume” (supplies aimed at), and the situation after the thinning.

The distribution of the stand stem wood volume supply in all cases almost matches the normal distribution (Figure 1). Stand stem wood volume of seed stand compared to the management unit is characterized by higher volume in almost all degrees at breast height diameter (an exception is the least “diameter degree” of 1-20cm, where management class has a higher volume). But, the fact that the average volume of oak forests in “Banja Luka” unit in this management class is 188.8 m3/ha, and the seed stand, before logging, was 244.6 m3/ha, is one reason why this stand was picked out as a seed stand.

Based on the above mentioned, the conducted thinning of this intensity (more than 3% of the total stand stem wood volume) had primarily sanitary character. The reason for a small percentage of cut trees should be primarily found in the fact that some parts of the seed stands have a very low canopy (0.4). No trees were cut in these parts of the stand. The part where the canopy was higher and where it was possible to make a selection of trees, a strong selection criteria was the second limitation factor that affected the total stand stem wood volume which was cut.

By the implementation of the thinning, conditions are created to conduct another action in the future. The emphasis will be put on thinning with the aim of highlighting the crowns of seed trees, bringing the canopy to 0.6 in the part where it is possible to implement.

Chart 1. *Normal distribution of the overall stand stem wood volume before, during, and after thinning.*

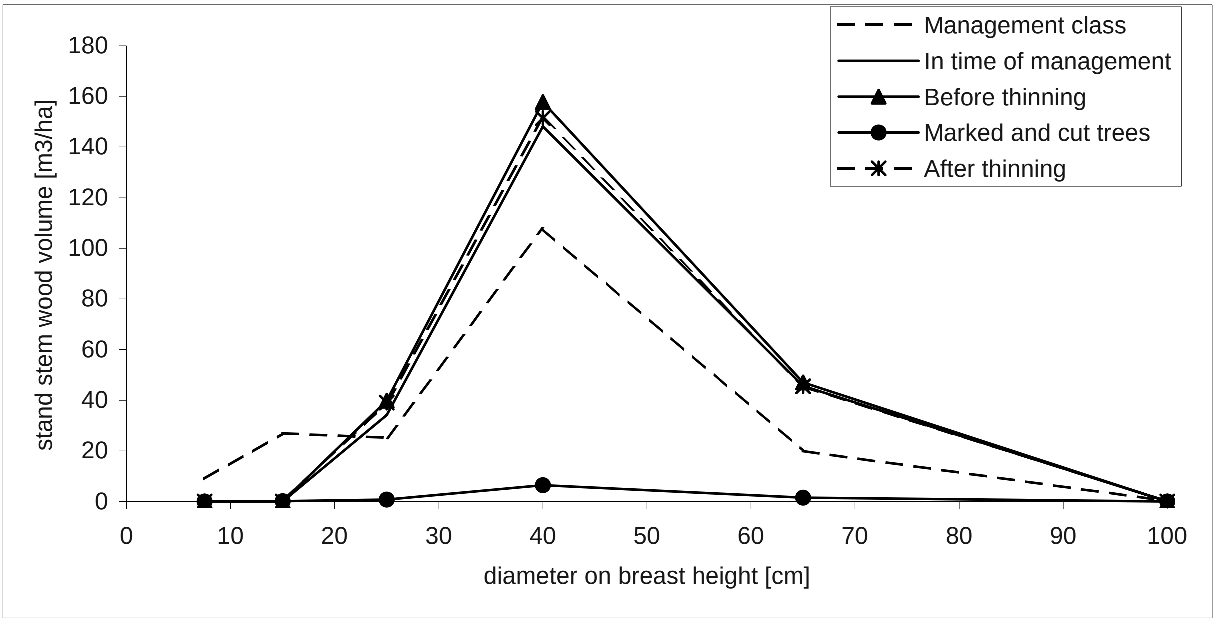

Table 1. *Distribution of stand stem wood volume*

Species	5-10	11-20	21-30	31-50	51-80	>80	Total
Stand stem wood volume of management class 1414 in management period [m^3/ha]							
Sessile oak	9,0	26,9	25,1	107,7	20,0	0,1	188,8
Other species	8	5,8	3,5	3,5	1,4	0	22,2
Total	17,0	32,7	28,6	111,2	21,4	0,1	211,0
Stand stem wood volume of seed stand in management period [m^3/ha]							
Sessile oak	-	-	34,1	148,1	45,6	-	227,8
Other species	6,5	4,7	1,9	0	4,0	-	17,1
Total	6,5	4,7	36,0	148,1	49,6	-	244,9
Stand stem wood volume of seed stand before thinning [m^3/ha]							
Sessile oak	-	-	39,8	157,8	47,0	-	244,6
Other species	8,9	6,3	2,1	0	4,6	-	21,9
Total	8,9	6,3	41,9	157,8	51,6	-	266,5
Stand stem wood volume of marked and cut trees in seed stand [m^3/ha]							
Sessile oak	-	0,1	0,8	6,4	1,5	-	8,8
Other species	-	0,5	0,3	0,3	1	-	2,1
Total	-	0,6	1,1	6,7	2,5	-	10,9
Stand stem wood volume of seed stand after thinning [m^3/ha]							
Sessile oak	-	-	39,0	151,4	45,5	-	235,9
Other species	8,9	5,8	1,8	0	3,6	-	20,1
Total	8,9	5,8	40,8	151,4	49,1	-	256,0
"Normalna" stand stem wood volume of management class 1414 between two cuting [m^3/ha]							
Sp./diameter	1-20	21-40	41-60	61-80	81-100	101-120	Total
Sessile oak	2,0	20,8	38,0	51,1	64,0	36,7	212,6
Other species	0,5	2,7	4,3	5,3	6,1	3,3	22,2
Total	2,5	23,5	42,3	56,4	70,1	40,0	234,8

Source: The Project of genetic melioration and management of seed stand of sessile oak in FE "Banja Luka"

The reasons for conducting genetic melioration (in this case referring to the thinning) in two steps are:

-the size of intervention in the stand: since a big number of diseased trees in the stand were present, quite a number of trees had to be removed with intensive sanitary thinning (over 20%). That inevitably led to a number of new damages in the stand, that occurred during the works on the cut and trees export. Those works to protect the stand would be far more difficult and expensive, and the stand would need more time to recover.

-incomplete and insufficient data on the abundance of seed harvest (flowering and abundance of harvest were followed two years before the first thinning). The best time to implement thinning is a year after the full harvest of seeds, when trees with the full abundance of seed and vice versa could be clearly defined.

In case the criteria is met after the procedures of thinning, and considering the age of the trees in the stand, there would be no need for major interventions in the years to come apart from the possible removal of the tree from the category of damaged or diseased trees that will occur over time. The "final genetic melioration", does not mean the end of all the works, but it will significantly reduce the volume of work. That means from immediate works the shift will be made to the works done in permanent stands (here certainly come activities defined as long-term planning activities in seed stand).

Monitoring of flowering and seed production and keeping record

Phenological observations were made by methodology Isajev, V. and Mančić, A. (2001). Given the size of the stand and the number of seed trees in this stand, observations were carried out on 70 trees more than the planned number (provided sample is 25-100).

Observations of stands began in 2006, so we have data on the abundance blossom and seed production for four years (Table 2)

Table 2 *Abundance of flowering and harvest observed in four years (classification by Kaper)*

Year	Flowering	Seed production
2006	Very good (5)	No harvest (0)
2007	Good (4)	Medium (3)
2008	Weak (2)	Bad (1)
2009	Weak (2)	Weak (2)

Source: Ilić, B., (2009)

Stand was observed three times each year as follows: in the time of blossom, in the time of creation of fruit (acorn) and immediately before the fall of fruit or during the fall. That blossom abundance does not necessarily mean abundant fruit was proved in 2006, when the trees in the stand flowered well but the amount of seeds totally failed. Certain severe weather conditions during the development of flowers or at the time of pollination, and weather conditions during the same year can, to a great extent, reduce the amount of fruit. After detailed analysis we concluded that the abundant precipitation during the rainy end of April and the beginning of May that year probably caused such a result. The results partially confirm the earlier conclusions regarding the abundance and frequency of harvest seeds in which sessile oak shows very strong genetic control in the field of blossom and acorn production and the sessile oak requires at least one year of recovery after the full harvest of seeds (Johnson, et al. 2002).

Of course, we still can't talk about the frequency of full production of seed in the stand or some other conclusions from the observations because the number of years of observation is small. Only after a ten-year analysis of the observations some preliminary conclusions could be made. That's why it is necessary to continue with the observations in the stand and regularly kept books of seed objects, and to collect as much data as possible from the phenophases standpoint. From year to year train other technical staff as well in order to get more data. Also we should pay attention to the individual variability of individual trees, and pick out the trees with the above-average features.

Proposal for long-term and permanent activities in the stand

It must be admitted that the fertilization as a method of stimulating more often and more effective seed production is very rarely applied, and lately in this area only on the experimental plots. The examples from other countries indicate more frequent turning to this method and that it becomes one of the regular measures in places where they apply intensive form of forestry production, and of course, in places that meet certain conditions that this method requires. However, here we should emphasize the importance of fertilization in terms of strengthening the stability of sessile oak and its physiological tolerance to loss, which have been described above. New research suggests that stands aged 100 years will be less responsive in terms of growth unless fertilization and thinning are done in parallel (West, P., 2006).

Taking into account the above mentioned, before making a decision on the application of fertilizer in this or similar seed stands, it will be necessary to analyze in detail the fertilizer used, according to the desired effect and the real state of nutrients in the soil. We should bear in mind the following: a) forest land slowly responds to fertilization compared_to agricultural land, but forest soil retains more fertilizer; b) fertilization is ameliorative measure whereby the flow of goods between the leading plants and soil occurs, so we need to take into account that it is done only on soils deep enough and with more appropriate physical properties, because in the shallow soils fertilizers quickly rinse; c) fertilizer application directly affects the land in order to increase its production capacity, ie. this treatment has no effect on vegetative growth of trees, while the positive effects of fertilization on production of seed occur only after a certain number of years and only in cases when the tree reached the height increment culmination d) fertilization should be done partially around each seed tree.

From the above analysis of the conditions of soil it can be seen that this stand has all the conditions for fertilization, but the very high costs which this method requires are a disadvantage because the profit obtained from the seeds will certainly not cover the cost of fertilizer (profit would be achieved on other principles and over the next years).

5. CONCLUSIONS

Having considered the health condition of the analyzed and similar seed stands of sessile oak, it is concluded that there is a big participation/percentage of trees in various stages of dying. Without considering the reasons for that in this particular case, and by analysing the previous research, it could be concluded that one of the reasons for that is the climate change currently happening. Natural selection, as a consequence of dying, is just a consequence of more or less expressed tolerance of certain genotypes in response to climate change. For this reason, the possible option was to carry out the activities in the implementation of genetic melioration mostly through the sanitary logging and partly through the "classical" thinning. This helps accelerate natural selection, and by the elimination of the less tolerant genotypes it favors the production of genetically better quality seed.

The selection and marking of seed trees by previously defined methodology with a stronger selection criteria in relation to the “trees of future” leads to the fact that there is an insufficient number of selected seed trees. This is particularly expressed in mature and over-mature oak stands. The number of trees which have been selected is not enough for possible more intensive activities with the aim to implement genetic melioration. At the same time, it is necessary to partially know the genetic variability of oak, and cover as many trees from which seed is collected in one seed stand as possible. By increasing the sample we increase the likelihood to include the rare haplotype in the population.

All of the above is in favour of the following:

-The necessity of performing genetic melioration with the aim of implementation of the mass and individual selection in all sessile oak stands. By removing trees in which the occurrence of chronic dying was recorded, we help enhance the already initiated natural selection of tolerance to drought.

-The appreciation of the aspects of genetic resources conservation and the new methods of breeding and seed production. The transfer of reproductive material from a registered source ensures that future forests fight more easily with climate change.

Genetic melioration of these seed objects should be based on basic knowledge of population and evolutionary genetics, emphasizing and respecting the importance of sanitary cutting. The aim of the implementation of these measures is primarily the production of genetically better quality seed, but through the selection and "physiological strengthening" of the stands in the context of climate change.

-The selection and marking of seed trees as the main source of seed production in registered seed stand is an important step in already confirmed large genetic variability of sessile oak and the first step of individual selection

- The necessity of registration of young oak stands as seed stands. The earlier practice of the selection of the mature and over-mature stands as seed stands should be abandoned.

The implemented thinning in oak stands should be of less intensity and with greater frequency. Permanent observations of reactions of the stands to the derived thinning should be made among the derived thinning, as well as the reaction to the further processes of dying and the resulting changes in the abundance and frequency of blossom and production of seed.

Although it is not directly related to this research, it is necessary to emphasize the necessity to define the space in which to conduct the transfer of seeds. It means moving beyond the defined limits of transfer of seeds to 100-200 meters higher altitudes. New research in North America is already implemented in law and Rules and Regulations (Chief Foresterćs Standards for Seed Uses, 2009) where, according to the predicted climate change for each type, a range of possible transfers of seeds in terms of latitude, longitude and altitude is provided (O 'Neill G., Aitken, S., 2004, O'Neill G and Ukrainetz, N., 2008, O'Neill, G., 2007, O'Neill, G., at al., 2008; Ying, CC Liang and , Q. 1994; Ying, CC; Yanchuk, AD 2006).

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BASIC PROBLEMS OF RECLAMATION OF FORESTS OF HUNGARIAN AND TURKEY OAK ON THE TERRITORY OF BELGRADE

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Abstract: *The total area of forests on the territory of Belgrade is 38.853 ha, with wood volume of 4.8 million cubic meters and annual increment of 229.870 cubic meters. The forest cover percentage in Belgrade amounts to 11.8%. The stands of the climatic communities of Hungarian and Turkey oak (Quercetum frainetto-cerris Rud. 1949), which belong to the special purpose forest category, account for a significant part of Belgrade forest fund. These forest complexes are characterized by the following: a considerably high portion of coppice stands (90%); unfavourable age class proportions (more than 80% of these stands are in the same age class, i.e. 60-70 years); unfavourable composition of tree species, with a big proportion of Turkey oak and a small proportion of Hungarian oak; a certain portion of degraded and at some places devastated stands etc. All these factors, together with the negative succession of vegetation and inadequate introduction of autochthonous and allochthonous woody species, have lead to both decreased utilization of production capacities and inadequate provision of multiple benefit forest functions. Conducted research projects present a synthesis of all past analyses of stand condition and silvicultural aims on certain pilot objects in the stands of Hungarian oak and Turkey oak on the territory of Belgrade. The findings are particularly demonstrative of the need for strategic planning of future development and for defining measures for successful acclimatization of these forests to markedly negative factors of abiotic and biotic nature in the urban conditions and to particularly negative climatic changes. In order to improve the state of these forest complexes which are of great importance for Belgrade, suitable reclamation operations have been proposed as the basis for comprehensive models of solutions.*

Key words: Hungarian oak, Turkey oak, special purpose forests, reclamation, climatic changes

1. INTRODUCTION, PROBLEM AND RESEARCH TASK

Importance of the issue of studying reclamation of forests of Hungarian oak and Turkish oak in Serbia is a result of the fact that these forests cover a substantial part of the total forest fund area. Further, two more very important issues highlight the up-to-date aspect of these researches: a very small percentage of preserved stands of Hungarian oak and Turkish oak of the high silvicultural form and the specific position of the majority of areas covered by forests of Hungarian oak and Turkish oak surrounding towns and residential areas in central Serbia. Such position predetermines specific forest management aims and places these forests into the category of special purpose forests (Krstić, M., 2008/a; 2008 /b).

Forest fund of the territory of Belgrade is characterized by a large portion of forests of Hungarian oak and Turkish oak which occupy the northern part of the so-called *'Šumadijska greda'* i.e. parts of the territory towards central Serbia. These forest complexes are mainly of coppice origin. Taking into account the fact that these forests are special purpose forests and to a great extent fall into the subgroup of especially significant forests reclamation problems contain certain aspects which demand the ever growing attention of forestry experts. Up to now the researches which were carried out in these forests on the territory of Belgrade were mainly of ecological and vegetative nature (Jovanović, B., Duljić, R., 1951; Gajić, M., 1952, 1986; Tomić, Z., 1972; Antić, M. *et al*., 1977; Jovanović, B., Vukićević, E., 1977; Vučković, B., 1984, 1986, 1991; Dražić, D., 1999; etc.). Researches regarding silviculture were carried out by: Marić, B. (1933); Bunuševac, T., Jovanović, S. (1967); Bunuševac, T. (1976); Stojanović, Lj. (1982);

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Consequently, the above mentioned led to the following research task:

- to perform the analysis of the current state of forests of Hungarian oak and Turkish oak on the territory of Belgrade;
- to provide directions for the creation of a strategic concept for further development of these forests aimed at improving all multiple benefit forest functions, based on the analysis of the forest state and previous forest management.

2. RESEARCH MATERIAL AND METHOD

Research object are forests of Hungarian oak and Turkish oak on the territory of Belgrade with special attention to forests managed by FE Beograd PC Srbijašume. The analysis of the current state of these forests was performed based on prior researches and findings regarding the issue of reclamation of coppice forests on the territory of Belgrade as well as our own researches. The study used recently available data from scientific expert researches in the field of artificial stand regeneration and establishment on the territory of oak forests in Serbia. Due to the bulkiness of the data collected and the limits of the scope of this research synthesized research data were presented. On the basis of data analysis the method of inductive and deductive reasoning was applied with the aim of defining optimum reclamation operations and the concept for further development of the investigated forests.

3. RESEARCH RESULTS AND DISCUSSION

3.1. Basic data on the forests of Hungarian oak and Turkish oak on the territory of Belgrade

The forest covered area on the territory of Belgrade amounts to 38.853 ha, with wood volume of 4.8 million cubic meters and the annual increment of 229 870 cubic meters. Forest cover percentage of the area of Belgrade amounts to 11.8% which is 0.0243 ha of forest per capita. FE Beograd manages the largest part of Belgrade forest fund (83.2%), with a total of 32 322.70 ha of forests, of which 16 686.70 ha are state owned forests and 15 636 ha are private forests (according to Živadinović, V., Isajev, D., 2006).

Table 1 gives a review of areas covered by state owned forests within FE Beograd regarding stand origin. On the basis of data from table 1 it can be concluded that the portion of coppice forests within the total territory managed by FE Beograd is high (43.5% of the totally covered forest land), particularly compared to high natural forests (10.5%). If the large portion of artificially established stands (45.9%) is left out from the totally covered forest land of state owned forests, **coppice forests' percentage amounts to 80.5% of the total area of natural stands.** This is an indicator of a bad forest fund structure. Keeping in mind that a large part of these forests falls into the category of special purpose forests the issue of their regeneration is far more complex. The largest part of the complex of forests of xerothermophilic Hungarian oak and Turkish oak forest type on the territory of Belgrade is managed by FE Beograd. In the total area of high forests the portion of stands of Hungarian oak and Turkish oak amounts to 58.09 ha (4.0%) and pure Turkish oak stands cover 17.45 ha (1.2%). Preserved mixed Hungarian oak and

Turkish oak stands make up for 2 573.98 ha (43.4%) of the total area of state owned coppice forests within FE Beograd. The preserved pure stands of Turkish oak account for 311.15 ha (5.3%), and the devastated coppice stands of Turkish oak and Hungarian oak amount to 7.8 ha (0, 1%). All of these data indicate that the area of state owned mixed Turkish oak and Hungarian oak forests and pure Turkish oak forests within FE Beograd amount to 2 968.47 or 22% of the forest covered land. In private forests the portion of forests of Hungarian-oak and Turkish oak forests is significant, *cca* 30%. However, reliable data on their structure and stand condition are not available.

Table1. *State of state owned forests within FE Beograd by origin*

Forest origin	area	
	ha	%
High - well-preserved	744,29	5,5
High - insufficiently stocked	674,63	4,9
High - devastated	13,27	0,1
TOTAL HIGH FORESTS	**1.432,19**	10,5
Coppice - well-preserved	5.258,15	38,6
Coppice - insufficiently stocked	639,78	4,7
Coppice - devastated	32,03	0,2
TOTAL COPPICE	**5.929,96**	43,5
TOTAL ARTIFICIALLY ESTABLISHED: FORESTS	6.260,78	45,9
TOTAL SCRUB AND BRUSHLAND:	8,19	0,0
TOTAL WOODLAND	**13.631,12**	100
OTHER LAND USES	3.055,58	
TOTAL STATE FORESTS AT THE FOREST ESTATE LEVEL	**16.686,70**	

3.2. Basic problems of reclamation of Hungarian oak and Turkish oak forests in the investigated area

The present state of forest complexes in the oak belt in this region is a direct consequence of the negative influence of two factors: climatic and antropogenous. The translatory character of the climate in Serbia, a mixture of temperate continental, steppe and Mediterranean climates had an impact on the great floristic diversity of the forests in this area. Forests of Hungarian oak and Turkish oak (*Quercetum frainetto-cerris* Rud. 1949) in Serbia are climatogenous communities with great ecological and floristic diversity (Jovanović, B., 1986), and they prevail in sites of high production potential. Former secular climatic changes which resulted in a more continental climate led to xerophytization of oak forests and changes in the composition of plant species. This succession had a regressive course and it was mainly influenced by long summer droughts which last for 2-3 months. During that time there is great competition among trees, shrubs and herbaceous species for moisture from the soil. It is necessary to point out that, the more thermophilic the ecological type of forest community the faster the degradation processes and slower stand regeneration. On the other hand, significant past decrease in forest covered areas, reclamation works on streams and many other causes led to changes in Hungarian oak and Turkish oak forests stand structure. All the above listed factors resulted in certain changes in interrelations of these woody species, as well as the composition and dynamics of the development of their communities and eventually to rapid degradation processes. For that reason, functional value of xerotermophilic Hungarian oak and Turkish oak types of forests in Belgrade area is currently unsatisfactory taking into account the fact that the area concerned is a great urban area which requires durable sustainable development regarding special purpose forests.

3.2.1. The analysis of stand condition of forests of Hungarian oak and Turkish oak in the investigated area

Within the complex of xerothermophilic Hungarian oak and Turkish oak and other types of forests in Serbia 6 groups of ecological units have been distinguished (Jović, N. et al., 1996). In Belgrade area most common are 3 groups of ecological units: **Forests of Hungarian oak and Turkish oak** (*Quercetum frainetto-cerris* Rud. 49 s. l.) **on different brown and lessive soils**; **Forests of Hungarian oak and Turkish oak with hornbeam** (*Quercetum frainetto-cerris carpinetosum betuli*) **on different brown and lessive soils and diluvium** and **Forests of Hungarian oak and Turkish oak with oriental hornbeam** (*Quercetum frainetto-cerris carpinetosum orientalis*) **on distric and eutric brown soils**. Within each of the above listed groups there are stands which occur in somewhat different site conditions and three typical stand situations: **I** mainly pure Turkish oak stands; **II** mixed Hungarian oak and Turkish oak stands with a lower percentage of Hungarian oak and **III** stands with prevailing or equal portion of Hungarian oak in the mixture. The largest area is covered by group I stands (about 60%). Group II stands cover a smaller area (about 30%) and the smallest area is covered by stands of group III (about 10%). All the above mentioned factors directly determine the reclamation operation in a specific stand. Basic research results for a certain number of stands are shown in Table 2. From the available data it can be concluded that in the stands with the prevailing portion of Hungarian oak (stand groups I and II), the percentage of Hungarian oak per tree number is 22.9%, and 30.4% respectively whereas its percentage per wood volume is lower by about 10% than its percentage per tree number (i.e. 11.5% and 20.6% respectively). This indicates that in these stands Hungarian oak trees are of smaller dimensions than Turkish oak trees. In group III stands, which have a dominant or equal percentage of Hungarian oak in the mixture, the percentage per tree number and per wood volume is approximately the same (58,2% and 56,0% respectively), which means that Hungarian oak is not slower in growth than Turkish oak. This explains for the fact that Hungarian oak is not endangered by Turkish oak in this group of stands.

Table 2. *Average values of tree numbers and wood volume in the investigated stands (FMU Lipovica)*

STAND	AGE (years)	N						V						I_V (m^3/ha)	p_{Iv} (%)
		Hungarian oak		Turkish oak		total		Hungarian oak		Turkish oak		total			
		per ha	%	per ha	%	per ha	%	(m^3/ha)	%	(m^3/ha)	%	(m^3/ha)	%		
I	65-70	163	22,9	550	77,1	713	100	32,5	11,5	250,0	88,5	282,5	100	6,10	2,2
II	65-70	161	30,4	368	69,6	529	100	44,1	20,6	170,0	79,4	214,1	100	4,31	2,0
III	65-70	425	58,2	305	41,8	730	100	132,0	56,0	103,5	44,0	235,5	100	5,42	2,3

Based on our own research laid out above and the estimated state of the investigated stands the following conclusions can be reached:

- the majority of forests belong to specific-purpose class - forests within urban areas (98) categorized as **special purpose forests** with characteristics of protective reclamation forests and especially significant forests;

- at the same time most of these forests are of coppice origin (about 90%), in different degradation stages with slow regeneration, insufficiently stocked with intensive weediness and changes in the soil;
- most of the stands have **even-age structure** (80%). They were formed after clear cuttings during World War II. These stands are in the phase when conversion has to be started (age class VI), with unfavourable mixture of main species in favour of Turkish oak. Hungarian oak is characterized by a much slower diameter and height increment. This species requires a denser canopy and relatively higher humidity than Turkish oak. Complex parallel influence of antropogenous and historical factors on the one hand and changes in climatic and microclimatic factors on the other caused slower growth, lower percentage in the mixture, giving way to the biologically stronger Turkish oak and negative succession of vegetation;
- **inadequate introduction** of different autochthonous and allochthonous woody **species** occurred on a certain part of the territories, which led to both decreased utilization of production potentials of the site and insufficient provision of multiple benefit forest functions.
- **calculated rotation** for forest management of these forests is about **80 years which means that all these stands should be regenerated in a very short period during next 10 years.**

3.3. Proposal of silvicultural reclamation measures aimed at providing functional multipurpose utilization of forests of Hungarian oak and Turkish oak

Taking into account the need for a functional specific-purpose approach in utilization of Forests of Hungarian oak and Turkish oak in Belgrade area, their current state and high potential of their sites as well as the fact that they are endangered by extremely unfavourable climatic influence silvicultural measures which should be carried out in these forest complexes have reclamation character with specific features. The main silvicultural operation proposed is **indirect conversion** but in a **much longer future period than the one enabled by the calculated rotation.** As a part of it artificial introduction of seeds or seedlings of Hungarian oak and valuable broadleaves should be combined in order to improve the mixture and enhance ecological, aesthetic, educational and other values of these forests i.e. fulfil numerous social functions (Krstić, M., 2006; Medarević, M., 1983, 1991; Isajev, V. *et al*, 2006). Substitution should be carried out in places where percentage of Hungarian oak is insignificant, total wood mass small and biologically stronger and invasive tree species dominate. In well preserved habitats and relatively well preserved forests, where Hungarian oak percentage is 30% and more, natural reforestation by regeneration cutting can be applied. Also, in places with lower degradation the method suggested is **direct conversion** under the protection of a parent stand. This method means keeping a number of older trees which protect the land and the newly established stand from further degradation with their canopy and at the same time provide long lasting of a fully grown forest, fulfilment of primary social and protective functions and creation of uneven-age structure. In bad stands at good sites there should be reconstruction. The most urgent stands for reclamation which should be given priority are bad stands in good sites, followed by good stands in good sites and finally bad stands in bad sites. During carrying out of all the above mentioned reclamation operations care should be taken that grassland-meadow ecosystems are provided, on average 8-15% of the total area of the complex which should form the so-called semi-open forest landscapes (Tomanić, L. *in litt.*, 1988).

4. CONCLUSIONS

One of the features of Belgrade forest fund is high percentage of stands from the complex of xerothermophilic Hungarian oak and Turkish oak and other types of forests. These forests are permanently excluded from regular management as special purpose forests, and they are mainly vegetative in origin, of even-age structure, with unfavourable composition of tree species and of various degradation stages. Silvicultural needs imply application of specific reclamation operations which depend on stand characteristics, ecological factors and management aims adapted for a specific purpose. The proposed silvicultural operations are: conversion, substitution and restitution, i.e. reconstruction of these stands aimed at creating stable stands of the high silvicultural form, with favourable mixture of species and uneven-age structure.

Conversion of forests of Hungarian oak and Turkish oak on the territory of Belgrade, as well as on the territory of other large settlements and significant facilities in our country requires defining of highly specific model solutions which must be the result of detailed studies, produced on the basis of all the necessary bioecological, technical and economic parameters. **Prolonged conversion phase** during which **major changes in stand condition** (next **50-60 years**) are possible should be the base for the strategic concept of further development and defining of measures for adapting of these forests to the impact of prominent negative abiotic and biotic factors in urban conditions and especially climatic changes. The application of such prescribed measures will significantly improve the state of the investigated forests because of the future social needs of great urban conglomeration and numerous integral multiple benefit functions they should provide. For that reason they represent highly significant forest complexes of Belgrade.

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MODELS OF BEECH HEIGHT GROWTH IN DIFFERENT ECOLOGICAL CONDITIONS

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Abstract: *This paper presents the results of the modelling of height growth of the dominant beech trees on the different sites in Western Serbia and the needs for their use for the determination of site indexes and projection of the silvicultural and management methods.Beech in Serbia occupies the largest part of the area under forest, and only pure beech forests occupy above 30% of the area. Numerous associations, sub-associations and facies indicate the wide range of beech, which results in different production potentials of beech, but also the need of planning different silvicultural and management measures. Models of dominant tree height growth are a strong foundation of site class assessment, projection of silvicultural and management measures, evaluation of the actual state and the forecast of the future state. The models of beech height growth are based on the data of analysed trees in 13 ecological units (strata) with five repetitions in each ecological unit (65 trees). The subjects of analysis were the trees which were not shaded for a longer time during their development. Ecological units were singled out based on geological, soil and phytocoenological studies. The analysis of variance shows that in all study years, there are statistically significant differences in tree heights of the dominant layer. The differentiation of ecological units in the attained tree heights starts already from the age of 10 years. The order of ecological units according to the attained heights is variable till the age of 70 years. After that, there are almost no changes in the order of ecological units according to heights, meaning that the site effect on the attained maximum height becomes evident only after the age of 70 years. Based on a series of heights of all ecological units, in order to generalise the characteristics of height growth, we formed the site indices for beech. Altogether eight SIs for the age of 150 years were formed. Growth models were applied for soil class assessment and for the determination of terms for silvicultural and management operations in the stands. The beginning of the silvicultural operations and their periodicity depends on the site productivity and they should differ.*

Key words: site indexes, beach stands, growing model, climate change

MODELI VISINSKOG RASTA BUKVE U RAZLIČITIM EKOLOŠKIM USLOVIMA

Izvod: *U radu se prestavljaju rezultati modelovanja visinskog rasta dominantnih stabala bukve na različitim staništima u Zapadnoj Srbiji i potreba njihovog korišćenja za bonitiranje staništa i projekciju uzgojnih i gazdinskih mera. Bukva u Srbiji zauzima najveći deo površina pod šumom, a samo čiste šume bukve zauzimaju preko 30% površine. Brojne asocijacije, subasocijacije i facijesi ukazuju na široku ekološku amplitudu bukve što ima za posledicu ratličite proizvodne mogućnosti bukve, ali i potrebu planiranja različitih uzgojnih i gazdinskih mera. Modeli visinskog rasta dominantnih stabala predstavljaju snažno uporište za bonitiranje staništa, projekciju uzgojnih i gazdinskih mera, ocenu aktuelnog i prognoza budućeg stanja. Materijal je prikupljen na stalnim i privremenim oglednim površinama pri čemu je obuhvaćeno 13 ekoloških jedinica (stratuma) sa po pet ponavljanja u okviru svake ekološke jedinice. Ekološke jedinice su izdvojene na bazi geoloških, pedoloških i fitocenoloških istraživanja. Na bazi snopa visina svih ekoloških jedinica, u cilju uopštavanja karakteristika visinskog rasta formirani su stanišni indeksi za bukvu istraživanog područja. Formirano je osam SI za starost 150 god. Formirani stanišni ideksi služe za proizvodno diferenciranje ekoloških jedinica, ali i za projektovanje različitih uzgojnih i gazdinskuh mera.*

Ključne reči: stanišni indeksi, bukva, ekologija, modeli rasta

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1. INTRODUCTION

The trends of growth are not in the accord with our understanding and the constructed models, and the complete adaptation to the new conditions, mainly to the intensive climate change, is still far-fetched. By the transformation of the current models by using correction factors or creating the new tables of increment and yield based on the old principles the satisfactory results cannot be obtained. The changes are so intensive that shortly after the creation (the process which is very complex and long-lasting) the tables often become outdating due to the altered growing conditions. Therefore, the models of growth which enable the easy parameterization and re-parameterization, the models which enable the incorporation of new information on the increment without the reconstruction of the whole model, are necessary for the future. These models enable the creation of different scenarios of the impact of the stimulating and disturbing factors, based on the principles "if-then", i.e. if certain conditions for growth occur then certain growth dynamics can be expected. These models are focused on the individual trees and defined as site indexes.

2. MATERIAL AND METHOD

The models of beech height growth are based on the data of analysed trees in 13 ecological units (strata) with five repetitions in each ecological unit (65 trees). The subjects of analysis were the trees which were not shaded for a longer time during their development. The differences in dominant tree height per ecological units were tested by the analysis of variance, and the correlation between height and age was described by Todorovic's function (Stamenkovic, Vuckovic, 1988). Ecological units were singled out based on geological, soil and phytocoenological studies: 5.2. Musco-Fagetum on skeletal very acid brown soil on schistose quartz sandstones. 5.1. Luzulo-Fagetum montanum on very acid brown soil on schistose quartz sandstones. 2.1.Fagetum montanum oxalidetosum on skeletal acid humus-siliceous soil on dacite-andesite. 2.2. Fagetum montanum oxalidetosum on shallow, very skeletal acid brown soil, on dacite-andesite. 1.1. Fagetum montanum calcicolum on shallow limestone chernozem. 4.1. Festuco drymeiae – Fagetum montanum on acid brown soil on sandstone. 2.5. Fagetum montanum typicum dentariosum bulbiferae on acid brown soil on phyllite schists. 2.6. Fagetum montanum typicum mercurialosum on skeletal acid brown soil on phyllitic schists. 2.8. Fagetum montanum typicum nudum on skeletal eutric brown soil on diabase. 2.4. Fagetum montanum typicum alliosum on acid brown soil on phyllitic schists. 2.7. Fagetum montanum typicum nudum on skeletal acid brown soil on hornstone. 2.3. Fagetum montanum typicum asperulosum on acid brown soil on sandstone in valleys. 2.9. Fagetum montanum typicum nudum on eutric brown soil on diabase.

3. RESULTS

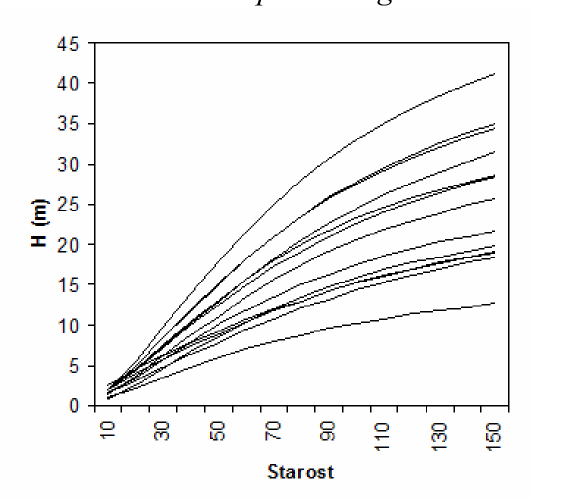
Since there was no visible felling in the observed beech stands, the different productive ability of the sites has the decisive impact on the development of the individual trees. It enables the determination of the productive differences between the observed ecological units, as well as the determination of the most favourable thinning periods based on some characteristics of growth.

3.1. The trend of height growth

The leveled heights of the medium-sized trees from the dominant layer are presented on the Graph 1. In all other observed years the variances are homogenous as well and there are statistically significant differences in all years (from 10 to 150) in the height between the compared ecological units.

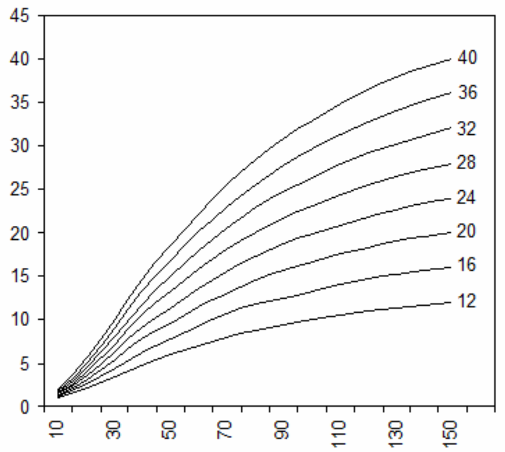
As early as at the age of ten, the differentiation of the ecological units based on the height of the dominant trees begins. At the age of 30 the ecological unit 2.9 is significantly different, and it retains its superiority over the other ecological units until it is 150 years old. The trend of height of the ecological unit 5.2 is considerably less expressed (until it is 30 years old) in comparison with the other ecological units. The arrangement of the ecological units based on the tree height varies until they are 70 years old. Over the next period there are almost no changes in the sequence of the height per ecological units. Given that, it can be concluded that the stand conditions mainly influence the trend of height of the mid-dominant trees until they are 70 years old, and afterwards the site factors are crucial.

Graph 1: *The trend of height growth of the observed trees per ecological units*



The arrangement of the ecological units (from top to bottom): 2.9, 2.7, 2.3, 2.4, 2.8, 2.6, 2.5, 2.2, 1.1, 2.1, 4.1, 5.1 and 5.2.

Graph 2: *Site indexes for the beech*



3.2 Creation of site indexes

The site index is the total height expressed in meters of the mid-dominant trees at the age of 15. For the creation of site indexes 65 trees, which were felled and analyzed in the different ecological conditions, were used. Their height growth was used for the construction of models by which the sites were divided into eight groups. The lowest site index 12 denotes the mean height of the dominant beech trees (12 meters), at the age of 150, whereas the site index 40 denotes the mean dominant height at the same age. The site indexes are marked by 12, 16, 24, 28, 32, 36 and 40, i.e. the differences between them is 4 m. This difference (4m) between the site indexes is the double average standard deviation from the regression line, which is 0.97 m, i.e. approximately 1m. The width variation of the growth curve at the age of 150 is divided into 7 parts, which is conditioned by the fact that these units are 4 meters wide. In other age classes the width variation is divided into 7 equal parts, and by the leveling of them the curves of site indexes were obtained (Ratknic, 1998).

3.3 The relation of the site indexes with the orographic and climate factors

The site indexes for the beech stands were associated with the following orographic factors: altitude, exposure, inclination and relief (the position on the relief and the form of it). Along with the orographic conditions, the site indexes were associated with the annual sum of precipitation (Model 1). Model 1 shows the great significance, of both individual parameters and the model as a whole. By the analyzed factor 93.2% of phenomenon was explained, which is very high value, given the complexity of the ecological conditions in the beech stands.

3.4 The relation of the site indexes with the soil characteristics

The dependence of the site indexes on the soil characteristics was determined. For the analysis all factors of standard analysis were used, separately per horizon and for the whole profile. By using "stepwise" regression two factors were singled out from the analyzed ones: soil depth and hydrolytical acidity (Model 2). The high significance of parameters and model as a whole was determined. Model 2 shows that by the increase of soil depth and decrease of hydrolytical acidity, the site index for beech increases.

Model 1: *The dependence of the site index on the orographic and climate factors*

Variable	Value of parameter	Standard error of parameter	t – test
Constant	78.405424	7.282941	10.76
Exposure	0.609499	0.286961	2.12
Altitude	-0.058832	0.008590	6.85
Inclination	-0.480330	0.090530	5.30
Position in the relief	7.675369	2.129043	3.60
Relief form	0.675498	0.383315	1.96
Annual sum of precipitation	-0.008941	0.006219	1.97

Standard error of regression- 2.63; Coefficient of determination - .0.932; F-test - 16.09

Model 2: *The dependence of site index on soil characteristics*

Variable	Value of parameter	Standard error of parameter	t – test
Constant	38.077691	3.116638	12.21
Profile depth	0.078359	0.033784	2.31
Hydrolytical acidity	-0.301274	0.035796	8.41

Standard error of regression- 2.39; Coefficient of determination- 0.93; F-test - 55.84

3.5 Height increment

The height increment to a great extent depends on site conditions, i.e. on the sites of high classes the maximum height increment is reached earlier, whereas on the sites of low classes it happens later. Since at the moment of culmination on the sites of high classes the high values are achieved (Stamenkovic, 1988), the time of culmination and the increment at the moment of culmination can be good indicators of the productive differences of the sites. The observed ecological units of beech stands reach the maximum height increment in the very wide interval, which ranges from 10 to 100 years. By association this parameter with the ecological conditions of the site, the significant relation with the altitude, mean stand height, exposure, age of mid-dominant trees and pH value was reported. The correlation coefficient is 0.93, and the coefficient of determination is 0.87. The constructed model is in the additive form (Model 3).

The standardized regression coefficients are: for the altitude 1.22, for the mean stand height 0.74, for the exposure 0.44, for the height of the dominant trees 0.54, and for pH 6.15. By using this model to some extent the claim by Stamenkovic et al (1988) that out of the site factors which influence the time of culmination of height increment the altitude is of the particular importance is confirmed, but the importance of pH, which in this model proved to be almost 5.5 stronger factor than the altitude, should not be neglected.

The maximum height increment of this species depends on the altitude, site index, soil (expressed by the number of points) and its depth (Model 4). The standardized regression coefficient is: for altitude 0.40, for site index 1.40, for soil 0.58, and for depth of soil 0.85.

Model 3: *The dependence of the time of culmination of height increment on the site and stand conditions*

Variable	Value of parameter	Standard error of parameter	t – test
Constant	-908.464327	49.205399	18.46
Altitude	0.268392	0.020636	13.01
Mean stand height	5.722807	0.560946	10.20
Exposure	23.547457	4.477680	5.26
Age of the dominant trees	0.886193	0.102487	8.65
pH	82.25342	5.644574	14.57

Standard error of regression - 10.72; Coefficient of determination - 0.87; F-test - 90.11

Model 4: *The dependence of the current height increment at the time of culmination on the site and stand conditions*

Variable	Value of parameter	Standard error of parameter	t – test
Constant	-6.736326	1.698148	3.96
Site index	0.586084	0.143451	4.08
Soil	0.297741	0.131249	2.26
Depth of soil	0.480248	0.088767	5.41

Standard error of regression - 0.17; Coefficient of determination - 0.49; F-test - 16.42

3.6 Trend of diameter increment

The diameter of trees per ecological units and age are presented on the Graph 4. By using variance analysis of the diameter per ages it was determined that in all observed years the variances are homogenous and that in all years (from 10 to 150 years) there are statistically significant differences in the diameter between the compared ecological units. The sequence of the ecological units which are 150 years old is the following: 2.3, 2.6, 2.4, 1.1, 2.8, 2.2, 2.9, 2.5, 2.7, 2.1, 4.1, 5.1 and 5.2. The testing of the significance of differences between the diameters of trees per 10-year periods was conducted by using the variance analysis. After the significance of the differences was determined, the t-test was used for the individual testing of the differences between the men diameters within the same age class.

The frequent changes of the sequence of the ecological units in regard to the diameter at the breast height points to the fact that it is strongly influenced by the site characteristics (relation between the analyzed trees and the trees in the very vicinity), but also to the fact that the influence of the microclimate site conditions should not be neglected. Spearman’s rank correlation coefficient of the diameter at the age of 150 and soil types expressed by the normalized number of points is 0.62. The significance of coefficient is 0.03. By testing the differences in the correlation coefficient between the soil type and the total height, on the one hand, and the type of soil and the diameter, on the other hand (both parameters refers to the ecological units which are 150 years old), this coefficient is considerably lower. It means that the soil has a much greater impact on the height of dominant trees at the age of 150, than on the diameter increment of these trees. The results obtained in this paper show that the trend of diameter of beech trees is not the reliable indicator of the productive differentiation of site, and, therefore, it should be used only in some instances.

The culmination of the current diameter increment ranges over a long interval, from the age 35 (ecological unit 2.7) to the age 125 (ecological unit 5.2). In some ecological units the occurrence of the secondary maximum was reported – in the ecological units 2.4, 2.5, 2.6, and 2.7.

The ecological units grouped per site indexes point to the almost complete correlation of the time of culmination of the diameter increment of individual trees with the determined empirical data on the site characteristics (site indexes).

The great differences in the time of culmination of the diameter increment of beech can be explained by the unifying the site and stand characteristics, which does not imply neglecting of the conditions which are needed for the normal natural regeneration of stands. If the site conditions aggravate, the possibility of the effective regeneration of stand is possible on the great, cleared areas (forest gaps), where the plants are not subject to the influence of the old stand, and, due to the increased penetration of light, the diameter increment culminates much earlier. An interesting impression on the occurrence of two maximum (culminations) of diameter increment, which is reported in the ecological units 2.4, 2.5, 2.6 and 2.7, should be also mentioned. This phenomenon which occurs in the beech can be associated with the productive soil potential. The better indicator of the productive differentiation of site, in beech is "secondary" culmination of diameter increment.

The maximum diameter increment of this species is also the good indicator of site characteristics. By associating this parameter with the site indexes the model 26 was constructed. The parameters of model (5) are presented in the Table.

Model 5: *Relation between the site index and diameter increment at the time of culmination*

Variable	Value of parameter	Standard error of parameter	t – test
Increment at the time of culmination	0.013085	0.000536	24.4

Standard error of regression - 0.06; Coefficient of determination - 0.99; F-test - 597.02

The increase of the current diameter increment at the time of culmination shows the improvement of the site conditions, expressed by the site index.

3.7 The trend of volume and volume increment

The influence on the volume of the dominant trees is significant as early as at the age of 60. The trend of the increase of the correlation coefficient with age points to the higher degree of harmony and the stronger impact of the soil at the site factors, up to the age of 120. Since some ecological units change places when they are at older age, the rank correlation is lower, but it is still above the limit of significance. These changes show that the tree volume, as the parameter which is subject to the alternation of the stand conditions, can, with a certain limitations, serve as the additional indicator of the site productivity.

The influence of soil of the volume increment of the dominant trees is also significant when they are over 60 years old, but the correlation coefficient does not increase with age, unlike the volume. Undoubtedly, it is the result of the stand factor, but also of the already reported secondary culmination of the diameter increment. Therefore, it shows that the volume increment, as the parameter which is subject to change of the stand conditions, can, serve only as the additional indicator of soil productivity, as well as volume.

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THE INFLUENCE OF THE SILVICULTURAL TREATMENTS ON THE CHANGE OF QUALITY OF THE ARTIFICALLY ESTABLISHED JAPANESE LARCH STANDS

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Abstract: *This paper presents the results of the research of the quality of the artificial Japanese larch stands established on the site of the mountain beech forests in Chemernik. On the selected sample plots, based on the studied stand condition, environmental conditions and analysis of the development of trees and silvicultural needs, the low selective thinning of high and moderate weigh was suggested as the silvicultural measure. In addition, the trees were classified based on the biological location, as well as on the quality of stems and crowns. The three-degree classification was applied, which means that the trees were classified as dominant, codominant, or depressed trees, and at the same time the quality of stem and crown of each tree on the sample plots was estimated. By analysing the obtained results of the quality and biological position of the trees, the quality of the stand was evaluated prior and after the marking for thinning. The stable stand of the better quality has a greater influence on the creation of the more favourable microclimate of the vicinity, on the mitigation of the temperature extremes, and it enables the increase of the relative air humidity by the evapotranspiration, as well as the reduction of the concentration of the air pollutants, etc.*

Key words: artificially established stand, Japanese larch, the quality of stand, silvicultural treatment, microclimate

UTICAJ UZGOJNOG ZAHVATA NA PROMENU KVALITETA VEŠTAČKI PODIGNUTE SASTOJINE JAPANSKOG ARIŠA

Izvod: *U radu su prikazani rezultati istraživanja kvaliteta veštačke sastojine japanskog ariša podignute na staništu planinske bukove šume na Čemerniku. U izdvojenim oglednim površinama na osnovu proučenog sastojinskog stanja, uslova sredine i analize razvoja stabala i uzgojnih potreba, kao uzgojna mera predložena je niska selektivna proreda slabe do umerene jačine zahvata. Takođe je izvršena klasifikacija stabala prema biološkom položaju, kvalitetu debla i krune. Primenjena je trostepena klasifikacija na dominantna, kodominantna i potištena stabla, a ocenjen je i kvalitet debla i krune svakog stabla na oglednim poljima. Analizom dobijenih rezultata kvaliteta i biološkog položaja stabala procenjen je kvalitet sastojine pre i posle doznake stabala za proredu. Stabilna sastojina boljeg kvaliteta ima veći uticaj na stvaranje povoljnije mikroklime neposrednog okruženja, ublažavanje temperaturnh ekstrema, pomaže povećanju relativne vlažnosti vazduha putem evapotranspiracije, smanjenju koncentracije polutanata u vazduhu i dr.*

Ključne reči: veštački podignuta sastojina, japanski ariš, kvalitet sastojine, uzgojni zahvat, mikroklima.

1. THE PROBLEM AND THE OBJECTIVE OF THE PAPER

Conifer cultures and artificial conifer stands in Serbia currently cover an area of 174.800,00 ha, which constitutes 78% of the total forest fund (Serbian Statistical Annual 2009., based on the data acquired from the Ministry of Agriculture, Forestry and Water Management – the Forestry Department). The area of conifer cultures and artificially established stands managed by PC "Srbijašume" amounts to 120.320,09 ha. Apart from afforestation of barren land, conifer species were employed in coniferisation of forests of a various tree type and

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degradation degree, in sites of different production characteristics. Most commonly, cultures were established on the sites of far greater production potential, which conifer species do not exploit to the maximum extent. Those stands are largely neglected, of poor quality and health condition, uncared for, with reduced crowns and of high slimness degree, and, consequently, prone to snow–wind throws and breakage, entomological and phytopathological damage, and threatened by fire.

The area of Čemernika and Ostrozuba has been afforested in recent decades. To a lesser extent, cultures have been established in an oak forest zone (Italian oak and cerris), on a site of hilly beech forest, while most of it has been planted in the mountain beech zone. Given their significant representation in the forest fund, being largely neglected in terms of silvicultural treatment, it is necessary to study the condition and quality of these artificial stands, in order to effect their improvement by the application of appropriate silvicultural measures. Although spruce, Scots pine and Black pine are generally used for establishing cultures, close attention ought to be paid to studying stand characteristics of the Japanese larch, a species that produces good results in terms of growth rate and increment at altitudes higher than 1.250 m (Ćirković, T., 2006). The Japanese larch (*Larix leptolepis* Gord.) is an allochthonous tree species, a decidious conifer originating from the island of Hondo in Japan, where it grows at the altitudes from 1.600 to 2.700 m. It is a high – mountain species, a distinct heliophyte, developing a deep adventive root, which makes it resistant to snow –wind throws, more than spruce and fir are. It can be also found at lower altitudes.

In early youth, it is a species of rapid growth, and it reaches its physiological maturity early, particularly when planted in cultures, as well as when growing freely (it matures at the age between 10-15). The paper presents the results of the research of the quality of the Japanese larch artificial stand, established on the site of the mountain beech forest at Čemernika, as well as the influence of silvicultural treatment on the change of quality of the artificially established stand.

2. THE OBJECT OF RESEARCH AND WORK METHOD

A series of sample plots was set up in the studied Japanese larch artificial stand (*Larix leptolepis* Gord.). The stand was established on the site of the mountain beech forest (*Fagetum moesiacae montanum* B. Jov. 1953). It is located at the altitude from 1.250 to 1.280 m. The inclination is 5-10°, exposure south, and structure from 0,7 to 0,9. The geological layer consists of crystal shale, and the soil is district cambisol.

Climate – vegetation characteristics of Čemernik were studied by Krstić, M. i Ćirković, T. (2005). The climate is characterised as humid, according to the Lange bio-climatic classification, and the forests are in their biological optimum. The average annual temperature is 4,8 °C, while during vegetation period it is10,2 °C. The average annual amount of precipitation is 843 mm, that is 454 mm during vegetation period (53,9% of the annual value).

The survey and collection of taxational elements in permanent sample plots, as well as the processing of the obtained data, are conducted according to the established work method.

The biological position of all trees, stem and crown quality were evaluated. A three-degree classification was applied in the evaluation.

3. RESEARCH RESULTS

The basic taxational data concerning the studied stand, including the starting condition, marked trees and the stand condition after a conducted thinning operation, are presented in Table

1. Differentiation of trees according to their biological position, stem and crown quality and starting condition, is presented in Table 2.

Table 1. *Basic forest stand taxational data*

Number of trees	Basal area	Stem volume	Stem volume increment
N/ha	m^2/ha	m^3/ha	m^3/ha
starting condition			
1.478	38,14	300,51	19,24
marked trees			
329	5,84	45,00	2,99
mfter thinning operation			
1.149	32,30	255,51	16,35

The average number of trees in the studied stand accounted for 1.478 per ha, 38,14 m^2/ha of basal area, and 300,51 m^3/ha of stem volume. There were no instances of interventional care measure wood felling in the stand thus far, its condition being a reflection of natural tree selection. Illumination and clear felling were not conducted. On the basis of the studied stand condition, environmental condition and the analysis of tree development and silvicultural needs, low selective thinning of low and moderate weight was suggested as the silvicultural measure. 329 trees were marked, with the basal area of 5,84 $m^2 \cdot ha^{-1}$, stem volume of 45,00 $m^3 \cdot ha^{-1}$ and stem volume increment of 2,89 $m^3 \cdot ha^{-1}$. The weight intensity was 22,3% in regard to the number of trees, 15,3% regarding the basal area and 15,0% regarding the stem volume.

Following the conducted thinning felling, 1.149 trees per hectare remained in the stand, with the basal area of 32,30 $m^3 \cdot ha^{-1}$, stem volume of 255,51 $m^3 \cdot ha^{-1}$ and stem volume increment of 16,35 $m^3 \cdot ha^{-1}$.

Table 2. *Differentiation of trees according to biological position, stem and crown quality – starting condition*

	N		G		V		i_v	
		%	$m^2 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	%
	biological position							
I	592	40,0	20,60	54,0	163,80	54,5	10,47	54,4
II	675	45,7	15,04	39,4	118,28	39,4	7,59	39,4
III	211	14,3	2,50	6,6	18,43	6,1	1,18	6,2
∑	1.478	100,0	38,14	100,0	300,51	100,0	19,24	100,0
	stem quality							
I	328	22,2	11,30	29,6	89,55	29,8	5,70	29,6
II	610	41,3	17,17	45,0	136,36	45,4	8,76	45,5
III	540	36,5	9,67	25,4	74,60	24,8	4,78	24,9
∑	1.478	100,0	38,14	100,0	300,51	100,0	19,24	100,0
	crown quality							
I	659	44,6	21,74	57,0	172,64	57,4	11,03	57,3
II	489	33,1	11,69	30,6	92,31	30,7	5,93	30,8
III	330	22,3	4,71	12,4	35,56	11,9	2,28	11,9
∑	1.478	100,0	38,14	100,0	300,51	100,0	19,24	100,0

Prior to conducted marking and wood felling, there were on average 40,1% of dominant, thickest trees in the stand. The average diameter of these trees is 21,1 cm, and they amount to 55% of total basal area, stem volume and stem volume increment. The most numerous trees in the studied artificially established Japanese larch stand belonged to the group of codominant trees, which accounted for 45,7%, and were more numerous in thinner thickness degrees than dominant ones. The average diameter is 16,9 cm, and share of codominant trees in total basal area, stem volume and stem volume increment constitutes approximately 40%. The thinnest stand trees, 14,3% of the total number, are depressed. The average diameter of these trees is 12,3 cm, and they amount to only 5% of the total basal area, stem volume and stem volume increment.

Only a relatively low number of trees, 22,2% , had a quality stem. Their average diameter is 21,0 cm, and their share in basal area, stem volume and stem volume increment constitutes approximately 30%. 41,3% of trees had a stem of a medium category quality, transitional from best to worst, which amounted to 45% of basal area, stem volume and stem volume increment. 36,5% of trees of all thickness degree had a stem of poor quality.

In terms of crown quality, the most numerous trees are those of first category, with good crowns, of the best phenotype characteristics. These trees constitute 44,6%, in all thickness degrees, mostly in 20 cm degree, which is also the average diameter (20,5 cm). Their share in basal area, stem volume and stem volume increment constituted 60%. 22,3% trees had a crown of poor quality (third), with the average diameter 13,5 cm, and they amounted to 10% of total basal area, stem volume and stem volume increment. Trees with a crown quality ranging from first to third, of medium quality, accounted for 33,1% of total number.

On the basis of stem and crown, the studied stand can be characterised as of **medium quality,** since it has 33,4% of 'good' trees, which, although at lower limit, constitutes between 1/3 and 2/3 of total number.

Differentiation of trees according to their biological position, stem and crown quality, after conducted thinning operation and removal of marked trees from the stand, is presented in table 3.

Table 3. *Differentiation of trees according to biological position, stem and crown quality – after conducted thinning operation*

	N		G		V		i_v	
		%	$m^2 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	%
	biological position							
I	527	45,9	18,43	57,1	146,46	57,3	9,40	57,5
II	601	52,3	13,65	42,3	107,44	42,1	6,95	42,5
III	21	1,8	0,22	0,7	1,61	0,6	0,00	0,0
∑	1.149	100,0	32,30	100,0	255,51	100,0	16,35	99,4
	stem quality							
I	321	27,9	11,08	34,3	87,78	34,4	5,58	34,2
II	522	45,4	14,83	45,9	117,72	46,1	7,56	46,3
III	306	26,7	6,40	19,8	50,01	19,6	3,21	19,6
∑	1.149	100,0	32,30	100,0	255,51	100,0	16,35	100,0
	crown quality							
I	581	50,6	19,33	59,9	153,61	60,1	9,81	60,0
II	445	38,7	10,86	33,6	85,77	33,6	5,51	33,7
III	123	10,7	2,11	6,5	16,13	6,3	1,03	6,3
∑	1.149	100,0	32,30	100,0	255,51	100,0	16,35	100,0

After the conducted thinning operation, the share of dominant trees in the total number of trees accounted for 45,9%. The relative share of these trees increased by 5,8%. In total basal area, stem volume and stem volume increment, it amounted to more than 57%. The number of depressed trees was 1,8%, being reduced by 12,6%, following the conducted low selective thinning.

Also, the tree ratio concerning the stem and crown quality, changed in favour of phenotype better trees following the marking and removal of marked trees from the stand. Consequently, the relative share of trees of the best quality stem increased by 5,7%, while share of those with the best quality crown increased by 6,0%, in relation to the starting condition.

In total basal area, stem volume and stem volume increment, trees with stem of first category quality account for 34%, and those with a crown of first category amount to more than 59%. The relative share of trees with poor stem was reduced by approximately 10%, while those of a poor quality crown by 11,6%

The studied stand, after conducted thinning operation and on the basis of stem and crown of first category quality, can be characterised as of medium quality, but with far greater share of 'good' trees. These trees are represented with 39,25%, which is 5,85% increase in the total number of trees in the studied stand, in relation to the starting condition.

4. CONCLUSIONS

Research for the purpose of this paper is conducted at Čemernik, in the Management unit Kačer-Zeleničje, in a series of sample plots in artificially established stand of Japanese larch on the site of a mountain beech forest. On the basis of studied stand conditions, environmental condition, tree development and silvicultural needs, low selective thinning of low and moderate weight was proposed as a care measure in selected sample plots. The weight intensity is 22,3% in regard to the number of trees, 15,3% in regard to basal area and 15,0% in regard to stem volume. Additionally, a classification of trees according to the biological position, stem and crown quality was conducted. A three- degree classification including dominant, codominant and depressed trees is applied, and the stem and crown quality of each tree in sample plots was evaluated.

The studied stand, prior to application of silvicultural measures and on the basis of stem and crown of best quality, was characterised as of medium quality, since it had 33,4% of "good" trees, which, although at lower limit, constitutes between 1/3 and 2/3 of the total number. After conducted marking for thinning and thinning operation, the stand quality was changed in favour of the most quality trees. It can also be characterised as of medium quality, but with far greater share of "good" trees. These trees account for 39,25% which is 5,85% increase in total number of trees in the studied stand in relation to the starting condition.

A stable stand of better quality has a larger influence on creating a more favourable vicinity microclimate, mitigating temperature extremes, it helps increase of relative air humidity by evapotranspiration, reduces the concentration of air pollutants, etc. For that reason, the increase of the stand quality has multiple importance, since it improves and intensifies multiple functions of forest ecosystems.

Although the quality of the studied artificially established Japanese larch stand is of "medium" category, this species produces good results in terms of growth rate and increment at the altitudes higher than 1.250 m and, therefore, more attention ought to be paid to it in this altitude zone, with application of appropriate and timely silvicultural measures.

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ANALYSIS OF TREE GROWTH ELEMENTS AS A CRITERION FOR STAND CLASSIFICATION BY REGENERATION PRIORITY

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Abstract: *Felling and dendrometric analysis of altogether 18 mean stand trees and 18 mean dominant trees was performed in different ecological conditions of sessile oak coppice stands in the area of Mt. Cer, North-Eastern Serbia. The subject of the research were the stands in the mature stage which are absolutely prevalent throughout the area, which points to an unfavourable age structure. Although these are coppice stands, formed by clear cutting during the Second World War, there were also individual trees of different ages, of seed origin. This paper, based on growth and increment lines of trees of both vegetative and seed origin, points to the duration periods of certain stand development phases, as well as to silvicultural measures which were carried out, i.e. which were absent at a given time. Based on tree development, i.e. the analysis of growth elements and their trend, as one of the criteria, stand classification was performed by the priority for regeneration, aiming at the establishment of as good as possible age structure.*

Key words: sessile oak, coppice stand, development phases, growth elements, rotation length.

ANALIZA ELEMENATA RASTA STABALA KAO KRITERIJUM ZA KLASIFIKACIJU SASTOJINA PO PRIORITETU ZA OBNAVLJANJE

Izvod: *U severozapadnoj Srbiji, na području planine Cer, u različitim ekološkim uslovima izdanačkih sastojina hrasta kitnjaka, izvršeno je obaranje i dendrometrijska analiza ukupno 18 srednjih sastojinskih i 18 srednjih dominantnih stabala. Predmet istraživanja su sastojine koje su u fazi zrelosti i koje apsolutno preovlađuju na celom području, što ukazuje na nepovoljnu starosnu strukturu. Iako se radi o izdanačkim sastojinama, koja su nastala čistom sečom u toku Drugog svetskog rata, konstatovano je prisustvo pojedinačnih stabala generativnog porekla različite starosti. U radu je na osnovu linija rasta i prirasta stabala vegetativnog i generativnog porekla, ukazano na periode trajanja određenih razvojnih faza sastojina, kao i na uzgojne mere koje su tada sprovedene, odnosno koje su u datom momentu izostale. Na osnovu razvoja stabala, tj. analize elemenata rasta i njihovog trenda, kao jednog od kriterijuma, izvršena je klasifikacija sastojina po prioritetu za obnavljanje, kako bi se koliko je to moguće uspostavila bolja starosna struktura.*

Ključne reči: hrast kitnjak, izdanačke sastojine, razvojne faze, elementi rasta, dužina ophodnje

1. INTRODUCTION

Sessile oak (*Quercus petraea* agg. Ehrh. 1967) is one of the most significant species of European dendroflora. The Balkan Peninsula is one of the most interesting regions where oak evolution was affected by climate xerothermisation (Janković, M. 1973). In the ecological sense, sessile oak forests are azonal vegetation and they depend mainly on orographic-edaphic conditions.

In the Republic of Serbia, as well as in the greater part of the Balkan Peninsula, a significant percentage in the growing stock is still the forests of coppice origin reproduced by stumps and shoots. They were mostly created by clear cutting during the Second World War. Because of their shorter life cycle, poorer quality, productivity and health, as well as due to

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incomplete utilisation of the site production potential Medarević, M. *et al.* (2006), they are at the moment nearing the end of the planned rotation of the mainly prescribed 80 years in Serbia. The problem of coppice forests was not extensively dealt with by the West European countries thanks to the lower percentage of these forests in their growing stock. Despite the efforts to solve the problem of coppice forests in Serbia, there are still no visible results (Aleksić, P. 2006). Taking into account the method of their reproduction, it was mainly thought that they consist of exclusively of the trees of coppice origin. However, the dendrometric analysis shows that in the Second World War clear cutting was focused on economically more attractive trees of greater dimensions and better quality. The trees which remained in the stands were of generative origin, of larger sizes, poorer phenotype characters, often diseased and semi- decayed. Along with them, there remained generative trees of smaller sizes in the form of overtopped trees and undergrowth. Larger-sized diseased trees died sooner or later, and thinner trees of the undergrowth merged in the growing coppice stand. Some of them were killed and a small number succeeded in the struggle for survival with the growing coppice trees and sooner or later most often occupied the dominant position. The trees of seedling origin are subject to different rules of development than the trees of coppice origin, which complicates additionally the problem of conversion of these stands into a higher silvicultural form. An additional problem is that coppice forests, both in the study area and in the entire region, are mainly of the approximately the same age. Their regeneration and conversion at certain time is neither technically feasible nor ecological justified. On the other hand, the regeneration grading in time and space could improve the now unfavourable age structure. There are numerous criteria for the classification of these stands by the regeneration priority (Dražić *et al*. 1990, Čokeša V. 2007, Ratknić, M. *et al*.1987, Ratknić, M. *et al*. 1987, Dražić, M. *et al* 1987). The task and the objective of this paper is to deal with one of them, that is the analysis of tree growth elements, both of vegetative and of generative origin. To support the effect of this criterion of stand classification by the regeneration priority, it is compared to other parameters, such as stand production, quality, and health.

2. STUDY AREA AND METHOD

The study stands are located in the Podrinjsko-Kolubarski forest district (north-western Serbia), managed by FE "Boranja", on the area of FA "Šabac" in FMU "Iverak" and FMU "Cer-Vidojevica". The study stands are commercial, well-preserved, mature, coppice forests of sessile oak, of good quality. Their conversion is possible. There are more than 80% of maturing and mature sessile oak coppice forests, which should be regenerated i.e. converted in the higher silvicultural form, in the district of which in FMU "Iverak" more than 50%, and in FMU "Cer-Vidojevica" more than 90% (in the complex Vidojevica – almost all).

Six series of sample plots were established in the study area, in different ecological conditions, i.e. three on Iverak and three on Vidojevica. Each series consists of three sample plots. In each sample plot, the dendrometric analysis was performed on one felled mean stand tree and on one felled mean tree in the dominant layer (mean of the 20% largest-diameter trees), so the dendrometric analysis was performed on altogether 36 trees. The disks for the stem analysis were taken at each 2m, and for the crown area, at each 1 m. Annual rings were counted using the ADDO Tree-Ring Measuring Instrument to the nearest 0.01mm per 5-year periods. Statistical processing was based on the programme „Tree Analysis" (Marković, N.). In diameter and height analysis, fitting was mainly done using the parabola of the third degree, and in volume analysis, by the parabola of the fifth degree with a high correlation coefficient.

3. RESULTS

The correct estimation of the stand state requires the knowledge of its past, present and development tendencies. During its life cycle, each even-aged or approximately even-aged stand passes through determined stages or periods (Jovanović, S. 1980). The present state of the study stand production characteristics is the result of the past development stages and the undertaken silvicultural measures. Each of the stand development stages was characterised by key moments defined by growth elements (intensity of growth in height, diameter and volume, moments of culmination of current height, diameter and volume increment, as well as the time of culmination of the average volume increment). To stimulate the life processes, in some development stages defined by the state and dynamics growth elements, it is essential to perform some silvicultural measures, from the negative selection, moment of the first thinning to the identification of the moment of maturity for cutting, i.e. harvesting of the old stand and the establishment of the new stand.

The Diagrams and Tables present the mean values of growth elements per years, both for the trees of vegetative and the trees of generative origin, per ecological units. It should be noted that the development of stands and individual trees does not have the same performances. Thus for example the culmination of the average, and also the current volume increment, according to Stamenković(1974) after Asman, occurs earlier in the stand than in individual trees. This is the consequence of the decrease in the number of trees per unit area, and in this way also the increase in the standing area. The analysis of trees can show the starting point and the termination point of the individual development stages, and whether the adequate silvicultural measures were implemented. The time of culmination of current volume increment and the average volume increment, in accordance with the existing production and quality characteristics, is the key parameter in the stand classification by regeneration priority, i.e. in the definition of the silvicultural goals and further treatments in the study stands. Based on ecological and stand characteristics, the stands are classified by ecological units (Čokeša, V. 2007, Cvijetićanin, R. 2005, Stojanović, Lj. *et al.* 1980).

Ecological unit I: Xerophilous forests of sessile oak with green weed *(Quercetum montanum genistetosum)* on leached acid (series-4) and acid brown soil (series-5).

This ecological unit consists of coppice stands with trees of generative origin in the dominant layer. The age of the trees of coppice origin is 60-70 years and the age of dominant trees of generative origin is 80-85 years (Supplement 1).

Judging by the culmination of current height increment of coppice trees, tree differentiation and mass selection occurred before the age of 20. When the shoots started sprouting from stumps and roots after clear cutting, the age of the overtopped fore growth of generative origin in the form of a thicket was about 20 years (classification after Koestler). However, vegetative shoots, thanks to their intensive juvenile growth overtopped the existing layer. After the culmination of current diameter increment (30-35 yrs.), height increment of coppice trees started decreasing and their diameters stagnated. This is the time to begin the opening up of the canopy (Jovanović, S. 1980). As this is the site liable to weed invasion, and as considerable sanitation cutting was already performed in these stands because of oak dying the opening up of the canopy should be omitted. Natural self-thinning started after the current diameter increment culmination, which created the opportunity for the trees of generative origin to take advantage of their accumulated growth energy and to occupy the first crown class. Although they stagnated under the canopy of coppice trees, their root system developed. All the above facts postponed the culmination of current height increment of the trees of generative origin and practically it occurred simultaneously with the culmination of current diameter increment (about the age of 50), which could not be postponed due to biological characters of the species. When the dominant coppice trees attained the culmination of height increment they were

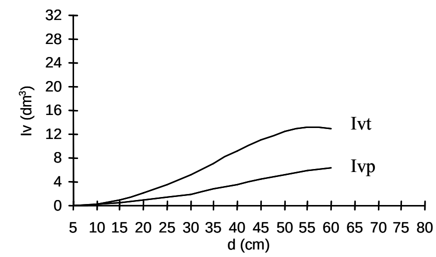
20 years old. However, already from the age of 30, they were overgrown by the trees of generative origin which were then about 50 years old. Based on the culmination of current diameter increment of coppice trees and based on their volume development, it is assumed that there had been no tending before the age of 30.

The culmination of current volume increment of dominant trees of coppice origin occurs about ten years earlier than that of mean stand trees with a somewhat higher culmination level. The average volume increment of dominant trees of coppice origin compared to mean stand trees of coppice origin also culminates a little earlier and with a higher culmination level. The culmination of current and average volume increments of the trees of generative origin occurs even later and with a considerably higher culmination level compared to the trees of coppice origin. The values in series-5 which are lower than the average values are the consequence of the poorest site class.

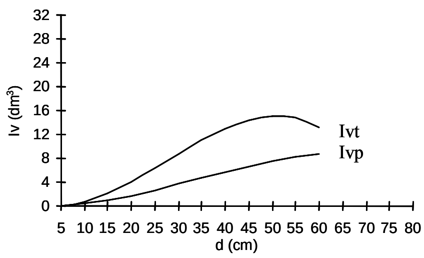
Table1. *Development of trees in the stands of xerophilous variety of sessile oak forests*

Series	Origin	Time of culmination							
		Iht		Idt		Ivt		Ivp	
		M.stand	M.dom.	M.stand	M.dom.	M.stand	M.dom.	M.stand	M.dom.
4	Veg.	20 (48)		35 (4.6)		55 (14.8)		65 (7.5)	
	Gen.		50 (37)		50 (4.7)		110 (30.0)		130 (13.0)
5	Veg.	15 (50)	15 (54)	30 (3.7)	30 (5.3)	65 (13.0)	50 (15.0)	70 (6.5)	65 (9.0)
	Gen.		45 (43)		45 (5.6)		70 (17.4)		90 (8.5)

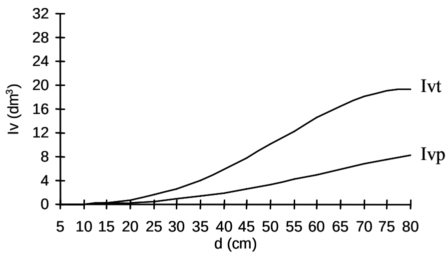
Graph 1. *Mean stand tree of vegetative origin*



Graph 2. *Mean dominant tree of veg. origin*



Graph 3. *Mean dominant tree of seedling origin*



Ecological unit II: Xero-mesophilous forests of sessile oak *(Quercetum montanum typicum)* on leached acid soil.

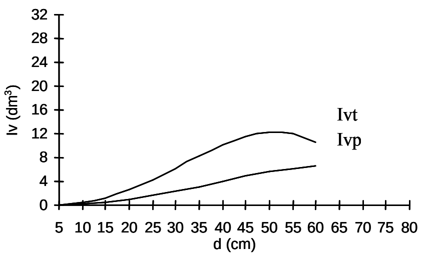
This ecological unit consists of stands in which the trees of generative origin occur both among the dominant trees and among the mean stand trees. The age of the trees of coppice origin is 62-63 years, and the age of the trees of generative origin is 65-73 years (prilog-2).

Current height increment of dominant trees of coppice origin culminated 5-10 years earlier than that of mean stand trees, and 5 years earlier than that of dominant trees of generative origin. Also Table 2 shows that the culmination level of current height increment is always higher in dominant trees than in mean stand trees, and also in dominant trees of coppice origin compared to dominant trees of generative origin. Namely, the age difference between the trees of generative and coppice origin is on average less than 10 years, which means that during the clear cutting, the trees of generative origin were in the seedling stage. The trees of coppice origin could grow faster thanks to the inherited root systems; they differentiated by height and occupied the dominant position. The trees of generative origin, practically throughout their life time, developed in the shade of dominant trees of coppice origin. Only individual trees of generative origin could occupy the first crown class. This shows that in the thicket stage (Koestler classification) it is essential to enrich the upper layer with the good-quality individuals from the middle layer (Mlinšek D., 1968).

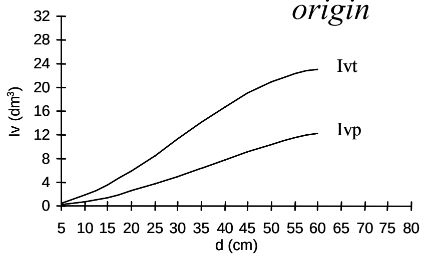
Table2. *Development of trees in the stands of xero-mesophilous variety of sessile oak forests*

Series	Origin	Time of culmination							
		Iht		Idt		Ivt		Ivp	
		M.stand	M.dom.	M.stand	M.dom.	M.stand	M.dom.	M.stand	M.dom.
3	Veg.	25 (53)	15 (61)	30 (4.2)	15 (5.7)	50 (13.0)	55 (21.5)	60 (6.9)	70 (13.0)
	Gen.		30 (47)		40 (4.8)		55 (19.2)		75 (9.8)
6	Veg.	25 (55)	20 (55)	30 (4.2)	25 (6.2)	60 (12.8)	65 (30.0)	75 (7.5)	90 (15.0)
	Gen.	35 (46)	30 (52)	25 (4.5)	35 (5.3)	50 (11.3)	100 (30.0)	65 (6.1)	120 (13.0)

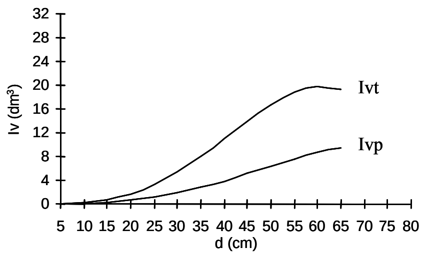
Graph 4. *Mean stand tree of vegetative origin*



Graph 5. *Mean dominant tree of vegetative origin*



Graph 6. *Mean dominant tree of seedling origin*



Current diameter increment culmination of mean trees of coppice origin occurred at the same age as the current height increment culmination of dominant trees of generative origin (30 yrs.). Current diameter increment culmination of dominant trees occurred about ten years earlier and at a considerably higher level. Intensive diameter growth between the age of 10 and 15 years and the earlier culmination of current diameter increment of coppice trees is the result of the inherited roots. The culmination of current diameter increment of the trees of generative origin generally occurred later, however this culmination was about ten years later in dominant trees of generative origin than in mean stand trees and also its level was higher. Judging by the current diameter increment in these stands there were two significant thinnings – one before the age of 30 and one before the age of 60 years.

Volume development of coppice trees shows a clear difference between dominant and mean trees. Volume development of dominant trees of coppice origin in the early youth was more intensive, and it lasted for a longer time thanks to good site conditions and tree position in the stand, so the current volume increment culmination of these trees occurred 5 years later and its level was almost twice higher than that of the mean stand trees of coppice origin. The average volume increment of dominant trees of coppice origin occurred even later than that of mean stand trees.

Thanks to a small age difference, the trees of generative origin were very soon suppressed by coppice trees, which was reflected on volume development not only at the beginning but also throughout their life. Current volume increment of dominant trees of coppice origin culminated later on and with twice higher value compared to mean stand trees. The average volume increment of dominant trees of coppice origin culminated still later also with twice higher value compared to mean stand trees. The culmination of current volume increment of dominant trees of generative origin also occurred later, but with almost three times higher value than that of mean stand trees. The average volume increment of these trees will by all means also culminate later with a considerably higher value than that of mean stand trees.

Ecological unit III: Mesophilous forests of sessile oak with hornbeam *(Quercetum montanum carpinetosum betuli)* on leached acid soil.

This ecological unit consists of typical coppice stands in which the trees of generative origin occur extremely individually as codominant trees. The age of trees of coppice origin is very uniform (60-64 years). The age of trees of generative origin is about 70 years (Table 3).

When shoots from roots and stumps expanded after clear cutting, the present trees of generative origin were about 10 years old and they were in the stage of suppressed saplings (Koestler classification). Thanks to exceptionally good site conditions and the inherited roots, coppice trees started an intensive height growth and suppressed the progeny of seedling origin which could not react so rapidly to the new conditions. The differentiation and the period of negative selection, and the unproductive sapling and thicket stages lasted to the age of 25, and current height increment of dominant coppice trees culminated. The upper layer could hardly be further enriched by better quality individuals of seedling origin from the lower layer (Mlinšek D. 1968). At these sites, coppice trees of sessile oak exceeded considerably the upper height limit of the first site class in coppice forests in Serbia Trifunović, D. *et al*. (1966). The trees of seedling origin, although about ten years older, in the expansion of shoots after clear cutting could not reach the first crown class, because the extraordinarily favourable site conditions of the first site class supported the growth of coppice trees. Current height increment of individual trees of seedling origin culminated at the age of 35. If we take into account the age difference of about ten years, current height increment of the trees of seedling origin and coppice origin culminated approximately at the same time, but the trees of seedling origin at that moment could not overtop the dominant trees of coppice origin.

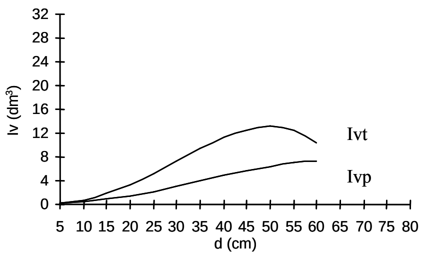
Current diameter increment of dominant trees of coppice origin and codominant trees of generative origin, culminated at the age of about 35, which is 5-10 years later compared to the same increment of mean stand trees of coppice origin. However, when the dominant trees of coppice origin were 35 years old, the trees of generative origin were about 45 years old, and their increment was already in stagnation. This means that current diameter increment of the trees of generative origin culminated under the canopy of dominant trees of coppice origin, which can also be seen from the level of their culminations.

The culmination of current volume increment of dominant trees of coppice origin occurred later and with twice higher values compared to the same increment of mean stand trees of coppice origin. The volume development of the trees of generative origin till the age of 20 years remains at a very low level, and after the age of 60 years its growth is still intensive. The culmination of current volume increment of the trees of generative origin occurred even later and with rather higher values compared to the dominant trees of coppice origin. Similar situation occurred also with the average volume increment. It culminated at the earliest and with the lowest values for mean stand trees of coppice origin. In dominant trees of coppice origin its culmination was 5-10 years later, and at twice higher level, while in trees of generative origin it culminated still later, bet the culmination level was not higher than these values of dominant trees of coppice origin. Taking into account the age difference of about 10 years, the culmination of current volume increment of the trees of generative origin and coppice origin occurred in practically the same moment. The same case also occurred with the average volume increment.

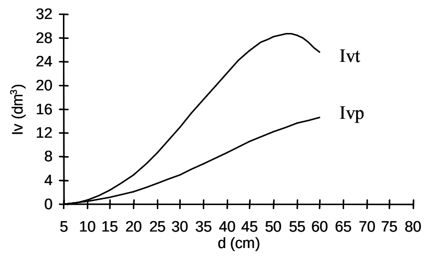
Table3. *Development of trees in the stands of mesophilous variety of sessile oak forests*

Series	Origin	Time of culmination							
		Iht		Idt		Ivt		Ivp	
		M.stand	M.dom.	M.stand	M.dom.	M.stand	M.dom.	M.stand	M.dom.
1	Veg.	20 (56)	25 (63)	20 (4.7)	30 (6.2)	45 (15.0)	50 (36.6)	60 (9.6)	65 (19.5)
	Gen.	35 (56)		35 (5.6)		65 (30.0)		85 (15.0)	
2	Veg.	20 (49)	25 (51)	30 (3.8)	35 (5.5)	50 (12.6)	55 (23.1)	65 (6.3)	70 (12.5)
	Gen.								
OP-6.1	Veg.	15 (63)	15 (54)	20 (5.3)	30 (5.6)	60 (12.4)	65 (28.7)	70 (7.6)	80 (18.0)
	Gen.								

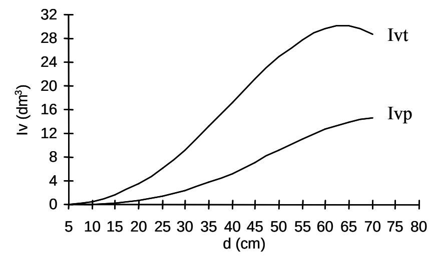
Graph 7. *Mean stand tree of vegetative origin*



Graph 8. *Mean dominant tree of veg. origin*



Graph 9. *Mean stand tree of seedling origin*



4. DISCUSSION

Ecological unit I: Xerophilous forests of sessile oak

Due to a poorer site class, the parent stands were more insufficiently stocked, so the juvenile trees of generative origin remained till the greater age and height, so they could attain the first crown class at the end of the thicket stage, and retained the position also over the stage of maturity. The analysis of current diameter increment shows that its culmination (30-35yrs.) was exactly in the middle of the period prior to the average volume increment culmination. Some authors claim that in the sense of length of production process, it is one half of the rotation (Jovanović, S. 1980). This means that, on this basis, the rotation should last for 65-70 years. The moment of maximal wood volume in the stand (between the ages of 65 and 70), in this case occurred before the end of the planned rotation of 80 years. In the entire ecological unit, the culmination of growth elements in coppice trees and trees of seed origin agreed with the data by other authors: Krstić, M. (1987); Aleksić, P. (2005); Krstić, M. (2003); Krstić, M. *et al*. (2006). To improve the unfavourable age structure, bearing in mind that it is the case of the production of the poorest stands by quality and health, with poor site potential, these stands should be assigned the first priority for regeneration and harvesting, so the rotation could be shortened to the age of 65-70 years and the stand should be harvested at the time of the highest timber supply in it, especially because they are at the moment of the lowest productivity, quality and the highest percentage of semi-dead and dead trees. This refers especially to the stands of the lower site classed on the shallower skeletal acid brown soil (Čokeša, V. 2007). Their further maintenance after the maximal wood volume, would lead to the loss, not only in wood volume but also in quality.

Ecological unit II: Xero-mesophilous forests sessile oak

Better site conditions and lower age differences between the trees of generative origin and coppice origin, in the period of negative selection were in favour of faster development of shoots and the reduction in the number of juvenile trees of generative origin. The culmination of current and average volume increment of mean stand trees of coppice origin occurred at the earliest and at the lowest level. Thanks to the good site conditions and the low age difference in this ecological unit, current and average volume increment of dominant trees of vegetative and generative origin had a very similar course, which means that the trees of coppice origin which immediately occupied the dominant position prevented the access of trees of generative origin in the first crown class. Based on the culmination of the average volume increment of dominant trees of coppice origin, maximal timber supply in the stands should be between the ages of 70 and 90. In the entire ecological unit, the times of culmination of growth elements of coppice trees, as well as of trees of generative origin, agree with the data reported by other authors (Krstić, M. 1987; Aleksić, P. 2005; Krstić, M. 2003; Krstić, M. *et al.* 2006), however, the values of their culmination are higher in the study stands. In this respect, previous studies show that it is the case of coppice stands of good productivity, quality and health (Čokeša V. 2007), so the stands of this ecological unit deserve the second priority for regeneration. Their productivity and quality point to the possibility of the harvesting after the culmination of the average volume increment i.e. between the ages of 90 and 100 years.

Ecological unit III: Mesophilous forests of sessile oak

The best site conditions and the lower age difference between the trees of generative origin and coppice origin, over the period of negative selection were in favour of the very fast shoot development and such a reduction in juvenile trees of generative origin, that they could not attain the first crown class throughout their life. Individual presence of the trees of generative origin is primarily seen by the line of development of growth elements, as well as by the culmination time and values of current height, diameter and volume increments. In the entire ecological unit, the times of culmination of growth elements of coppice trees, as well as of trees of generative origin, agree with the data reported by other authors (Krstić, M. 1987; Aleksić, P. 2005; Krstić, M. 2003; Krstić, M. *et al.* 2006), however, the values of their culmination are much higher in the study stands. Thanks to a small age difference between generative and vegetative trees and excellent site conditions, the trees of coppice origin which differentiated as dominant trees during the negative selection, dominated the trees of generative origin throughout the stand life. At the end of the rotation, the trees of generative origin, although in codominant position, surpassed the dominant trees of coppice origin by current volume increment. This is at the same time also the moment of the maximal biomass in the stand (Bunuševac, T. 1951). However, because of its position throughout the production process, they did not surpass them by the average volume increment. Judging by the culmination of average volume increment, the highest timber supply in the study stands should be attained at the age of about 75 years. As this is the case of the stands of the highest productivity, quality and health (Čokeša V. 2007), it is recommended to maintain this „value increment" at the high level as long as possible by the adequate silvicultural measures (Mlinšek, D. 1968) and the rotation should be prolonged to the period of 100-120 years. So, these stands should be assigned the third priority of regeneration, which should have a significant effect on the improvement of the age structure in the district.

According to Jovanović, S. (1980), the time of culmination of current diameter increment is the middle of the rotation, when canopy opening should be done to be able to concentrate the light increment of the best-quality trees till the end of the rotation. The study stands in all ecological units are more or less attacked by forest dying processes, which required frequent sanitation thinning which have already opened the, contributing to vigorous development of weed vegetation, to the extent that natural regeneration without additional measures, is questionable (Marinković, P., Stojanović, Lj. 1995, Karadžić, D. 2006). For this reason, the thinning is not recommended.

5. CONCLUSIONS

The study results on tree development through different life phases of a stand show the following:

*The greatest part of coppice stands in Serbia are in the development phase of maturity for felling and regeneration. Their regeneration in a shorter time period is neither feasible, nor economically and ecologically justified;

In addition to the trees of vegetative origin, these stands also contain various percentages of the trees of seedling origin, which makes the dynamics of their development and the planning of silvicultural measures more complex;

*The site class quality, productivity, quality and health of xerophilous sessile oak forests are the lowest, and the same values of mesophilous forests are the highest, which is reflected also on the tree development tendencies;

*On more xerophilous sites, the culmination of growth elements in dominant trees occurs mainly earlier, compared to mean stand trees. With the increase in mesophilousness, growth elements of dominant trees culminate later and with the higher culmination values;

*In the more mesophilous sites, of better site classes and with smaller differences between the ages of the trees of both generative and vegetative origin, the trees of vegetative origin differentiate more intensively and develop in height. In the struggle for survival in the earliest period, trees of generative origin remaining after clear cutting are more endangered because their dimensions are smaller and they are readily suppressed by the fast-growing shoots. For this reason, their number is smaller to the end of the production cycle, especially in the dominant layer, compared to the more xerophilous sites of the lower site class;

*The above conclusion points out that in the earliest youth it is essential to enrich the upper layer with the best-quality individuals of the middle layer. The trees which occupy the dominant position at the time of culmination of current height increment, mainly remain dominant till the end of the rotation;

*In all ecological units, current height increment is the first to culminate, it is followed by current diameter increment and current volume increment, and finally average volume increment. All the above growth elements always culminate first in the trees of vegetative origin and then in the generatively regenerated trees;

*As all oak stands are subject to forest dying processes, and as they are subject to intensive sanitation felling, the felling which opens up the canopy should not be carried out in the middle of the production period, when current diameter increment culminates, because of the weed invasion hazard which makes the natural regeneration more difficult;

*The stands on the drier sites with lower site class achieve the quantitatively lower timber supply earlier, which is related to the culmination of average volume increment. The stands on more mesophilous sites achieve the maximal, quantitatively higher timber volume in the later period.

*As productivity, quality and health increase with the increase in the site mesophilousness, also the time of attaining the maximal timber supply is changed towards the greater age. This supports the attitude that, at better sites, the length of production period can be increased, and finally the stand can be ranked by the priority for regeneration in time and space;

*In the xerophilous variety, further maintenance of stands above the age of 70 years, can only cause the loss in wood volume and quality. In the xero-mesophilous variety, a valuable increment can be maintained maximally to the age of 100 years without the losses in wood volume, whereas in the most productive, best-quality stands and least endangered by forest dying, valuable increment can be maintained to the age of 120 years;

*This is an illustration of the method how, based on the analysis of tree development, the momentarily unfavourable age structure can be improved, with the option of optimal utilisation of the site potential.

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ANALYSIS OF TREE GROWTH ELEMENTS AS A CRITERION FOR STAND CLASSIFICATION BY REGENERATION PRIORITY

Vlado ČOKEŠA, Snežana STAJIĆ, Zoran MILETIĆ

Summary

Felling and dendrometric analysis of altogether 18 mean stand trees and 18 mean dominant trees was performed in different ecological conditions of sessile oak coppice stands in the area of Mt. Cer, North-Eastern Serbia. The subjects of the research were the stands in the mature stage which are absolutely prevalent throughout the area, which points to an unfavourable age structure. The study stands are commercial, well-preserved, mature, coppice forests of sessile oak, of good quality. Their conversion is possible. The disks for the stem analysis were taken at each 2m, and for the crown area, at each 1 m. Annual rings were counted using the ADDO Tree-Ring Measuring Instrument to the nearest 0.01mm per 5-year periods. Statistical processing was based on the programme "Tree Analysis" (Marković, N.). In diameter and height analysis, fitting was mainly done using the parabola of the third degree, and in volume analysis, by the parabola of the fifth degree with a high correlation coefficient.

The study results on tree development through different life phases of a stand show the following:

*The site class quality, productivity, quality and health of xerophilous sessile oak forests are the lowest, and the same values of mesophilous forests are the highest, which is reflected also on the tree development tendencies;

*On more xerophilous sites, the culmination of growth elements in dominant trees occurs mainly earlier, compared to mean stand trees. With the increase in mesophilousness, growth elements of dominant trees culminate later and with the higher culmination values;

*In all ecological units, current height increment is the first to culminate, it is followed by current diameter increment and current volume increment, and finally average volume increment. All the above growth elements always culminate first in the trees of vegetative origin and then in the generatively regenerated trees;

*In the xerophilous variety, further maintenance of stands above the age of 70 years, can only cause the loss in wood volume and quality. In the xero-mesophilous variety, a valuable increment can be maintained maximally to the age of 100 years without the losses in wood volume, whereas in the most productive, best-quality stands and least endangered by forest dying, valuable increment can be maintained to the age of 120 years;

*This is an illustration of the method how, based on the analysis of tree development, the momentarily unfavourable age structure can be improved, with the option of optimal utilisation of the site potential.

ANALIZA ELEMENATA RASTA STABALA KAO KRITERIJUM ZA KLASIFIKACIJU SASTOJINA PO PRIORITETU ZA OBNAVLJANJE

Vlado ČOKEŠA, Snežana STAJIĆ, Zoran MILETIĆ

Rezime

U severozapadnoj Srbiji, na području planine Cer, u različitim ekološkim uslovima izdanačkih sastojina hrasta kitnjaka, izvršeno je obaranje i dendrometrijska analiza ukupno 18 srednjih sastojinskih i 18 srednjih dominantnih stabala. Sastojine koje su predmet ovih istraživanja su proizvodne, očuvane, zrele, izdanačke šume hrasta kitnjaka, dobrog kvaliteta u kojima je moguća konverzija. Koturovi za analizu u predelu debla su uzimani na svaka 2m, a u predelu krošnje na svaki metar. Brojanje godova je vršeno pomoću brojača godova „Addo“ sa tačnošću od 0,01mm po periodama od po 5 godina. Obrada je vršena pomoću urađenog programa „Analiza stabla“ (M a r k o v i ć , N.) Kod debljinske i visinske analize, za izravnavanje je uglavnom korišćena parabola trećeg stepena, a kod analize zapremine parabola petog stepena sa visokim koeficijentom korelacije.

Na osnovu rezultata istraživanja u pogledu razvoja stabala kroz različite životne faze sastojina, mogu se doneti sledeći zaključci:

*Kserofilne kitnjakove šume su najslabijeg, a mezofilne najboljeg boniteta, produktivnosti, kvaliteta i zdravstvenog stanja, što se odrazilo i na razvojne tendencije stabala;

*Na kserofilnijim staništima, elementi rasta uglavnom ranije kulminiraju kod dominantnih stabala u odnosu na srednja sastojinska stabla. Sa povećanjem mezofilnosti, elementi rasta kod dominantnih stabala kasnije kulminiraju i sa većim vrednostima kulminacije;

*U svim ekološkim jedinicama najpre kulminira tekući visinski prirast, zatim tekući debljinski prirast, zatim tekući zapreminski prirast i na kraju prosečan zapreminski prirast. Svi ovi elementi rasta uvek pre kulminiraju kod vegetativnih stabala nego kod generativnih;

*U kserofilnoj varijanti, daljim održavanjem sastojina preko 70 godina, može se samo izgubiti na drvnoj zapremini i kvalitetu. U ksero-mezofilnoj varijanti, najdalje do 100. godine može se gajiti neki vrednosni prirast, a da se ne gubi na drvnoj zapremini, dok u najproduktivnijim, najkvalitetnijim i u sastojinama koje su najmanje ugrožene sušenjem, ovaj prirast se može negovati do 120. godine;

*Ovo je primer kako se na osnovu analize razvoja stabala može popraviti trenutno nepovoljna starosna struktura, uz mogućnost optimalnog korišćenja stanišnog potencijala.

THE SITE CHARACTERISTICS OF THE GRDELICKA GORGE AND VRANJSKA BASIN AREAS

Sonja BRAUNOVIĆ, Mihailo RATKNIĆ, Ljubinko RAKONJAC[1]

Abstract: *This paper presents the analysis of the orographic, geological, pedological and vegetational characteristics of Grdelicka Gorge and Vranjska Basin areas. This area is located at the altitudes ranging from 252 to 1,923 meters above the sea level. In the altitudinal zone ranging from 700 to 1000 meters above the sea level 26.75 % of the area is located, in zone above 1000 above the sea level 24.97 % of the area is located, in the zone ranging from 500 to 700 meters above the sea level 24.42 %, of the area is located, in the zone ranging from 300 to 500 meters above the sea level 23,29 % of the area is located, and in zone up to 300 above the sea level 0.57% of the area is located. The metamorphic rocks account for 41,1 %, sedimentary rocks for 32.5 %, and igneous rocks for 26.4 % of the area. The acid brown soils account for 58.54 %, eutric brown soils for 10.37 %, vertisols for 8.57 %, alluvial soils for 6.16 %, etc. The oak and beech forests are the most common. Based on the model the changes in the forest ecosystems caused by the moderate increase of the air temperature (average increase of the temperature by 2.6 – 3.0ºC) were determined.*

Key words: climate model, changes of the ecosystems, vegetation, soil, site

STANIŠNE KARAKTERISTIKE PODRUČJA GRDELIČKE KLISURE I VRANJSKE KOTLINE

Izvod: *U radu će biti prikazana analiza orografskih, geoloških, pedoloških i vegetacijskih karakteristika područja Grdeličke Klisure i Vranjske Kotline. Područje se nalazi u visinskoj zoni od 252 do 1874 metara nadmorske visine. U visinskoj zoni od 700-1000 metara nadmorske visine nalazi se 26.75 % područja, u zoni preko 1000 mnv 24.97 %, od 500-700 mnv 24.42 %, od 300-500 mnv 23.29 % i u zoni do 300 mnv 0.57%. Metamorfne stene čine 41.1 %, sedimentne 32.5 % i magmatske 26.4 % površine. Kisela smeđa zemljišta zauzimaju 58.54 %, eutrična smeđa 10.37 %, smonice 8.57 %, aluvijalna zemljišta 6.16 % itd. Najzastupljenija su hrastova i bukova staništa. Na osnovu modela utvrđene su promene u šumskim ekosistemima sa povećanjem temperature vazduha po umerenom scenariju (prosečno povećanje temperature za 2,6 - 3ºC).*

Ključne reči: klimatski model, promene ekosistema, vegetacija, zemljište, stanište

1. INTRODUCTION

In Grdelicka Gorge and Vranjska Basin the tendency of the increase of the seasonal and annual air temperature was reported. The detailed analysis of the temperature for the 50-year period points to the changes of the minimal temperatures in summer, in average by +3.79 ^{o}C. The significant increase of the maximum temperatures in spring, in average by +2.84 ^{o}C was also observed.

The significant increase of the maximum temperatures in spring, in average by +2.84 ^{o}C was also observed. In regard to the quantity of precipitation, over the past 50 years the decrease in winter and summer has been expressed, which is followed by the fundamental decrease of the quantity of precipitation. The number of days with precipitation also increased in summer, and decreased in winter. The greatest changes occured in the temperature extremes. The extremely

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cold days and nights became less frequent, whereas the number of tropical days and nights increased.

If this trend continues, the current and future vegetation in Serbia will develop in the conditions of the increased temperatures and decreased quantity of precipitation in comparison with the previous conditions. This trend of changes also points to the increase of the summer temperature extremes, which makes the conditions for the development of the vegetation more unfavourable. The planned activities aimed at the reforestation must be adapted to the climate change, mainly by the selection of the suitable plant species.

2. RESEARCH AREA AND METHOD

Grdelicka Gorge and Vranjska Basin occupy 42°22' to 42°55' degrees north latitude, and 19°21' to 20°0' degrees east longitude from Greenwich. The direction of the spreading of the area is mainly southwest-northeast, it is about 60 km long, and the area of the drainage basin is 173,261 ha.

The climate characteristics of the area were processed based on the data from 5 climate and 12 precipitation stations. The average monthly minimal and maximum air temperatures, the relative air humidity, monthly sum of precipitation, sum of precipitation over the growing period were analyzed, as well as the annual sums of precipitation, speed and frequencies of the winds for the climate stations, which are located in the research area, were observed. The map of the altitudinal distribution of the area (up to 300 m, 300-500 m, 500-700 m, 700-1,000 m and above 1,000 meters above the sea level) was created based on the digital model of the terrain. The research area is divided into 26 drainage basins of the greatest tributaries of the Juzna Morava River. The geological map in the digital form was created, the types of the parent rock were determined, and the percentage of them was calculated. The map of the area, with the classification into igneous, sedimentary metamorphic rocks was created. Based on the map by the Institute of Soil Science (1953) and our researches, the pedological map of the area was made. The types of soil were based on the WRB classification. The system of classification of Serbian sites is based on EUNIS system of site classification.

3. RESULTS

3.1 Climate characteristics

Generally speaking, in this area three climate zone, out of which one refers to Vranjska Basin and wider river valleys, the second to the mountain area, and third to the Grdelicka Gorge, can be singled out in this area. Vranjska Basin and south part of the area were exposed to the Mediterranean influences from the Vardar valley. In contrast to the climate in Vranjska Basin, the mountain climate, characterized by the very long and severe winters with the great quantity of snow and short summers with somewhat higher precipitation than in the valley, are typical for the mountain area.

The warmest months in all stations are July and August (Vranje), whereas February (-3.2 Vlasina) and January (-3.1 Kukavica) are the coldest months. The amplitude of the annual oscillation of the temperature ranges from 17.5 to 21.4°C. The average air temperature in winter ranges from 2.5°C in Kukavica to 0.9°C in Leskovac and Vranje, in winter from 13.7 °C in Vlasina to 20.4 °C in Vranje, in spring from 5.2 in Vlasina to 11.2 °C in Leskovac, and in autumn from 6.6 °C in Vlasina to 11.4°C in Vranje.

The annual quantity of precipitation ranges from 564.1 (Klenike) to 999.4 (Kriva Feja). The highest quantity of precipitation during the growing season was reported in Kukavica (547.6 or 58.55% of the total).

3.2 Hydrographic characteristics

Hydrographic network of Grelicka Gorge and Vranjska Basin is well-developed and by its characteristics is unique in the mountain relief of Southeastern Serbia. The concentration of the relatively great torrential tributaries is located in the direction from Vladicin Han town to Dzep village. The concentration of the destructive torrents is greatest between Dzep Village and Palojce (Caricina Valley, Bunavejska Valley, Bakarna Valley, Krpejska Valley, Babicska Ravine, Predejanska, Licindolska and Palojska rivers (right tributaries) and Dzepska Zla Valley, Gorunska Valley, Doljaca and Celija (left tributary)). Along with the above floods, there is a series of the small, frequently very dangerous tributaries in all parts of Grdelicka Gorge (Mlakacka, Rasiceva, Kaldrma, Seliski Brook, Karina Baraka, Kamilja Luka, Goli Cukar), the drainage basin area of which is only 1.5 km^2. In average, each kilometer of Grdelicka Basin is attacked by five torrents. Almost all river courses in the study area has its source under the mountain-ridges, in which the well-developed spring areas are curved. For their upper courses the great slopes and well-curved stream beds of the stream sides are typical, with the occurrence of the rocky blocks. The middle courses are also very steep, whereas the upper courses have the gentler slopes and cointain a lot of sediment. The greatest tributaries in Vranjska Basin are Vrla River, Trnovacka, Jelasnicka, Krsevicka and Korbevacka rivers.

3.3 Orographic characteristics

The mountain relief of Grdelicka Gorge and Vranjska Basin as a whole is high to mid-high mountains, although no peak is located above 2,000 meters. Since the highest peak of Besna Kobila is 1,923 meters high, and the lowest point of relief is located at the mouth of the Kozarska River into the Juzna Morava River (252 m), the amplitude is 1,671 meters. In the altitudinal zone ranging from 700 to 1,000 meters above the sea level, 26.75 % of the area is located, in the zone above 1,000 above the sea level, 24.97 % of the area, in the zone ranging from 500 to 700 meters above the sea level, in the zone ranging from 300 to 500 meters above the sea level 23.29 % of the area, and in zone up to 300 meters above the sea level 0.57%.

3.4 Geological characteristics

The metamorphic rocks account for 41.1 %, sedimentary for 32.5 % and igneous for 26.4 % of the area. Crystalline schist account for almost 40% of the total study research. These schists are made of gneiss, phylite, amphibolite, amphibolite schist and quartzite. Crystalline schists are of the different degree of crystallinity, and very favourable as a base for the development of the erosion processes. Sandstones, clayey stones, marl and flysch are also very frequent, whereas the eruptive rocks and seprentines occur in the vicinity of Surdulica.

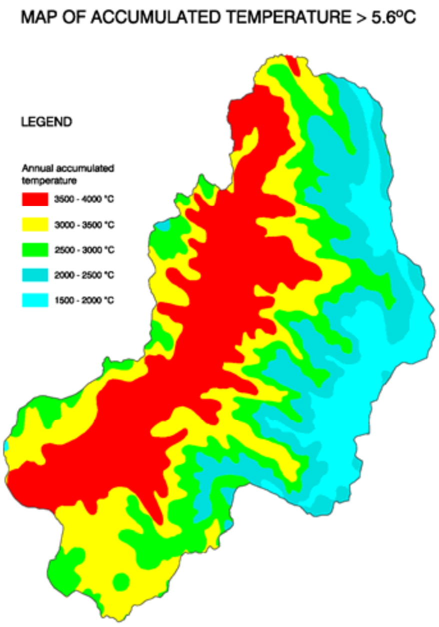
In Juzna Morava valley the neogene sediments are found in Vranjska Basin, so numerous torrents are curved into the non-resistant sandstones and conglomerates and carry the great quantity of sandy material (Pavlovacka River, Neradovacka River, etc).

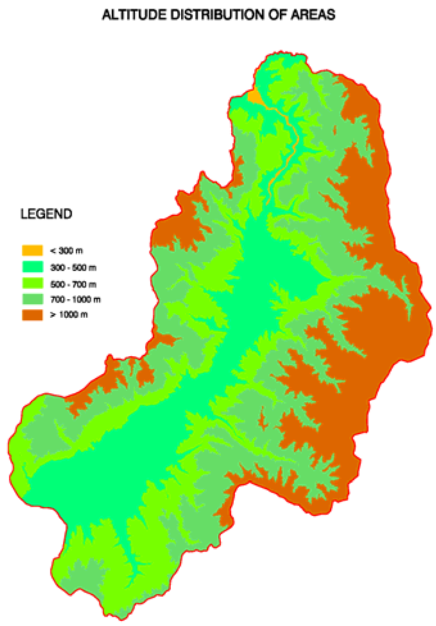
3.5 Pedological characteristics

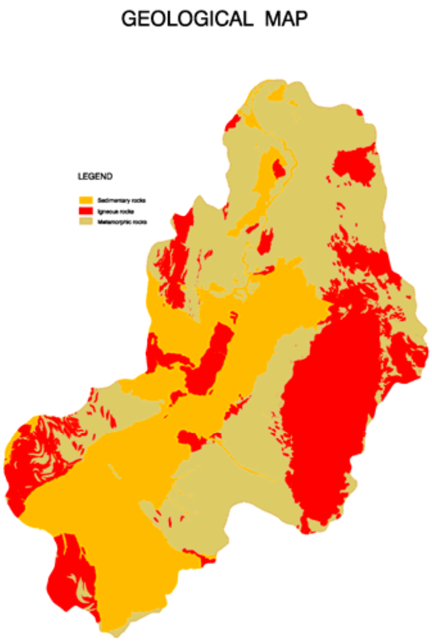
Ten types of soil occur in study area. Dystric cambisols (58.54%) and Eutric cambisols (10.37%) occupy the greatest area (Table 1).

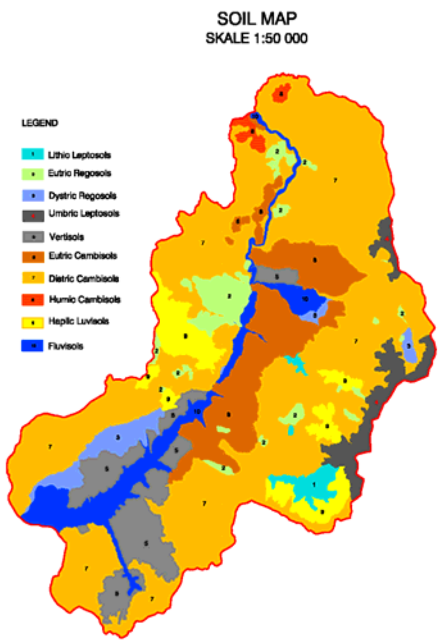
Table 1: *Types of soil and the percentage of them*

Type of soil	Area km^2	%
Lithic Leptosols	19,84	1,15
Eutric Regosols	55,82	3,22
Dystric Regosols	48,53	2,80
Umbric Leptosols	56,08	3,24
Vertisols	148,28	8,56
Eutric cambisols	179,66	10,37
Dystric cambisols	1014,26	58,54
Humic Cambisols	8,82	0,51
Haplic Luvisols	94,51	5,45
Fluvisols	106,81	6,16









4. SITES

The site is defined as the "place inhabited by plant and animal species, which is above all characterized by the physical conditions (topography, plant or animal physionomy, soil characteristics, climate, water quality, etc), and then by the plant or animal species which live there".

The following sites were reported in Grdelicka Gorge and Vranjska Basin:

D – Mire, bog and fen sites

E – Grassland and i tall forb sites

F –Heathland, scrub and tundra sites

G – Forests and forest sites and other areas covered by forest

H – Mainland sites with the underdeveloped vegetation

I – Frequently or almost cultivated agriculture, horticulture or domestic sites

J – Constructions, industrial and other artificial sites.

It is very important to monitor the changes of the ecological site conditions and their spatial distribution during the climate change. In order to achieve this goal, the model of change of the accumulated temperature >5.6^{0}C, depending on the increase of the anticipated temperatures by 1^0, 2^0, 3^0, 4^0 i 5^0 is constructed (Ratknic, M. 2010).

Based on these parametes, as well as on the ecological characteristics of each individual sites and main species, the forecast of the survival of all forest and scrub sites registered in Serbia, has been made.

This model includes all site peculiarities: location, size of mountain massif, bedrock, type of climate, altitudes, exposition and microclimate conditions, possibility of extending of association (limited by the orographic conditions), etc. In this way the realistic forecast of the ecological conditions was obtained. The term SITE DISSAPPERANCE refers to the drastical change of the ecological site condtions in which the association lives today.

G - WOODLAND AND FOREST HABITATS AND OTHER WOODED LAND

G1 - BROADLEAVED DECIDUOUS WOODLAND								
		Climate	NV (m)	Increasing air temperature				
				1^0	2^0	3^0	4^0	5^0
G1.1 - Riparian [Salix], [Alnus] and [Betula] woodland								
G1.111	Middle European [Salix alba] forests	UK	200-700	a, c,d	b,c, d	b,d	A	A
G1.1141	Continental [Salix] galleries on recent aluvial soil	P	do 250	a, b	b	A	A	A
G1.117	Populus nigra forest	UK i KP	do 500	a,b	c	A	A	A
G1.6 - [Fagus] woodland								
G1.6914	Moesian [Fagus] forests with Quercus petraea	UKMB i KPB	400-800	c,d	c,d	c,d	c,d	c,d
G1.6922	Moesian [Fagus] forests with mosses	UKMP	700-1400	c,d	c,d	A	A	A
G1.6923	Moesian [Fagus] forests with Vaccinium myrthyllus	UKMP	500-1400	c,d	c,d	c,d	c,d	c,d
G1.6924	Moesian [Fagus] forests with Blechnum spicant	UKMP	500-1400	c,d	c,d	c,d	c,d	c,d
G1.6941	Moesian monodominant [Fagus] forests	UKMP	500-1600	c,d	c,d	c,d	c,d	c,d
G1.6943	Moesian [Fagus] forests with Prunus laurocerasus	UKMPU KMSu	1200-1300	f,c, d	f,c, d	f,c, d	f,c, d	f,c, d
G1.6951	Moesian monodominant alpic [Fagus] forests	UKMSu	1400-1800	b,c, d	b,c, d	b,c, d	b,c, d	b,c, d
G1.7 – Thermophilous deciduous woodland								
G1.7611	Typical hungarian and austrian oak	UKM	do 600	h,d	h,d	h,d	h,d	h,d

G1.7614	Hungarian and austrian oak forest with (Carpinus orientalis)	UKM	do 700	h,d	h,d	h,d	h,d	h,d
G1.9 - Non-riverine woodland with [Betula], [Populus tremula], [Sorbus aucuparia] or [Corylus avellana]								
G1.91B	Balkanic Common silver birch forest (Betula) on non wetlands	UKM	700-1300	h,d	h,d	h,d	h,d	h,d
G1.922	Lowland nemoral [Populus tremula] woods		!					
G1.95	[Populus tremula] and [Betula] woods with [Sambucus]	UKM	700-1300	d	d	d	d	d
G1.A - Meso- and eutrophic [Quercus], [Carpinus], [Fraxinus], [Acer], [Tilia], [Ulmus] and related woodland								
G1.A1C1	Mesian durmast oak-european hornbeam (Quercus petrae – Carpinus betulus) forest	UKM	200-700	a,b	a,b	A	A	A
G1.A32	East europian hornbeam (Carpinus betulus) forest	UKM i KP	do 300	h,d	h,d	h,d	h,d	h,d

F - HEATHLAND, SCRUB AND TUNDRA HABITATS

F2 – ARCTIC, ALPINE AND SUBALPINE SCRUB HABITATS								
F2.2	**Evergreen alpine and subalpine heath and scrub**							
F2.231	Balkanic subalpin scrub formation with domination of ((Juniperus sibirica) (= (Juniperus nana))	BrAl	1500-2000	b,c	b,c	b,c	b,c	A
F2.26	(Bruckenthalia) heaths	BrAl	1500-2000	j,b,c	j,b,c	j,b,c	j,b,c	A
F2.27	Alpin (Arctostaphylos uva-ursi) i (Arctostaphylos alpinus) heaths	BrAl	>1600	b,c	b,c	b,c	b,c	A
F2.2A1	Balkanic high mountain heaths with (Vaccinium uliginosum)	BrAl	>1700	b,c	b,c	b,c	b,c	A
F3 – TEMPERATE AND MEDITERRANEO-MONTANE SCRUB HABITATS								
F3.1	**Temperate thickets and scrub**							
F3.17	[Corylus] thickets			h	h	b	b	b
F3.2	**Mediterraneo-montane broadleaved deciduous thickets**							
F3.242C	Balkanic subkontental broaedleaved thickets with Carpinus orientalis	SubMe-SubK	100-1400	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d
F3.242E	Balkanic subkontental broaerleaved thicket with Ostrya carpinifolia	SubMe-SubK	500-1400	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d
F9 – RIVERINE AND FEN SCRUBS								
F9.1	**Riverine and lakeshore [Salix] scrub**							
F9.111	Orogenous Salix eleagnos scrub			b	b	b	b	b
F9.112	Orogenous Salix purpurea scrub			b	b	b	b	b
F9.113	Orogenous Salix pentandra schrub			b	b	b	b	b

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THE STATE OF FORESTS AND FORESTS ECOSYSTEMS IN THE AREA OF GRDELICA GORGE AND VRANJE BASIN

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Abstract: *This paper presents the results of the research of the state of Grdelica gorge and Vranje basin forests, which belong to the region of south – east Serbia, the Juzna Morava and Jablanica forest area. These forest areas cover the area of 263.888,82 ha (44,6% state owned, 55,4% privately owned). The forests and forest land of Grdelica gorge and Vranje basin, managed by Public Enterprise „Srbijašume", cover the area of 45.675,12 ha, which constitutes 17,3 % of the total area. The largest part of the forests, 86,9%, is managed by "Vranje", a forest estate from Vranje, and part of them, 13,1%, is managed by „Šuma", a forest estate from Leskovac.*

According to the general function, the forests of the researched area are classified into three categories: forests with a production – protection function (most represented), forests with a primary protection function, and special natural reserves. The forests with production of technical wood as basic function cover the largest area. Forests with a primarily protection function – soil protection level one - are also represented.

Harmonisation of plans, measures and work with the defined needs and established state of forests of the area of Grdelica gorge and Vranje basin, offers an opportunity for improvement of forest ecosystems.

Key words: state of forests, forest functions, soil protection, environment

1. INTRODUCTION

The area of the Serbia Forest Fund, according to the data from the National Forest Inventory of the Republic of Serbia, amounts to 2.252.400 ha. In relation to the total area of Serbia, its forest cover constitutes 27,3%. Broadleaf forests account for 88,3%, conifer forests form 9,3%, while mixed broadleaf and conifer forests constitute 2,4%. In relation to the area that tree species cover, beech is the most represented. Beech forests cover a total area of 569.600 ha or 42,9% of the total area. The total area of forests and forest land, managed by „Srbijašume" amounts to 917.317,58 hectares, 776.613,50 hectares of which are covered by forest. The total stem volume of these forests is 118.624.998,9 m^3, while stem volume increment amounts to 3.039.369,3 m^3.

The subjects of the research are forests in the area of Grdelica gorge and Vranje basin, managed by forests estates from Leskovac and Vranje, within the Juzna Morava and Jablanica forest area. The forest estate from Vranje manages the area of 149.802,05 ha. 149.802,05 ha of the total area are covered by forests. High forests amount to 52.131,70 ha or 40,7% of land area covered by forest, while coppice forests cover 48.032,89 ha or 37,5%. The total area of Grdelica gorge and Vranje basin managed by the forest estate from Vranje amounts to 39.482,72 ha, while the land area covered by forest is 33.033,37 ha or 83,3%. The most represented, in this area too, are beech forests with 86,2% of the total forest coverage.

A part of Grdelica gorge and Vranje basin is managed by the forest estate "Šuma" from Leskovac. The researched area belonging to this forest estate amounts to 6.192,40 ha or 16,7% of the total area of Grdelica gorge and Vranje basin.

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The most represented species as per area it covers, in this part of the researched area too, is beech, accounting for even 96%.

2. THE OBJECT OF THE RESEARCH AND WORK METHOD

In the course of producing this paper analytical method is applied, with the use of results from previous research on state of forests, as well as the data from the forest estates from Leskovac and Vranje, data from general management plans for the Juzna Morava and Jablanica forest area and special forest management plans for forest estate units “Vardenik”, “Borovik”, “Južna Morava”, “Kukavica II”, “Karpina”, “Petrova Gora”, “Soboršnica”, “Kijevac”, “Kukavica I”, “Granična šuma”, “Rujan” and “Trnovačka reka”, belonging to the Vranje forest estate, as well as forest estate units “Kačer-Zeleničje” and “Kukavica II” which are part of the Leskovac forest estate.

3. THE RESEARCH RESULTS

The researched area, consisting of Grdelica gorge and Vranje basin, amounts to 173.200 ha. The largest part of state owned forests and forest land in the area of Grdelica gorge and Vranje basin is managed by FE “Vranje”, and belongs to the Juzna Morava forest area, while part of it is managed by FE “Šuma” Leskovac and these forests belong to the Jablanica forest area.

Table 1 presents the land area covered by forests and non-stocked forest land and the total researched area, managed by forests estates from Leskovac and Vranje.

Table 1. *The survey of land area covered by forest and non-stocked forest land and the total area of Grdelica gorge and Vranje basin*

LAND AREA COVERED BY FOREST							
High forests		**Coppice forests**		**Artificially established stands**		**Shrubs**	
ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
17.411,40	44,8	14.989,26	38,6	4.683,47	12,0	1.784,51	4,6
NON-STOCKED FOREST LAND							
Forest land		**Infertile soil**		**For other purposes**		**Estate**	
ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
5.418,31	79,7	553,44	8,1	350,05	5,1	484,68	7,1
TOTAL AREA							
Land area covered by forests		**Non-stocked forest land**		**Total**			
ha	**%**	**ha**	**%**	**ha**	**%**		
38.868,64	85,1	6.806,48	14,9	45.675,12	100		

State owned forests and forest land, which belong to the Juzna Morava forest area, are managed by FE “Vranje” by means of its six Forest Offices. The forests and forest land area are divided into 21 estate units.

State owned forests and forest land, which belong to the Jablanica forest area, are managed by FE “Suma” Leskovac by means of its six Forest Offices. The forests and forest land area are divided into 16 estate units.

The Juzna Morava forest area covers the area of 149.802,05 ha, 76.751,05 ha (51,2%) of which are state owned, while privately owned land amounts to 73.051,00 ha (48,8%).

Habitat conditions of this area are particularly favourable for development of autochthonous tree species, in particular beech, hornbeam and oak. For that reason, nearly the whole forest area has a production – protection function.

The ratio between the land area covered by forest and non-stocked forest land is 85,1% to 14,9%. As per origin, high forests account for 40,7%, coppice forests form 37,5%, artificially established stands 17,4% and shrubs 4,4%. As per the level of preservation, preserved stands account for 58,8%, rarefied stands form 19,3%, while devastated forests, thickets and shrubs constitute 21,9%.

The most represented are beech stands, which account for 56,9%. Oak stands constitute 20,5%, other broadleaf stands account for 2,6% and conifer stands (artificially established) form 15,6%. The average volume of these stands is 140 m^3/ha, and volume increment is 3,2 m^3/ha.

The most represented species as per its volume is oak (81,2% of the total wood volume), followed by Italian oak (8,2), The Sessile Oak (4,0%), other broadleaves (2,1%) and coniferous (4,5%).

The area of Jablanica forest area amounts to 114.086,77 ha, 40.821,77 ha (36%) of which is state owned, while 73.265,00 ha (64%) is privately owned.

Habitat conditions of this forest area are highly favourable for the development of autochthonous tree species, in particular beech, hornbeam and oak. For that reason, nearly the whole forest area has a primarily production – protection function. Within the researched area, there are only two estate units from the Jablanica forest area – EU “Kačer-Zeleničje” and parts of EU “Kukavica II”. These estate units participate in the researched area with the area of 6.192,40ha.

The ratio between land area covered by forest and non-stocked forest land is 93,2% to 6,8%.

As per origin, high forests account for 57,9%, coppice forests 29,0%, artificially established forests 12,6%, thickets 0,1% and shrubs 0,4%. Preserved stands form 89,5%, rarefied stands 8,0%, devastated forests 2,1% and thickets and shrubs 0,5%.

The most represented species is beech, accounting for 96%, other broadleaf species jointly form 1,5%, while conifer species account for 2,5%.

The average volume value is 203 m^3/ha, while average volume increment is 4,5 m^3/ha.

The total researched area (forests and forest land, other land and someone else’s land) which refers to state owned land amounts to 45.675,12ha.

The state of forests as per their function

The most represented functional entities in the researched area are:

- functional entity 10 (the area for technical wood production);
- functional entity 26 (soil protection level one);
- functional entity 66 (areas with permanent forest protection – with no interventions by forest estates)
- functional entity 16 (a big game hunting – maintaining centre);
- functional entity 17 (a seed stand);
- functional entity 82 (the area of outstanding natural beauty, protection level two)
- functional entity 83 (the area of outstanding natural beauty) and
- functional entity 84 (a strict forest reserve).

The most represented are functional entities10, 26 and 66, while other functional entities are represented to far lesser extent.

Table 2. *The state of forests as per functional entities*

Functional entity	Area		Volume			Volume increment		
	ha	%	m^3	m^3/ha	%	m^3	m^3/ha	%
10	24.017,01	61,9	3.937.846,85	163,96	69,2	93.962,20	3,91	72,4
16	256,37	0,7	38.905,60	151,75	0,7	1.157,10	4,51	0,9
17	1,82	0,0	366,80	201,54	0,0	7,70	4,23	0,0
26	12.722,96	32,7	1.660.008,82	130,47	29,2	33.706,22	2,64	26,0
66	1.712,28	4,4	1.933,34	1,12	0,0	21,60	0,01	0,0
82	10,10	0,0	254,52	25,20	0,0	7,07	0,70	0,0
83	27,90	0,0	2.042,28	73,20	0,0	66,96	2,40	0,0
84	119,20	0,3	52.017,70	436,39	0,9	876,70	7,35	0,7
TOTAL	**38.868,64**	**100**	**5.693.375,91**	**146,47**	**100**	**129.805,55**	**3,34**	**100**

Forests with a primarily production function (the function entity 10) cover the largest area, even 61,9%. They account for 69,2% of the total forest wood volume in this area. The average volume amounts to 163,96 m^3/ha, while volume increment is 3,91 m^3/ha.

The protection forests of functional entity 26 account for 32,7% of land area covered by forests – which is 12.722,96 ha. The average volume amounts to 130,47m^3/ha, while volume increment is 2,64 m^3/ha. The most represented are coppice forests, while regarding tree species, beech is the most represented.

The areas under permanent forest protection (function entity 66) cover 1.712,28 ha, or 4,4% of the area. Other functional entities (FE 16, 17, 82, 83, and 84) are far less represented and cover the area of 415.39 ha.

The state of forests as per their origin and preservation

Within the researched area, high forests cover 17.411,40ha (44,8%), while coppice forests amount to 14.989,26 ha (38,6%). Artificially established stands cover an area of 4.683,47 ha or 12%. Thickets and shrubs cover the area of 1.784,51 ha (4,6%).

Table 3. *The state of forests as per their origin*

Origin	Area		Volume			Volume increment		
	ha	%	m^3	m^3/ha	%	m^3	m^3/ha	%
High	17.411,40	44,8	3.614.648,80	207,60	63,5	72.198,89	4,15	55,6
Coppice	14.989,26	38,6	1.893.663,37	126,33	33,3	47.614,14	3,18	36,7
Artificially established	4.683,47	12,0	183.130,40	39,10	3,2	9.970,92	2,12	7,7
Thickets and shrubs	1.784,51	4,6	1.933,34	1,12	0.0	21,60	0.01	0,0
TOTAL	**38.868,64**	**100**	**5.693.375,91**	**146.47**	**100**	**129.805,55**	**3.34**	**100**

High forests have an average volume of 207,60 m^3/ha, while volume increment is 4,15 m^3/ha. As for the coppice forests, the average volume amounts to 12.633 m^3/ha, and volume increment is 3,18 m^3/ha, while artificially established stands have the average volume of 39,10 m^3/ha and volume increment of 2,12 m^3/ha.

In the researched area, preserved stands cover 58,8% of the area and their share in the total volume accounts for 71,2%. Rarefied stands cover 19,3% of the area and account for 24,2% of the volume, while devastated forests cover 17,5% of the area and account for 4,5% of the volume. Within devastated forests, high forests account for 38,8% of the area and 47,7% of the volume, while coppice forests cover 61,6% of the area of devastated forests, and 52,2% of the volume.

4. CONCLUSIONS

By analysing the data concerning the state of forests in Grdelica gorge and Vranje basin, it can be noticed that it is characterised by unfavourable production effects, unfavourable stand condition, as well as insufficient exploitation of the production potential.

First of all, there is a high share of coppice and degraded forests in the total forest fund of this area. Coppice forests cover 38,6% of the area, while high forests cover 44,8%. The preserved stands account for 58,8% of the area, rarefied stands form 19,3% and devastated stands account for 17,5% of the area. As per their volume, high forests account for 44,8%, coppice forests 38,6%, highly devastated forests 2,2% and coppice devastated forests constitute 2,3% of the wood fund. As per the volume increment, high forests account for 55,6%, coppice 36,7% and artificially established stands constitute approximately 8%.

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GROWTH IN THICKNESS OF SCOTS PINE (*PINUS SILVESTRIS* L.) PLANTATIONS IN CENTRAL BALKAN RANGE IN PERIOD OF CLIMATIC ANOMALIES

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Abstract: *The dynamics of growth in thickness of Scots pine plantations of age class III has been studied in the low-mountain belt of Central Balkan Range. Periods of accumulation of radial growth of 1, 2 and 3 cm have been determined, as well as passing of the trees through thickness degrees every 2 cm. The rank (position) of average thick tree is also investigated.*

1. INTRODUCTION

Scots pine plantations, established in the last 50-60 years in Central Balkan Range, are characterised with specific growth and ecological plasticity towards soil conditions and present climate. Changes in growing environment, humid, thermal and luminous regimes lead to changes in their structure and productivity. Average annual growth most precisely reflects the complex influence of environment-modelling factors, genetic facts and opportunities for adaptation and development of Scots pine plantations in the period of climatic anomalies in the last 10-15 years.

This study is directed to determining of 10-year-long dynamics of growth of artificially created Scots pine dendrocoenoses in the low-mountain vegetation belt of Central Balkan Range (Fore-Balkan). It will give the answer for what period of time (at different age and conditions) annual radial growth of 1, 2 or 3 cm is formed, for how long and what percentage of pine trees pass from one thickness degree into next one or after the next.

2. OBJECTS AND METHODS OF WORK

Objects of study are 6 Scots pine stands growing in the low-mountain vegetation belt of mixed deciduous forests in Moesian forest-vegetation area of Central Balkan Range.

In the period of investigation of growth parameters of Scots pine (1998–2007) climate elements are with bigger deviations than typical average statistical values in the region (average annual temperature from 10,8°C to 11,9°C and average annual precipitation 500–650 mm) (Dimitrov, 1984).

Totally for the country in the period 1998–2000 have been recorded extremely high average day temperatures, due to the transfer of warm air from North Africa in the beginning of growing period (2000) and durable droughts in July, August and September (Raev et al., 2003).

After 2006, improvement of climatic conditions is observed (larger quantity of precipitations and normal values of day temperatures) (Tsakov et al., 2009).

Sample plots (SP) are part of the monitoring network for observation of forest ecosystems in Stara Planina Mountain (Balkan range). In each SP, 40 Scots pine trees were investigated, situated between the four geographic angles of the SP. Trees are predominantly from I and II height class after Kraft and are reflectors of the site. Due to illegal fellings or withering the number of trees in some sample plots has decreased. Object of analysis are only those trees which really exist in the period of investigation. Growth in thickness was regularly measured in the middle of growing period (July) by measurement tape at basic diameter (DBH 1.3 m). In the process of work, dendrometric means and methods were applied to determine the average diameter (D_{av}), basal areas (G) and rank (position) of average thick tree, determined through natural thickness degrees. For absolute thickness degree, the 2-cm limit was accepted.

Table 1 shows the inventory characteristics and percentage share of Scots pine trees according to thickness degrees in the sample plots in the end of investigated period in 2007.

Thickness of trees is within the range from 10 to 38, and most of them are concentrated within 5–15%. Participation in SP1 and SP5 is bigger (up to 25%). Share of trees is most even in SP5. Only in this combination the maximum of number of trees is about mean diameter. In SP4 this participation is slightly moved to the left, which shows that larger number of trees is with diameters less than the average one. There is also shift to the right (SP6), confirming the presence of trees thicker than the average one.

3. RESULTS AND DISCUSSION

On the basis of 10-year-long measurements of the diameters of Scots pine trees, table 2 shows the dynamics of growth in thickness of depersonalized percentage of number of trees, through changing radial growth within the range 1, 2 or 3 cm.

In the youngest investigated sample plot (SP1) the first centimetre of growth has been formed two years after beginning of measurements (1998) in 10,2% of trees. Maximum number of stems (20,5%) have formed 1 cm radial growth (at $d_{1.30}$) in 2002, and least (5,1%) – during the 8-th year. In 2004 slow growth was recorded and no tree has formed increment of 1 cm.

Second centimetre began to form immediately after the 4-th year from the beginning of measurements in 38,5% of Scots pine trees. Third centimetre is formed in 4 trees, which had initial thickness close to the average diameter of the sample plot.

In SP2 only three trees of II class of thickness (with diameters over 18 cm) accumulated one centimetre of wood. This process lasted with various intensity up to the 9-th year – totally for 71,9% of the trees (good growth in 2001 and poor – in 2003-2005). Largest number of trees (18,8%) has reached this value only in 2006 and 2007. Eight trees (25,0%) have growth increment in thickness 2 cm in the period from the 6-th to the 9-th year from the beginning of measurements, and only 2 stems have increased their average diameter with 3 cm and it was after 2006.

In SP3, until the 6-th year from the beginning of measurement 64,9% of trees formed wood of 1 cm with most intensive increment in 2001 (27,0%). The rest 8 stems (21,6%) began to accumulate second centimetre from the 5-th to 7-th year of measurement. None single tree formed 3 cm increment.

In SP4, 89,7% of the trees reached one centimetre growth in thickness for the period from 2-nd to 9-th year of measurement, and 18,6% were accumulated in 2001–2003 with maximum number (20,5%) in the third year. The two-centimetre limit is reached by 56,4% of the trees after 4-th – 9-th year. Three centimetres of increment have 15,4% of trees, which are also thickest (from II class of thickness). This SP is with most even structure and growth for the period 1998–2007.

In SP5, 94,1% of pine trees have grown with 1 cm for an year for the investigated period. From 3-rd to 9-th year of the period 76,5% have growth in thickness of 2 cm with a maximum in the 5-th year (20,6%). The diameters of 26,5% of the trees were changed with 3 cm between the 6-th and 8-th year.

In the oldest sample plot (SP6) 86,8% of trees formed 1 cm growth and the maximum of accumulation is in 2001.

Two centimetres of growth accumulate 42,1% of pine stems from 5-th to 9-th year of investigation. None single tree (as in SP3) does not form 3 cm radial growth. Growth in thickness is normal and no sudden changes were recorded.

The status (possibility for change in thickness degrees) of Scots pine trees in the process of their growth is followed in table 3.

In SP1 (A_{av}=44) average diameter for the investigated 10-year-long period grows from 15,4 cm to 16,8 cm. With increment less than 2 cm (one thickness degree) are 61,5% of the trees. They do not accumulate radial increment of 2 cm and remain in the same thickness degree, i.e. without any change. In the next thickness degree (step 2 cm) are the rest 38,5% of the trees. With least radial increment (under 1 cm) were 9 trees. The thickest tree changed its diameter from 20,2 to 24,0 cm, i.e. increment is 18,8%.

The rank of average thick tree changed from 61,5% to 50% and shows improvement of thickness structure of the tree stand.

In SP2 (A_{av}=46) mean diameter has increased with 0,6 cm (from 17,2 to 17,8 cm). Without change (within the frame of degree) are 75,0% of trees. The rest 25,0% have passed into the next 2-cm thickness degree. No tree in the next degree has accumulated over 3 cm radial increment. At average diameter 17,2 cm for SP, the thickest tree from the combination with diameter 23,8 cm has reached for 10 years average diameter 27,0 cm – increment of 13,4%. The rank of 56,7% has decreased with 3,5 percentage points (reaches 60,2%), which is due to worsening of stand's status in the last years. The high percentage of trees damaged by root fungus [*Heterobazidion annosus* (Fr.) Bref.] and partial losses by snow-break disturb the stand structure. The occurred understorey of cerris oak (*Quercus cerris* L.) will gradually support the formation of mixed pine-oak stand.

In SP3 (A_{av}=48), 78.4% of Scots pine trees could not grow with 2 cm and have preserved their position in the relative thickness degree, although that average diameter has increased from 18,9 cm to 19,4 cm. The rest 21,6% of trees have passed into the next thickness degree, and the rank of average thick tree has changed from 63,0% to 61,2%. Thirteen trees do not reach radial increment of 1 cm, and none of them accumulates the increment for next thickness degree.

In SP4 (A_{av}=50) average diameter of trees reaches up to 19,7 cm from 18 cm after 10 years. Only 29,4% of trees in this sample plot are with lower growth rate and do not cross the 2-cm limit of real increment. Almost 60% of trees pass into the next thickness degree, and 11,8% reach the 3-cm increment. The rank of combination has improved from 54,0% to 52,7%. The stand is with good growth and health status.

In SP5 (A_{av}=53) average diameter increases from 20,9 to 22,3 cm, and the rank of average thick tree – from 49,9% to 47,3%. Only 33,3% of the trees do not change their thickness degree. Into the next thickness degree pass 66,7%, which is good opportunity for transition into the next thickness degree.

In the oldest SP6 (A_{av}=58) average diameter changes from 26,2 to 27,3 cm. The share of trees is almost equal – one part of 47,4% remain without change of the degree, and 52,6% pass into the next degree. The rank improves from 60,9% to 58,3%. In spite of their good growth, the Scots pine regeneration in the stand is poor and additionally complicated by the dense grass sinusia of *Nardus stricta* L., as well as the invasion of *Fraxinus ornus* L.

4. CONCLUSION

As a result from the investigation of 10-year-long dynamics of growth in thickness of Scots pine stands in Central Balkan Range, the following conclusions could be drawn:

- Radial growth of 1 cm is accumulated in almost 80% of the trees in investigated stands for 10-year-period (1998-2007);
- Increment of 1 cm is formed most often in the first 3-4 years from the beginning of investigation;

- Radial growth of 2 cm is reached after 5-th-7-th years from the beginning in 43% of the trees;
- 5-6% of the trees accumulate radial growth of 3 cm. These trees grow in the upper part of the stand canopy and are in height class I after Kraft;
- In the period of climatic anomalies (1998-2007) growth in thickness is best in 2001-2002 at initial increment accumulation of 1 cm;
- Slow down growth and less intensity of formation of the first centimetre of wood are observed in the period 2003-2004;
- Most favourable for growth and formation of 2-3 cm growth in thickness were the years 2005-2007.

The study has methodical character and will support forest management practice in forecasting of growth capabilities and future forestry activities in Scots pine plantations in Central Balkan Range.

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Table 1. *Percentage share of Scots pine trees according to thickness degrees in sample plots*

N	Sample plots	Alt.	Aav	Dav	N	Number of trees according to thickness degree in percentage														
		m	Age	cm		10	12	14	16	18	20	22	24	26	28	30	32	34	36	38
1	Omurtag	300	44	16.5	39	-	20.5	25.6	18.0	12.8	15.4	2.6	5.1	-	-	-	-	-		
2	Elena	400	46	17.0	32	3.1	15.6	18.7	18.8	6.3	12.5	15.6	3.1	6.3	-	-	-	-		
3	Drianovo	450	48	19.4	37	2.7	-	13.5	18.9	24.3	8.1	16.2	2.8	10.8	2.7	-	-	-		
4	Teteven	480	50	19.7	34	-	2.9	5.9	14.8	20.6	23.5	14.7	14.7	2.9	-	-	-	-		
5	Kotel	400	53	22.3	36	-	-	2.8	5.6	11.1	19.4	16.7	25.0	11.1	8.3	-	-	-		
6	Apriltsi	600	58	27.3	38	-	2.6	-	-	-	13.2	2.6	18.3	15.8	18.5	16.5	5.3	5.3	2.6	5.3

Table 2. *Dynamics of growth in thickness of Scots pine trees in the period 1998-2007*

N	Sample plots	A_{av}	DBH_{av}		Radial	Ages																	
			1998	2007	cm	2	%	3	%	4	%	5	%	6	%	7	%	8	%	9	%	N	%
1	Omurtag	44	15.4	16.5	1	4	10.3	6	15.4	8	20.5	4	10.3	3	7.7	–	-	2	5.1	2	5.1	29	74.4
					2	-	-	-	-	1	2.6	-	-	3	7.7	2	5.1	5	12.8	4	10.3	15	38.5
					3	-	-	-	-	-	-	-	-	1	2.6	-	-	1	2.6	2	5.1	4	10.3
2	Elena	46	17.2	17.8	1	3	9.4	4	12.5	3	9.4	1	3.1	-	-	1	3.1	6	18.8	5	15.6	23	71.9
					2	-	-	-	-	-	-	-	-	2	6.3	1	3.1	3	9.4	2	6.3	8	25.0
					3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6.3	2	6.3
3	Drianovo	48	18.9	19.4	1	2	5.4	10	27.0	7	18.9	4	10.8	1	2.7	-	-	-	-	-	-	24	64.9
					2	-	-	-	-	-	-	3	8.1	3	8.1	2	5.4	-	-	-	-	8	21.6
					3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Teteven	50	20.9	22.3	1	7	17.9	8	20.5	7	17.9	6	15.4	-	-	4	10.3	1	2.6	2	5.1	35	89.7
					2	-	-	-	-	3	7.7	4	10.3	-	-	7	17.9	6	15.4	2	5.1	22	56.4
					3	-	-	-	-	-	-	-	-	-	-	1	2.6	2	5.1	3	7.7	6	15.4
5	Kotel	53	18.0	19.7	1	11	32.3	8	23.5	3	8.8	3	8.8	3	8.8	3	8.8	1	2.9	-	-	32	94.1
					2	-	-	-	-	4	11.8	7	20.6	2	5.9	3	8.8	6	17.6	4	11.8	26	76.5
					3	-	-	-	-	-	-	-	-	1	2.9	2	5.9	6	17.6	-	-	9	26.5
6	Apriltsi	58	26.2	27.3	1	6	15.8	4	10.5	6	15.8	8	21.1	7	18.4	1	2.6	-	-	1	2.6	33	86.8
					2	-	-	-	-	-	-	2	5.2	2	5.2	8	21.1	3	7.9	1	2.6	16	42.1
					3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. *Status of Scots pine trees in the process of growth in thickness*

N	Sample plots	1998			Without degree change		Passed into degree				2007	
		D_{av}	Rank	N	N	%	next		after the next		D_{av}	Rank
		cm					N	%	N	%	cm	
1	Omurtag	15.4	61.6	39	24	61.5	15	38.5	-	-	16.5	50.0
2	Elena	17.2	56.7	32	24	75.0	8	25.0	-	-	17.8	60.2
3	Drianovo	18.9	63.0	37	29	78.4	8	21.6	-	-	19.4	61.2
4	Teteven	18.0	54.0	34	10	29.4	20	58.8	4	11.8	19.7	52.7
5	Kotel	20.9	49.9	36	12	33.3	24	66.7	-	-	22.3	47.3
6	Apriltsi	26.2	60.9	38	18	47.4	20	52.6	-	-	27.3	58.3

VOLUME MODELS OF BEECH HIGH STANDS IN THE AREA OF SERBIA

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Abstract: *The study results are two regression models intended for volume estimation in beech high stands. Model 1 has more theoretical significance and Model 2 has a practical significance. The models resulted from a large data-set collected in beech high forests in the area of Serbia. Eleven all-aged beech high stands were selected in six forest areas and measured using a simple systematic sample. Altogether 241 circular sample plots of 500 m² were distributed using the square grid network design, spacing 100 m. The models were constructed by the method of stepwise multiple regression. The model accuracy was tested on the material used for modelling. Theoretically, these are highly reliable models. However, the true reliability and efficacy of the models can be evaluated only after their practical implementation.*

Key words: Serbia, beech stand, stand volume, regression model

MODELI ZAPREMINE VISOKIH SASTOJINA BUKVE NA PODRUČJU SRBIJE

Apstrakt: *Rezultat ovog rada su dva regresiona modela namenjena za procenu zapremine visokih sastojina bukve. Model 1 ima više teoretski, a Model 2 praktični značaj. Modeli su dobijeni na bazi obimnog materijala prikupljenog u visokim bukovim šumama na području Srbije. U šest šumskih područja odabrano je i pomoću uzorka premereno jedanaest raznodobnih sastojina bukve. Primenjen je jednostavni sistematski uzorak. Postavljena je 241 probna površina, oblika kruga i veličine 500 m², u kvadratnom rasporedu na rastojanju 100 m. Za dobijanje modela primenjen je metod postepene (stepwise) višestruke regresije. Proverena je tačnost modela na materijalu koji je poslužio za njihovu izradu. Teoretski, radi se o jako pouzdanim modelima. Međutim, ocena stvarne valjanosti i efikasnosti dobijenih modela biće moguća tek posle njihove primene u praksi.*

Ključne reči: Srbija, sastojina bukve, zapremina sastojine, regresioni model

1. INTRODUCTION

In forest management planning, one of the most significant taxation elements is stand volume (growing stock) per hectare and over the entire area. The same is applied also to the larger forest management units or forest classification units (e.g. management class). The goal of forest inventory is to estimate the value of growing stock and its distribution per diameter degrees or classes, as accurately as possible both for the principal tree species and in total. The methods used to this purpose must be accurate and economic, i.e. efficacious. In the world and in our country, the most frequently implemented methods are based on the sample, i.e. on the partial stand measurement. Among the numerous stand inventory methods is the *method of stand volume models and tables.* The method of stand models and tables has been implemented for a long time in forestry of USA, Canada and some countries in Europe. The interest in the

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construction of stand volume models and tables for different tree species was especially increased after the construction of relascope and the development of relascopy method (Bitterlich, R. 1948, after Mirković, D., Banković, S. 1993). As it is known, the relascopy can determine the stand basal area (primarily even-aged) per hectare and its distribution per diameter degrees or classes relatively quickly and sufficiently precisely.

Models and tables are constructed based on the dependence of stand volume per hectare on other stand elements (most often mean height and basal area per hectare). The examples for the construction of stand volume tables for even-aged and uneven-aged stands of our principal tree species, in pure and mixed stands, were produced only for the area of Bosnia and Herzegovina (Matić, V. *et al*. 1963, Stojanović, O. *et al*. 1987). There are no models and tables of this type for natural stands in Serbia, there are only tables for artificially established stands of Austrian pine aged up to fifty years (Koprivica, M. 1995). In all the above cases, stand models and tables were calculated by the method of multiple regression analysis.

The aim of stand volume models and tables is to provide the data on stand volume per hectare and total area with relatively small amount of stand measurements, that is minimal forest inventory costs. This is most easily performed in pure and even-aged stands. The main disadvantage of this method is that it is not sufficiently accurate and that it does not encompass the distribution of stand volume per diameter degrees or classes. However, the approximate volume distribution can be estimated based on the percent distribution of stand basal area per diameter degrees or classes.

The task of this paper is to define the regression models for volume estimation in uneven-aged beech high stands in Serbia. The models should be analysed from three aspects: construction, accuracy and implementation.

2. MATERIAL AND METHOD

The data for this research were collected within the project „Method of evaluation of quality and assortment structure of beech high stands in Serbia", realised by the Institute of Forestry in Belgrade over the period 2005-2007 in six forest regions: Severno Kučajsko, Podrinjsko-Kolubarsko, Jabaničko, Golijsko, Donje Ibarsko, and Rasinsko. Eleven all-aged high stands of beech were selected under the predetermined criteria. Altogether 241 circular sample plots of 500 m^2 were established. In all stands, the simple systematic sample of sample plots was distributed using the square grid network design, spacing 100 m. The selection intensity accounted for 5% of stand area. The data were processed using the application programme „SORTIMENT" especially designed to this purpose (Marković, N. *et al*., 2007). More detailed information on the method of data collection and processing were reported by Koprivica, M. *et al*. (2005).

The main characteristics of the sample of plots are presented in Table 1.

Because of a small number of stands in the sample, further analyses had to start from the assumption that the sample plot characteristics (taxation and site elements) can be conditionally equalised with the characteristics of hypothetical stands. From the statistical aspect, this can be justified because the variability of all elements in the plot sample is higher than the variability of the same elements in the stand sample.

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

Table 1. *Statistics of elements of beech high forests in the sample (n = 241)*

Element	Statistical indicators							
	X_{mean}	X_{min}	X_{max}	S	CV%	m%	a_3	a_4
V	382.88	49.96	983.92	163.52	42.71	5.50	0.93	4.25
G	26.95	6.91	54.00	9.10	33.78	4.35	0.30	2.66
N	298.34	60.0	1200.0	145.55	48.78	6.28	1.72	10.04
H_l	28.42	13.73	40.33	4.77	16.78	2.16	0.07	2.62
H	23.79	11.7	39.4	5.02	21.08	2.72	0.43	2.94
D_g	35.76	17.95	61.26	8.31	23.23	2.99	0.47	3.02
D	32.66	17.50	60.20	8.35	25.58	3.30	0.64	3.16
SK	0.84	0.14	1.00	0.163	19.41	2.50	-1.54	5.40
TN	3.34	1.0	8.0	1.47	44.16	5.69	0.34	1.95
NV	846.5	406.0	1370.0	255.53	30.19	3.89	0.13	2.17
NT	21.4	6.0	42.0	8.23	38.42	4.95	0.07	2.23
EK	4.08	1.0	8.0	2.72	66.71	8.59	0.45	1.51

Legend:

V - stand volume per hectare
G - stand basal area per hectare
N - number of trees per hectare
H_L- Lorey's mean height
H - arithmetic mean stand height
D_g - stand quadratic mean diameter
D - arithmetic mean diameter
SK- canopy closure
TN - tariff series (site class)
NV- stand altitude
NT- stand slope
EK- stand aspect

The method of stepwise multiple regression was applied for the defining of statistical relations between stand volume (V) as dependent variable, and the selected stand and site elements (G, N, H_L, H, D_g, D, SK, TN, NV, NT, EK) as independent variables (Hadživuković, S. 1991). The data were processed using STATGRAF, ver. 5.0. From the formal – statistic aspect, the analysis includes not only eleven original independent variables, but also thirty-five independent variables obtained by the transformation of the original independent variables.

3. RESULTS AND DISCUSSION

The study results are two regression models: Model 1 and Model 2. The Models are applied in the volume estimation of beech high stands per hectare. Model 1 consists of four original independent variables (G, N, H_L, TN), and Model 2 consists of only two variables (G and H_L). Model 1 is better as the theoretical solution, and Model 2 as the practical solution of the problem.

3.1 Regression model as the best theoretical solution

The best theoretical solution is Model 1

$$V = -517.794 - 0.11352N + 2523.83/N + 23.6139H_L - 0.41161H_L^2 + 6731.57/H_L - 21.8015TN + 0.548231\,G\,H_L \quad (1)$$

In equation (1), all partial regression coefficients are statistically significant at the risk level $p < 0.001$ (t-test), as well as the whole regression (estimated by F-test). Standard error of regression is +/-11.58 m^3/ha, and mean absolute deviation is 8.62 m^3/ha. Coefficient of multiple determination is 99.51%. Despite the high reliability of this regression model for the estimation of beech stand volume per hectare, there is a significant disadvantage, because it is necessary to predetermine four elements: number of trees per hectare (N), Lorey's mean height (H_L), tariff series (TN), and stand basal area (G). Yet, in practice, it is really difficult to ensure the sufficient accuracy of all these stand elements. However, this model can be applied successfully in the analysis of "net" effects of taxation elements on stand volume per hectare.

3.2 Regression model as the best practical solution

The best practical solution is Model 2.

$$V = - 113.725 - 2.47698G + 8.93191H_L - 0.17812H_L^2 + 0.592762GH_L \quad (2)$$

In equation (2), all partial regression coefficients are statistically significant at the risk level $p < 0.001$, as well as the whole regression. Standard error of regression is +/- 16.74 m^3/ha, and mean absolute deviation is 12.70 m^3/ha. Coefficient of multiple determination is 98.97%. The stand volume tables constructed by this Model are illustrated only by Diagrams (Diagrams 1a and 1b).

The Model reliability is tested in several ways: by the analysis of residual deviations of original values of stand volume per hectare from the values estimated by this Model (analysis of residuals), by the Diagrams of linear correlation between the original values and the estimated values of volume per hectare (method of linear correlation) and by the analysis of percent deviations of the estimated values from the original values of stand volume per hectare.

The analysis of standardised residuals shows that the residuals are distributed approximately by the probability law of normal distribution. Of the total number of all residuals, there are 12 or 4.98% standardised residuals of absolute value above 2.0 and only 3 or 1.24% above 3.0. This practically means that it can be expected at the probability of 95% that the error of the estimated stand volume per hectare will not exceed +/- 33.50 m^3/ha.

Diagram 1a. *Dependence of beech stand volume on its basal area and mean height*

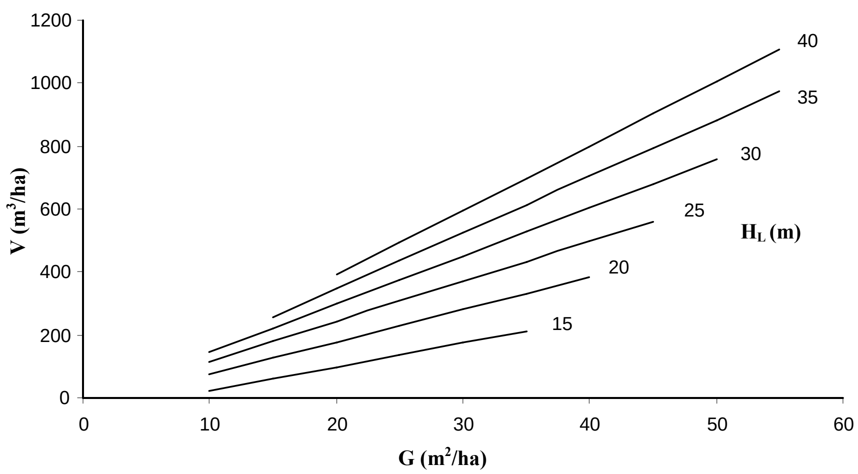
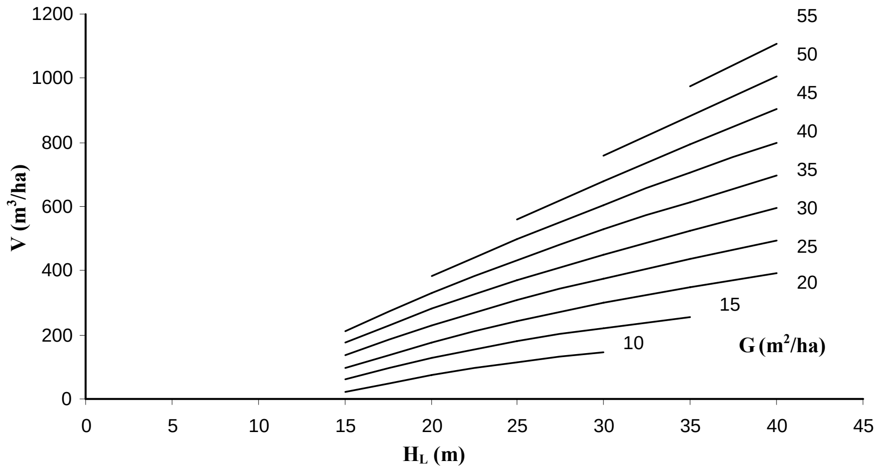


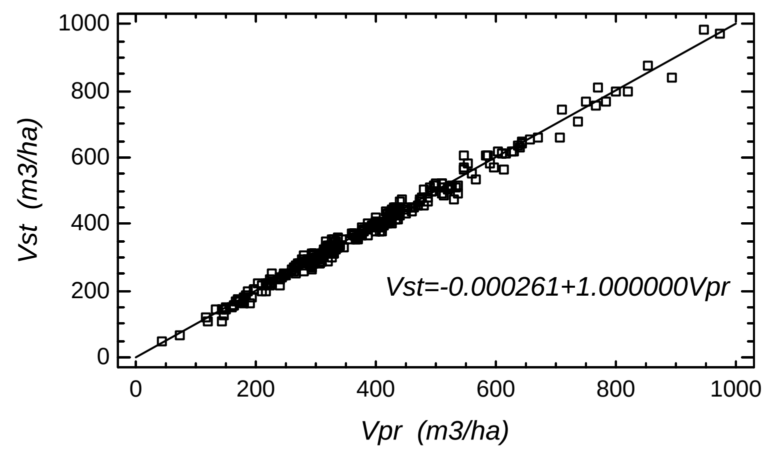
Diagram 1b. *Dependence of beech stand volume on its mean height and basal area*



The linear correlation between original and estimated values of stand volume per hectare is presented in Diagram 2.

In the ideal case, that is at the complete congruence of data, the values of straight line equation parameters are a = 0 and b = 1 (Stojanović, O., 1976). From the statistical aspect, true values of parameters of linear regression differ accidentally from the expected, so it can be concluded that Model 2 is reliable for the estimation of the beech stand volume per hectare. This is confirmed by a very narrow dispersion interval along the correlation line.

Diagram 2. *Correlation between original and estimated values of beech stand volume per hectare*



Percent deviation of the estimated values of beech stand volume from their true values is obtained by the equation,

$$p = 100\ (V_{pr.} - V_{st.})/V_{st.} \quad (3)$$

The accuracy of estimate is checked separately for all eleven beech stands analysed in this research and for all stands together, starting from the assumption that the stands belong to the same management class. The results are presented in Table 2.

Table 2. *Accuracy of estimated beech stand volume by Model 2*

Stand	n	$V_{st.}$ (m^3/ha)	$V_{pr.}$ (m^3/ha)	Δ (m^3/ha)	Δ (%)
33a	23	522.52	524.03	+1.51	+0.29
42a	18	379.57	379.11	-0.46	-0.12
42b	10	333.22	323.89	-9.33	-2.80
122a	29	503.68	502.10	-1.58	-0.31
27a	20	350.38	349.76	-0.62	-0.18
31a	32	290.89	301.13	+10.24	+3.52
46a	28	316.04	318.70	+2.66	+0.84
8a	16	385.19	393.72	+8.53	+2.21
8b	10	360.83	354.52	-6.31	-1.75
44a	22	502.25	499.83	-2.42	-0.48
116a	33	289.90	294.27	+4.37	+1.51
All	241	382.88	383.50	+0.62	+0.16

Percent deviation for individual stands varies from -2.80% to +3.52%, and for all stands together it accounts for +0.16%. Absolute deviations of the estimated value from the true volume range from -9.33 m^3/ha to +10.24 m^3/ha and they are much lower than the standard error of regression (+/-16.74 m^3/ha). This result confirms our original hypothesis in the construction Model - that sample plots characteristics can conditionally be equalised with the characteristics of hypothetical stands.

All methods of checking the accuracy of Model 2 show that the Model is highly reliable. However, the accuracy of this Model in practical application depends exclusively on the accuracy of the calculated stand basal area per hectare and Lorey's mean height. In the dataset used in the construction of the volume Model, basal area and mean height are determined with extremely high accuracy. In each sample plot, the height and the diameter at breast height were measured for all trees. Also, volume and basal area were calculated separately for each tree and converted into hectares. Of course, this level of accuracy cannot be achieved during the Model application in practice, so the error of estimated stand volume will be significantly higher.

4. APPLICATION OF THE MODEL

Regression equation (2), that is Model 2, is intended for practical application. Independent variables in the Model can be determined most readily using the *relascopy method.*

The procedure is in short as follows. First the stand structure should be evaluated (per tree diameter and per stand area) and then the tree enumeration factor should be selected, so that the average number of trees per sample plot is 20 - 25. The number of sample plots should be 3 - 5, and they should be located in the stand based on the professional assessment of the best stand volume variation in the stand area. Each selected tree in the sample plot should be enumerated and its height and diameter at breast height should be measured. Stand height curve can be constructed and Lorey's mean height (H_L) can be calculated based on the collected data. Stand basal area per diameter degrees (G_1, G_2, ... G_k) and total (G) per hectare are estimated based on the classification of the measured trees per diameter classes.

When basal area (G) and Lorey's mean height (H_L) are identified in the above way, stand volume (V) is calculated by Model 2. The distribution of stand volume per diameter degrees or diameter classes can be approximated based on the relative distribution of stand basal area. In the study beech stands, the difference between the relative distribution of basal area and the volume by diameter degrees is not great.

If the calculation accuracy of beech stand volume per hectare is to be increased, an additional number of sample plots can be established for the determination of basal area, without measuring the tree diameters and heights. This can be theoretically justified, because the coefficient of variation of basal area in the applied sample is twice higher than the coefficient of variation of Lorey's mean height (CV_G = 33.78%, CV_H = 16.78%). Taking into account the method of sample plot selection in the stand, this is a two-phase sample type (Kangas, A., Maltamo, M., 2006).

Example: In the stand 122a, based on the detailed measurement of 29 sample plots, it was calculated that the average volume amounted to 503.68 m^3/ha, average basal area 29.03 m^2/ha, and Lorey's mean height 34.35 m. In the same stand, 5 sample plots were randomly selected out of 29 sample plots and it was determined that G = 30 m^2/ha and H_L = 32 m. Based on Model 2, average stand volume was 484.44 m^3/ha. The difference in the average stand volume was -19.24 m^3/ha or -3.82%. Based on the basic sample amounting to 29 sample plots, the real average stand volume (resulting from the complete measurement) ranges between 434.62 m^3/ha and 572.73 m^3/ha, with the probability of 95%. The average stand volume calculated by the Model based on five randomly selected samples also ranges within these values.

In exceptional cases, when a fast assessment of beech stand volume per hectare, is necessary, the described procedure should be maximally simplified. Stand basal area (G) per hectare can be determined using the relascope based on 2-3 sample plots, without the measurement of tree diameters, and Lorey's mean height (H_L) can be estimated by measuring the height of a small number of dominant and codominant trees. However, this requires a high professional experience of the taxator.

5. CONCLUSION

The volume of beech high stands per hectare depends on numerous factors. Four factors (Model 1), i.e. only two factors (Model 2) with somewhat higher error regression are statistically significant factors in a stand are: number of trees per hectare (N), tariff series (TN), Lorey's mean height (H_L) and basal area per hectare (G). Model 2 shows that stand basal area per hectare and Lorey's mean height are the most significant factors in the estimation of stand volume. The effect of basal area on stand volume is linear, and the effect of mean height is curvilinear.

Model 1 has more theoretical significance and Model 2 has a practical significance. When Model 2 is applied to the concrete beech stands used in this research, it results in an exceptionally high accuracy. Percent deviation of stand volume per hectare varies from -2.80% to +3.52%, that is in absolute amounts from -9.33 m^3/ha to +10.24 m^3/ha. However, so high accuracy cannot be expected in practice, because the accuracy of the estimated stand volume will depend exclusively on the accuracy of the calculated basal area and Lorey's mean height.

The true reliability and efficacy of the regression Models can be evaluated only after their practical implementation. Namely, it is difficult to foresee the magnitude of the error which can occur in volume estimation of individual stands, but a satisfactory accuracy of volume per hectare of the management class comprising the estimated beech stands can be expected with high dependability. The accuracy of total stand volume or management class volume depends also on the accuracy of the determined area.

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VOLUME MODELS OF BEECH HIGH STANDS IN THE AREA OF SERBIA

Miloš KOPRIVICA, Bratislav MATOVIĆ, Vlado ČOKEŠA, Snežana STAJIĆ

Summary

The problem of defining the reliable regression models for volume assessment in beech high stands was researched. To date, there have been no similar models or tables for natural stands of principal tree species in Serbia. The study models were based on the data collected in six forest areas, i.e. eleven high all-aged beech stands. Altogether 241 sample plots were established using the square design, circular sample plots of 500 m^2, spacing 100 m. All trees above 10 cm in diameter were measured in all sample plots and site characteristics were defined. The data were processed using the application programme constructed to this purpose. In each sample plot, taxation elements were measured to get the average values (diameter, height, canopy) and aggregate values per hectare (number of trees, basal area, volume, volume increment), as well as site characteristics (tariff series, altitude, slope, aspect). The stepwise multiple regression method was applied. It was hypothesised that the characteristics of sample plots could simultaneously be the characteristics of hypothetical stands, and it was proved to be right. Two regression models were constructed: Model 1 and Model 2. Model 1 has more theoretical significance and Model 2 has a practical significance. All the parameters in regression models are statistically significant at the risk level $p < 0.001$. Standard error of regression in Model 1 is +/-11.58 m^3/ha, and the coefficient of multiple determination is 99.51%. In Model 2, standard error of regression is +/-16.74 m^3/ha, and the coefficient of multiple determination is 98.97%. Using Model 2, beech stand volume per hectare (V) is estimated based on mean stand height (H_L) and stand basal area per hectare (G). The deviation of stand volume by this Model from stand volume estimated based on sample plots established in the stand is from -2.8% to +3.5%, i.e. from -9.3 m^3/ha to +10.2 m^3/ha. Almost completely, the residuals are distributed by the probability law of normal distribution. The conclusion on the true reliability and efficacy of the regression models can be brought more reliably only after their practical implementation.

MODELI ZAPREMINE VISOKIH SASTOJINA BUKVE NA PODRUČJU SRBIJE

Miloš KOPRIVICA, Bratislav MATOVIĆ, Vlado ČOKEŠA, Snežana STAJIĆ

Rezime

U ovom radu istraživan je problem definisanja pouzdanih regresionih modela za procenu zapremine visokih sastojina bukve. Za prirodno nastale sastojine glavnih vrsta drveća u Srbiji do sada nisu rađeni slični modeli ili tablice. Modeli su dobijeni na bazi podataka prikupljenih u šest šumskih područja, odnosno jedanaest visokih raznodobnih sastojina bukve. Korišćen je kvadratni raspored probnih površina, oblika kruga i veličine 500 m^2, na rastojanju 100 m. Postavljena je 241 probna površina. Na svim probnim površinama izvršen je potpun premer stabala prečnika iznad 10 cm, i uzeti podaci o staništu. Obrada podataka izvršena je pomoću aplikativnog programa izrađenog u ovu svrhu. Za svaku probnu površinu utvrđeni su taksacioni elementi kao prosečne veličine (prečnik, visina, sklop) i agregatne veličine prevedene na hektar (broj stabala, temeljnica, zapremina, zapreminski prirast), kao i karakteristike staništa (tarifni niz, nadmorska visina, nagib terena, ekspozicija). Zatim je primenjen metod postepene (stepwise) višestruke regresije. Pretpostavljeno je da karakteristike probnih površina mogu biti istovremeno i karakteristike hipotetičkih sastojina. Kasnije, ovo se pokazalo kao ispravno. Dobijena su dva regresiona modela: Model 1 i Model 2. Prvi model ima više teorijski, a drugi praktični značaj. Svi parametri u regresionim modelima su statistički značajni na nivou rizika $p < 0,001$. Standardna greška regresije za Model 1 je +/-11,58 m^3/ha, a koeficijent višestruke determinacije 99,51%. Za Model 2 standardna greška regresije je +/-16,74 m^3/ha, a koeficijent višestruke determinacije 98,97%. Po Modelu 2 zapremina sastojine bukve po hektaru (V) dobija se na bazi srednje visine sastojine (H_L) i temeljnice sastojine po hektaru (G). Odstupanje zapremine sastojina po ovom modelu od zapremine sastojina utvrđene na bazi probnih površina postavljenih u sastojini iznosi od -2,8% do +3,5%, odnosno od -9,3 m^3/ha do +10,2 m^3/ha. Skoro u potpunosti, reziduali su raspoređeni po zakonu verovatnoće normalnog rasporeda. O stvarnoj pouzdanosti i efikasnosti dobijenih regresionih modela može se sigurnije zaključivati tek poslije njihove primene u praksi.

THE RESOURCES OF THE BEECH FORESTS IN THE PESHTER PLATEAU

Mihailo RATKNIĆ, Ljubinko RAKONJAC[1], Sabahudin HADROVIĆ[2]

Abstract: *The beech forests in the Peshter plateu are located at the altitudes ranging from 1,200 to 1,600 meters above the sea level. In the beech community on the limestones the total of 136 plants were reported, whereas 78 plants were reported on the silicates. In the beech forests the total of 66 medicinal plants, i.e. 40.7% was reported. In the first category of the healing rate, the total of 10 species were determined, in the second category of the healing rate the total of 4 species were reported, in the third category of the healing rate the total of 20 species, in the fourth category of the healing rate the total of 15 species, and in the fifth category of the healing rate the total of 17 species. By the analysis done in the beech forests 63 honey plants, out of which 10 woody, 21 bushy, and 32 herbaceous, were reported. The average honey yield of the communities is 2.98. The beech forests were reported on 2,027.03 hectares. The high even-aged forest stands account for 17.4%, high multi-aged forest stands for 7.7%, coppice forests for 49.6%, coppice even-aged forests for 3.0%, shrubs for 3.4%, high beech and sessile oak forests for 4.0%, high (even-aged) beech and hornbeam for 3.6%, coppice beech and hornbeam forests for 5.8%. The trees with the diameter up to 30 cm account for 61.3%.*

Key words: beech forests, sustainable use, natural resources

RESURSI ŠUMA BUKVE NA PODRUČJU PEŠTERSKE VISORAVNI

Izvod: *Bukove šume na Pešterskoj visoravni javljaju se od 1200 do 1600 m nadmorske visine. U zajednici bukve na krečnjacima konstatovano je 136 vrsta, a na silikatima 78 vrsta biljaka. U šumama bukve konstatovano je 66 lekovitih biljaka, odnosno 40.7%. U okviru prve kategorije lekovitosti ustanovljeno je 10 vrsta, u drugoj 4, u trećoj 20, u četvrtoj 15 i u petoj 17 vrsta. Na osnovu izvršene analize u šumama bukve konstatovane su 63 medonosne vrste, od čega 10 drvenastih, 21 žbunasta i 32 zeljaste. Srednja mednost zajednice iznosi 2.98. Šuma bukve konstatovana je na 2027.03 hektara. Visoka jednodobna šuma zabeležena je na 17.4%, visoka raznodobna na 7.7%, izdanačka šuma na 49.6%, izdanačka devastirana 5.5%, lisnička 3.0%, šikara 3.4%, visoka šuma bukve i kitnjaka 4.0%, visoka (jednodobna) šuma bukve i graba 3.6%, izdanačka šuma bukve i graba 5.8%. Stablja tanja od 30 cm učestvuju sa 61.3%.*

Ključne reči: šume bukve, održivo korišćenje, prirodni resursi

1. INTRODUCTION

The disapperance of 10 million hectares of forests a year points to the seriousness of the problem and requires the urgent measures aimed at stopping degradation and devastation of the current forest ecosystems. In the concept of ecocentric (or biocentric) use of the resources the term "ecosystem" stands for the complexity of the living organisms and has the value by itself, since the human needs and their attitude towards nature is treated in another way. The way in which nature creates and preserves the ecosystems is respected. The ecocentric concept protects, maintains and regenerates the functioning of the natural ecosystems by the stimultaneous use of all goods and servies aimed at the satisfaction of the human needs, on the stable and permanent

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bases. The ecological processes in ecosystems are favoured, so they satisfy the economic needs of the society, which does not imply the industrial use. The integral part is the soil, water, biodiversity and biomass tending. The achievement of these goals are based on the ecological, socio-demographic and economic criteria. The paper is based on the Concept of sustainable development and is focused on the smaller territorial units (areas).

2. MATERIAL AND METHOD

The beech forests in the Pester Plateau (Southwestern Serbia) were researched. The pedological characteristics were researched based on the soil profiles, and the types of soil were determined based on the soil classification (Skoric, Filipovski, Ciric, 1985). The basic life forms were classified by using Rankiaer's method (Raunkiaer, 1934). The area covered by forest and forest stands was analyzed, and the observed forests were classified per types of stands, volume and volume increment. The percentage of the trees in the total volume, with the diameter up to 30 cm was particularly analyzed.

3. RESULTS

The beech forests in the Peshter Plateau are located at the altitudes ranging from 1,200 to 1,600 meters above the sea level. At lower altitudes, in the vicinity of the rural inhabited places, the forest is completely destroyed, so in the progressive succession these places are now occupied by the pioneer tree species. The best stands, which were observed, are located at about 1,280 meters above the sea level. They are preserved at the colder northern, eastern and north-eastern exposures, whereas at the warmer exposures they did not manage to regenerate, in spite of the significant coppice vigour of the beech. At the higher altitudes (above 1,450 meters) the beech occurs in the form of the partially preserved stands, as well as at the western, south-western and southern exposures, at the slopes up to $40^{0.}$ It occurs on the limestone parent rock, as well as on the acid quartz conglomerates, sand pits and diabase-hornstone.

The beech stands on the limestone occur on the limestone dark soil and on the brown limestone soil. In regard to the acid parent rock, they occur on the dystric cambisol.

The following species occur in the beech stands on the limestone: Acer platanoides L., Agrimonia eupatoria L., Allium ursinum L., Anemone nemorosa L., Anthriscus nemorosus (M.B.) Spreng., Carex silvatica Huds., Cephalanthera alba (Cr.) Simk., Chaerophyllum aromaticum L., Chaerophyllum hirsutum L., Clematis alpina (L.) Mill., Convallaria majalis L., Daphne mezereum L., Digitalis ferruginea L., Doronicum columnae Ten., Dryopteris filix-mas (L.) Schot., Euphorbia carniolica Jacq., Evonymus europaeus L., Evonymus latifolius (L.) Mill., Evonymus verrucosus Scop., Galium silvaticum L., Geranium phaeum L., Geum urbanum L., Helianthemum nummularium (L.) Mill., Helleborus odorus W.et K. , Heracleum sphondylium L., Hypericum perforatum L., Lamium galeobdolon (L.) Nath., Lilium martagon L., Listera cordata (L.) R.Br., Lonicera xylosteum L., Lysimachia nemorum L., Melica uniflora Retz., Melittis melissophyllum L., Milium effusum L., Mycelis sonchifolia, Myrrhis odorata (L.) Scop., Orchis purpurea Huds., Oxalis acetosella L., Peucedanum austriacum (Jacq.) Koch., Pirus piraster Burg., Polygala comosa Schk., Polygonatum odoratum (Mill.) Druce., Polystichum setiferum (Forsk.) Moore, Potentilla micrantha Ram., Primula acaulis (L.) Gr., Primula veris Huds., Prunus spinosa L., Pulmonaria officinalis L., Ribes alpinum L., Rosa arvensis Huds., Rumex acetosa L., Scrophularia nodosa L., Senecio spathulifolius (Gm.) DC, Smyrnium perfoliatum L., Solidago virga-aurea L., Sorbus domestica L., Stachys silvatica L., Teucrium chamaedrys L., Thalictrum aquilegifolium L., Trifolium diffusum Ehrh., Ulmus carpinifolia

Gled., Veratrum album L., Verbascum adamovicii Vel., Viburnum lantana L., Viburnum opulus L., Vicia cassubica L., Vicia cracca L., Viola alba Bess., Viola hirta L., Viola odorata L., Asperula taurina L., Astrantia major L., Brachypodium silvaticum (Huds.) P.B., Cardamine enneaphyllos L., Carpinus betulus L., Coronilla varia L., Corylus avelanna L., Cotoneaster tomentosa (Ait.) Lindl., Festuca heterophylla Lam., Filipendula hexapetala L., Galium purpureum L., Geranium sanguineum L., Knautia dipsacifolia Kreutz., Lamium maculatum L., Laserpitium latifolium L., Laserpitium marginatum W.et K., Linum catharticum L., Phleum pratense L., Phyteuma spicatum L., Pleurospermum austriacum (L.) Hoffm., Poa nemoralis L., Salix capreae L., Sanicula europaea L., Sorbus austriacus (Beck.) Hedl.,

The following species occur in the beech stands on silicate: Anemone nemorosa L., Anthriscus nemorosus (M.B.) Spreng., Asperula taurina L., Astrantia major L., Avena planiculmis Schrad., Betula pendula Roth., Calamagrostis arundinacea (L.)Roth., Campanula glomerata L., Campanula persicifolia L., Campanula trachelium L., Corylus avelanna L., Equisetum hiemale L., Erica carnea L., Erigeron acer L., Frangula alnus Mill., Galium anisophyllum Vill., Galium verum L., Genista sericea Wulf., Geum montanum L., Hypericum maculatum Cr., Knautia csikii Jav.et Szabo, Laserpitium marginatum W.et K., Lathyrus pratensis L., Lilium martagon L., Lonicera nigra L., Medicago minima (L.) Bartl.

The following species occur on the limestone and silicate: Aegopodium podagraria L, Ajuga reptans L., Alchemila vulgaris L., Aremonia agrimonoides (L.) DC, Arum italicum Mill., Asarum europaeum L., Asperula odorata L., Cardamine bulbifera L., Carex montana L., Crataegus monogyna Jacq., Dactylis glomerata L., Daphne laureola L., Deschampsia flexuosa (L.) Tr., Epipactis latifolia (L.) All., Euphorbia amygdaloides L., Fagus silvatica L., Fragaria vesca L., Glechoma hirsuta W.et K., Helleborus multifidus Vis., Juniperus communis L., Laser trilobium (L.) Borkh., Luzula luzuloides (Lam.) Dan., Melampyrum pratense L., Mercurialis perennis L., Mycelis muralis (L.) Rchb., Paris quadrifolia L., Picea abies Kars., Polygonatum verticillatum (L.) All., Populus tremula L., Prunela vulgaris L., Prunus avium L., Pteridium aquilinum (L.) Kuhn., Rhamnus falax Boiss., Ribes grossularia L., Rosa dumetorum Thuill., Rosa pendulina L., Rubus hirtus W.et K., Sorbus aucuparia L., Stellaria holostea L., Symphytum tuberosum L., Thalictrum minus L., Viola silvestris Lam.

The total of 136 plant species were reported on the limestone, whereas 78 plant species were reported on the silicate. The richness in the plant species is the result of the bad stand condition and presence of the types of the grass associations, due to the scattered canopy. Given the fact that the beech associations are by rule poor, it can be determined that the forests of this association are degraded to a great extent.

In the spectrum of the life forms of the beech forests on the limestone and silicates, the high percentage of hemicryptophytes was reported (46.32%, i.e. 44.87%) (Tables 1 and 2). These plants are adapted to the life conditions in the moderate and cold regions, owning to which they are the most abundant group of the life form in this area. The high percentage of geophytes (22.06%, i.e. 21.79%) points to the more humid climate and edaphic conditions, since the stands are located at the colder exposures or higher altitudes, where the soil humidity and relative air humidity are high. There is the high percentage of phanerophytes, which accounts for above 23%. Chamaephytes account for 4.41% on the limestone, i.e. for 7.70% on the silicate.

Table 1. *Specter of the life forms of plants on the limestone*

Life forms (%)							
Phanero phytes	Nanophanero phytes	Woody chamae phytes	Herbaceous chamaephytes	Chemicrypto phytes	Geophytes	Terrophytes	Terro phytes/ Chamae phytes
p	np	dc	zc	h	g	t	th
11.03	13.24	1.47	2.94	46.32	22.06	1.47	1.47
24.27		4.41					

Table 2. *Specter of the life forms of plants on the silicates*

Life forms (%)							
Phanero phytes	**Nanophanerop hytes**	**Woody chamae phytes**	**Herbaceous chamaephytes**	**Chemicryptop hytes**	**Geophytes**	**Terrophytes**	**Terro phytes/ Chamaep hytes**
p	**np**	**dc**	**zc**	**h**	**g**	**t**	**th**
11.54	11.54	3.85	3.85	44.87	21.79	1.28	1.28
23.08		7.70					

In the beech association on the limestone, the Mid-European floral elements are most frequent (32.35%) (Table 3). There is the high percentage of Eurasian floral elements (22.79%). In addition, the group of circumpolar and cosmopolites (8.82%), along with the floral elements of the northen regions, accounts for 14.70%. The Sub-Mediterranean floral elements account for 16.18%, Pontic-Central Asian and Sub-Atlantic account for 6.62%, whereas endemites account for only 0.74%.

Table 3. *Specter of the floral elements of beech forests*

Name of the group of the floral elements	**Floral elements**	on limestone		on silicate	
		percentage %		percentage %	
1. FLORAL ELEMENTS OF NORTHEN REGIONS					
Arctic floral elements					
Boreal floral elements	Sub-boreal	0.74		**1.28**	
	Boreal-circumpolar	0.74			
	Sub-boreal -European-West Siberian	0.74		**1.28**	
	Sub-boreal-circumpolar	1.47		**3.85**	
	Boreal-Eurasian	1.47		**1.28**	
	Sub-boreal- Eurasian	0.74	**5.88**		**7.69**
2. MID-EUROPEAN FLORAL ELEMENTS					
Mid-European	Mid-European	16.18		**10.26**	
And European	Sub-Mid-European	15.44		**14.10**	
	Alpine Carpathian			**5.13**	
	Sub-Mid-European –Sub-Mediterranean	0.74	**32.35**		**29.49**
3. SUB-ATLANTIC FLORAL ELEMENTS					
Sub-Atlantic and Atlantic	Sub-Atlantic	0.74			
	Sub-Atlantic-Sub-Mediterranean	5.15		**2.56**	
	Euro-African	0.74	**6.62**		**2.56**
4 SUB-MEDITERRANEAN FLORAL ELEMENTS					
Sub-Mediterranean	Sub-Mediterranean	7.35		**2.56**	
East- Sub-Mediterranean	East- Sub-Mediterranean	2.21		**1.28**	
	Sub-Euxine	0.74		**1.28**	
Balkan and	Moesian	0.74			
Balkan-Apennine	Illyrian	0.74		**1.28**	
	Sub-Illyrian	2.21		**2.56**	
	Sub-Illyrian -(Sub)Apennine			**1.28**	
	Scardo-Pindic			**1.28**	
	Mid-Balkan	0.74			
	Balkan	0.74		**1.28**	
	Balkan-Central-South-Apennine			**1.28**	
	Sub-Balkan-Apennine	0.74	**16.18**		**14.10**
5 PONTIC-CENTRAL ASIAN FLORAL ELEMENTS					
Pontic	Sub-Pontic	4.41			
	Sub-Pontic-Sub-Mediterranean			**1.28**	
	Pontic- Sub-Mediterranean	1.47		**1.28**	
	Pontic-East-Sub-Mediterranean	0.74	**6.62**	**1.28**	**3.85**

6 EURASIAN FLORAL ELEMENTS					
	Sub-South-Siberian	4.41		**3.85**	
	Eurasian	11.76		**14.10**	
	Sub-Eurasian	6.62	**22.79**	**11.54**	
7 CIRCUMPOLAR AND COSMOPOLITAL FLORAL ELEMENTS					
	Circumpolar	5.88		**10.26**	
	Sub-circumpolar	0.74			
	Cosmopolites	2.21	**8.82**	**1.28**	**11.54**
8 ENDEMITES, SUB-ENDEMITES					
	Endemites	0.74	**0.74**	**1.28**	**1.28**

In the beech association on the silicate the highest percentage of the Eurasian and European floral elements was reported (29.49% each) (Table 32.). The group of circumpolar and cosmopolites accounts for 11.54%, and the floral elements of the northen regions account for 7.69%. Sub-Mediterran floral elements account for 14.10%. Pontic-Central Asian floral elements account for 3.85%, Sub-Atlantic floral elements account for 2.85%, and endemites account for 2.85%.

The association on the limestone is the thermophile association of the montane beech, which occurs on the limestone dark soil and brown limestone soil. These conditions are less favourable for the development of beech, and the association is of xeromesophilic (mesothermic) character. It is characterized by the greater floral diversity and by the differential thermophile and xeromesophilic species. The differential and some typical, "fagetal" species are the following: *Daphne mezereum, D. laureola, Viburnum lantana, Evonymus verrucosa, Evonimus latifolius, Evonimus europaeus, Ribes alpinum, Chamaecytisus hirsutus*. Due to the aggravation of the edaphic conditions, the beech trees become stunted, and this species loses the dominant role, whereas the hazel becomes dominant.

The beech associations on silicate occurs on the acid silicate soil parent rock, is poorer in floral elements, and the differential types of the spruce forests are present. The differential types of this sub-association are: *Luzula luzoloides, Vaccinium myrtillus, Calamagrostis arundinacea, Prenathes purpurea.*

3.1 The medicinal plants in beech forests

In the beech forests the total of 66 medicinal plants, i.e. 40.7% was reported. In the first category of the healing rate, the total of 10 species were determined, in the second category of the healing rate the total of 4 species were reported, in the third category of the healing rate the total of 20 species, in the fourth category of the healing rate the total of 15 species, and in the fifth category of the healing rate the total of 17 species (Table 33). The following species belong to the first category of the healing rate: Betula pendula, Crataegus monogyna, Dryopteris filix-mas, Hypericum perforatum, Juniperus communis, Primula veris, Rosa dumetorum, Sanicula europaea, Vaccinium myrtillis and Veratrum album. All these species, except for Rosa dumetorum are in circulation, and Veratrum album is in the Red Book, the decree on the limited collection, and by IUCN it is ultimately endangered and vulnerable taxon, so the collection of it is prohibited. The following species belong to the second category of healing rate: Agrimonia eupatoria, Pulmonaria officinalis, Rumex acetosa and Solidago virga-aurea. All these species are in circulation, and Rumex acetosa is excluded from the collection on the natural sites. The following species belong to the third category of the healing rate: Ajuga reptans, Allium ursinum, Asarum europaeum, Asperula odorata, Daphne mezereum, Erica carnea, Evonymus europaeus, Fagus silvatica, Geum urbanum, Glechoma hirsuta, Helleborus odorus, Melittis melissophyllum, Populus tremula, Potentilla erecta, Prunus spinosa, Rubus idaeus, Scrophularia nodosa, Sorbus domestica, Symphytum tuberosum and Viola odorata. The collection of the following species is limited by the decree: Allium ursinum, Asarum europaeum, Asperula odorata, Geum urbanum and Potentilla erecta. The following species belong to the fourth group of the healing rate: Acer platanoides, Campanula glomerata, Campanula trachelium, Corylus avelanna, Digitalis ferruginea, Euphorbia amygdaloides, Filipendula hexapetala, Fragaria vesca, Galium verum, Geum montanum, Heracleum sphondylium, Oxalis acetosella, Prunus avium, Sorbus aucuparia and Teucrium chamaedrys. Out of these species, the collection of the following four are limited by the decree: Corylus avelanna, Digitalis ferruginea, Fragaria vesca and Galium verum. The following species belong to the fifth group of the healing rate: Aegopodium podagraria, Alchemila vulgaris, Anemone nemorosa, Daphne laureola, Doronicum columnae, Frangula alnus, Lilium martagon, Paris quadrifolia, Picea abies, Primula acaulis, Prunela vulgaris, Pteridium aquilinum, Ribes grossularia, Salix capreae, Thalictrum aquilegifolium, Thalictrum minus and Viburnum opulus. The collection of Alchemila vulgais is limited by the decree.

3.2 Fruit trees in the beech forests

The following species of fruit trees were found in the beech forests : *Crataegus monogyna, Juniperus communis, Vaccinium myrtillis, Rubus idaeus, Sorbus domestica, Fragaria vesca, Sorbus aucuparia, Frangula alnus, Ribes grossularia, Cotoneaster tomentosa, Lonicera nigra, Lonicera xylosteum, Rhamnus falax, Ribes alpinum, Rosa arvensis, Rubus hirtus and Sorbus austriacus.*

3.3 Honey plants in the beech forests

In the beech forests the total of 63 honey plants, out of which 10 woody, 21 bushy, and 32 herbaceous, were reported. The following woody plants are present: Acer platanoides, Prunus avium, Picea abies, Populus tremula, Betula pendula, Carpinus betulus, Fagus silvatica, Sorbus aucuparia, Sorbus austriacus and Sorbus domestica. The following bushy plants are present: Corylus avelanna, Rosa pendulina, Rubus idaeus, Salix capreae, Viburnum lantana, Crataegus monogyna, Erica carnea, Evonymus europaeus, Evonymus latifolius, Evonymus verrucosus, Frangula alnus, Prunus spinosa, Ribes alpinum, Ribes grossularia, Teucrium chamaedrys, Viburnum opulus, Clematis alpina, Cotoneaster tomentosa, Daphne laureola, Daphne mezereum and Vaccinium myrtillis. The following herbaceous plants are present: Anemone nemorosa, Campanula persicifolia, Campanula trachelium, Geranium sanguineum, Lamium galeobdolon, Lathyrus pratensis, Pulmonaria officinalis, Stachys silvatica, Symphytum tuberosum, Thalictrum aquilegifolium, Vicia cracca, Ajuga reptans, Astrantia major, Campanula glomerata, Coronilla varia, Digitalis ferruginea, Filipendula hexapetala, Phyteuma spicatum, Primula acaulis, Prunela vulgaris, Scrophularia nodosa, Solidago virga-aurea, Thalictrum minus, Veratrum album, Aegopodium podagraria, Fragaria vesca, Helleborus odorus, Heracleum sphondylium, Hypericum perforatum, Lilium martagon, Polygala comosa and Primula veris. The average honey yield of the association is 2.98. The greatest number of the honey plants in blossom was reported in May, June and July.

3.4 Wood resources of the beech forest

The beech forests were reported on 2,027.03 hectares. The high even-aged forest stands account for 17.4%, high multi-aged forest stands for 7.7%, coppice forests for 49.6%, coppice even-aged forests for 3.0%, shrubs for 3.4%, high beech and sessile oak forests for 4.0%, high (even-aged) beech and hornbeam for 3.6%, coppice beech and hornbeam forests for 5.8%. The trees with the diameter up to 30 cm account for 61.3% (Table 4).

Table 4. *Wood resources of the beech forest*

P (ha)	Total volume (m^3)	Volume per diameter degrees										Volume increment (m^3)
		< 10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90	
High (even-aged) beech forest												
353.23	113692	40	12384	24021	28487	25355	16061	4974	1678	691		1728
High (multi-aged) beech forest												
155.93	47675	218	4302	9734	13366	10670	5767	2587	321	122	588	855
Coppice beech forest												
1006.25	183780	23240	87071	51767	15197	4364	1800	252	180			4982
Coppice devasted beech forest												
111.44	4487	2121	264	430	452	641	405	174				69
Broadleaved beech forest												
60.41	2380	2380										
Beech shrub												
68.76												
High forest of beech and sessile oak												
81.91	17318	861	3703	5001	2771	2354	1602	606	419			296
High (even-aged) beech and hornbeam forest												
72.01	18662		4586	4974	2589	3144	1328	834	207			271
Coppice beech and hornbeam forest												
117.09	18977	1722	5006	5652	4103	1989	404	102				363

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DEPENDENCE OF BEECH TREE VOLUME INCREMENT ON CROWN STRUCTURE

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Abstract: *The effect of crown structure on tree volume increment was researched in a beech high uneven-aged stand in the area of Severni Kučaj, Eastern Serbia. Taxation elements of all trees above 10 cm were measured on circular sample plots sized 500m². The sample included 133 trees, which were measured on 12 sample plots. Volume increment of individual trees was estimated based on their diameter increment using the regression model. Also, the elements of crown structure were measured. The relation between the elements of crown structure as dependent variables and tree diameter and height as independent variables was assessed by simple regression. The relation between tree volume increment as dependent variable and tree diameter, height and the elements of crown structure as independent variables was determined by multiple regression analysis.*

Key words: beech, tree, crown, volume increment, sample, regression.

ZAVISNOST ZAPREMINSKOG PRIRASTA STABLA BUKVE OD IZGRAĐENOSTI NJEGOVE KROŠNJE

Izvod: *U istočnoj Srbiji, na području Severnog Kučaja, u visokoj raznodobnoj sastojini bukve izvršeno je istraživanje uticaja izgrađenosti krošnje stabla na njegov zapreminski prirast. Na primernim površinama, oblika kruga i veličine 500 m², izvršen je premer taksacionih elemenata svih stabala iznad 10 cm. Veličina uzorka je iznosila 133 stabla, koja su premerena na 12 probnih površina. Zapreminski prirast pojedinačnih stabala određen je na bazi njihovog debljinskog prirasta primenom odgovarajućeg regresionog modela. Takođe, izvršen je i premer elemenata izgrađenosti krošnje. Jednostavnom regresijom utvrđena je veza između elemenata izgrađenosti krošnje, kao zavisno promenljivih, i prečnika i visine stabla, kao nezavisno promenljivih. Višestrukom regresijom utvrđena je veza između zapreminskog prirasta stabla, kao zavisno promenljive, i prečnika, visine i elemenata izgrađenosti krošnje, kao nezavisno promenljivih.*

Ključne reči: bukva, stablo, krošnja, zapraminski prirast, uzorak, regresija

1. INTRODUCTION

Of all tree species in the Republic of Serbia, beech forests occupy the largest area and have the greatest wood volume, so they are the most important part of the growing stock. According to Stojanović, Lj., Krstić, M. (2000), the percentage of pure beech forests in wood volume is 39.1% or 91,841,305 m³ and their annual volume increment is 2,109,586 m³ or 34.1%. Despite the large-scale and multidisciplinary research of beech forests in Serbia, their crown structure, as the essential element of forest structure, was insufficiently researched. Without doubt, the assimilation capacity, expressed by crown, is at least as important as the site itself (Panić, Đ., 1966). The crown shape and size do not affect only the increase in volume increment,

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but also the increase in the stand stability regarding the impacts of numerous adverse abiotic and biotic factors, creation of special forest microclimate, soil formation processes and soil protection against erosion and weeds, seed yield and forest regeneration, as well as many other multiple-use forest functions. Throughout the stand life cycle, crowns develop in harmony with the available space, so their size and form can be changed by implementing the silvicultural measures. Vučković, M., Stamenković, V. (1990) and Vučković, M., Stajić, B. (2003) report the coefficient of economy of growth space utilisation, based on which the optimal stand density can be defined per individual age classes. They advocate the typifying of the optimal state depending on site conditions, age, or the stand upper height. By affecting the crowns, we also affect the root increase and the assimilation capacity, which is by all means reflected on the stand productivity and stability. Bunuševac, T. (1951) claims that the culmination of current volume increment in the trees of seed origin coincides with the development of the maximum assimilation area. The magnitudes of basal area, volume and volume increment of trees and stands cannot be fully explained without the understanding of the crown form and structure, as the essential elements of structure.

2. STUDY AREA AND METHOD

The study area is a high beech stand in Eastern Serbia (stand 33a, Management Unit "Majdan-Kučajna"). The stand area is 22.7 hectares, altitude 410-520 m, slope gradient 7-28 degrees. The predominant aspect is north-west. Parent rock consists of dense limestones, the soil is calcocambisol, depth 40-80 cm. The stand is classified as submontane forest of beech (*Fagenion moesiacae submontanum* Jov. 1976). By silvicultural and structural form, it is a high group-selection uneven-aged beech stand of virgin forest characteristics. Site class is II, canopy 0.90, percentage of beech in volume 97%, stand quadratic mean diameter 39.4 cm, and Lorey's mean height 31.0 m. Number of trees per hectare is 274, basal area 33.4 m^2, volume 522.5 m^3 and volume increment 8.6 m^3 (Koprivica, M. *et al*. 2008).

Circular sample plots of 500 m^2 (radius 12.62 m) were established in the stand to investigate the effect of crown elements on tree volume increment. The circles were distributed in a systematic sample, with the spacing between them in one direction 200 m and the spacing between directions 100 m (a circle represents two hectares). All sample plots in the stand were measured as follows: diameter, total height, height of crown base and height of the maximal crown width of the trees above taxation limit of 10 cm. The area of horizontal crown projection was calculated based on eight radiuses. Volume increment of trees was calculated based on their diameter increment using the designed regression model (Koprivica, M., Matović, B. 2005).

Volume and crown surface area were calculated using the method after Pretzsch, H. (2002) and Kotar, M. (2003). These authors divided the beech crown into two portions at the point of the largest crown width (LCW) of the upper portion was calculated by the formula for cubic paraboloid and that of the lower portion was calculated by the formula for truncated cone:

Area of horizontal crown projection

$$bk = R^2 \cdot \pi$$

Upper crown volume

$$vk1 = \frac{3}{5} R^2 \cdot \pi \cdot lk1$$

Lower crown volume

$$vk2 = (R^2 + R \cdot r + r^2)(\frac{\pi \cdot lk2}{3})$$

Total crown volume

Legend of symbols:

- bk - area of horizontal crown projection
- R - crown radius;
- r - radius of crown base;
- π - Ludolf number
- vk1 - upper crown volume;
- vk2 - lower crown volume;
- vk - total crown volume;

$vk = vk1 + vk2$

Upper crown Surface area

$$pk1=\frac{a\cdot\pi}{2}\cdot\left[\left[\ lk1^{2/3}\cdot\sqrt{\frac{9}{a}\cdot lk1^{4/3}+1}+\sqrt{\frac{a}{9}}\cdot\ln\left(\ \frac{3}{\sqrt{a}}\cdot lk1^{2/3}+\sqrt{\frac{9}{a}\cdot lk1^{4/3}+1}\ \right)\ \right]\right]$$

where: $a = \frac{R^2}{lk1^{2/3}}$

Lower crown surface area

$$pk2 = \pi\cdot\sqrt{(R-r)^2 + lk2^2}$$

Total crown surface area

$$pk = pk1 + pk2$$

- lk1 - upper crown length;
- lk2 - lower crown length;
- lk - total crown length;
- pk1 - upper crown surface area;
- pk2 - lower crown surface area;
- pk - total crown surface area.

The relations between the elements of crown structure and other elements were estimated using the methods of simple and multiple regression and correlation.

3. RESULTS AND DISCUSSION

3.1 The investigated characters and the structure of tree sample

Crown elements investigated in this study are: length, width, area of horizontal projection, crown volume and surface area, and the stem elements: diameter at breast height, height and tree volume increment. The relations between the structure elements were estimated using the methods of simple and multiple regression and correlation. In simple regression and correlation, the focus was placed on the study of the relation between crown elements and diameter at breast height and in multiple regression and correlation the focus was on the relation between volume increment of trees and crown elements. This analysis was performed on the sample of 133 trees. The main statistical parameters for the study elements are presented in Table 1.

Table 1. *Main statistical parameters for the elements in the study sample (n =133)*

Taxation element	Symbol	$x_{min.}$	$x_{max.}$	X_{mean}	s_x	vk%	a_1	a_2
tree diameter	d	10.4	92.0	38.3	19.6	51.2	0.65	2.63
tree height	h	7.7	44.1	28.0	5.8	20.6	-0.57	4.37
tree volume increment	iv	0.0001	0.1496	0.0358	0.0352	98.5	1.18	3.79
crown length	lk	0.8	24.5	12.6	4.8	38.2	0.06	2.56
crown width	dk	0.2	17.7	6.8	4.5	65.0	0.54	2.34
crown projection	bk	0.0	244.7	52.27	58.3	111.5	1.38	4.23
crown volume	vk	0.1000	2785.1	458.8	605.6	132.0	1.71	5.65
crown surface	pk	3.9	494.7	143.4	125.4	87.4	0.99	2.84

The data in Table 1 show that the sample of the selected trees is well structured. According to the variation coefficient, the order of variability of the study characters is as follows: tree height (21%), crown length (38%), tree diameter (51%), crown width (65%), crown surface (87%), volume increment (97%), crown projection (112%) and crown volume (132%).

In order to explain the dependence of tree volume increment on other taxation elements, only the unmarked trees were set aside in a subsample. The size of the subsample was 72 trees, and variation coefficients of the study characters in it were the following: tree height (17%), crown length (32%), tree diameter (48%), crown width (63%), crown surface (89%), volume increment (90%), crown projection (115%) and crown volume (140%).

The characters with lower variation in the subsample of unmarked trees are: tree height, crown length, tree diameter, crown width and tree volume increment. On the other hand, crown surface, crown projection and crown volume show higher variation. The greatest differences are for volume increment of trees and crown volume. The matrix of the coefficient of linear correlation shows that all characters in the main sample and in the subsample are strongly intercorrelated. The volume increment is characterised by the fact that the correlation is stronger in the subsample of unmarked trees. Accordingly, a better explanation of the dependence of the volume increment of unmarked trees on other taxation elements compared to volume increment of all trees should be expected in the multiple regression.

3.2 Simple dependence between taxation elements

The statistical relation between taxation elements (crown and stem) was determined using the parabola of the second degree in the general form $y = a + bx + cx^2$. However, the analysis of the results of data fitting shows that, for small values of the selected independent variable, in some cases, we get the negative values of dependent variable, so the constant was left out and the implemented parabola form was: $y = bx + c x^2$.

Several dependences of crown and stem elements on diameter at breast height and tree height were analysed. The results are presented analytically, using regression equations (1 - 10) presented in Table 2 and in Diagrams 1 - 9.

Table 2. *Statistical parameters of simple regression between taxation elements*

Regression equation	y	x	Equation parameters			s_e	r^2 (%)
			a	b	c		
(1)	lk	d	-	0.470222	- 0.00297456	2.72 m	95.98
(2)	dk	d	-	0.15956	0.00043897	1.91 m	94.62
(3)	bk	d	-	0.0077829	0.0284493	26.13 m^2	88.98
(4)	vk	d	-	- 3.41549	0.32278	304.74 m^3	84.08
(5)	pk	d	-	2.24379	0.0329648	64.08 m^2	88.82
(6)	h	d	37.467	10.2934	-	3.14 m	70.74
(7)	iv	d	-	0.0005539	0.00000859	0.02145 m^3	81.97
(8)	iv	d	-	0.00051069	0.000011646	0.01682 m^3	88.15
(9)	d	dk	12.3534	3.46908	0.0327364	8.32 cm	82.35
(10)	lk	h		0.153705	0.0101118	2.74 m	95.94

Diagram 1. *Relation of crown length and tree diameter*

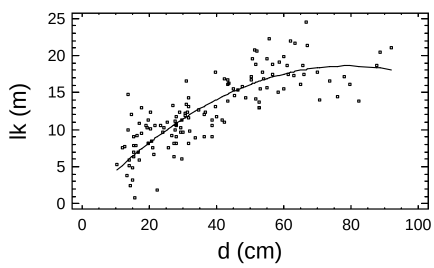


Diagram 2. *Relation of crown width and tree diameter*

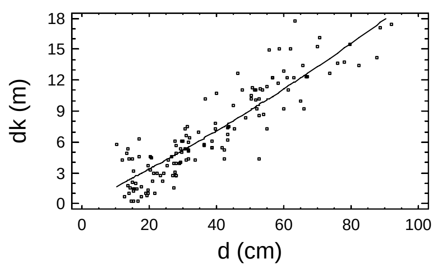


Diagram 3. *Relation of crown projection and tree diameter*

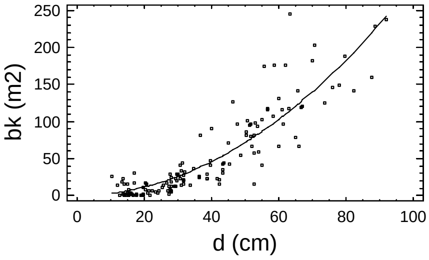


Diagram 4. *Relation of crown volume and tree diameter*

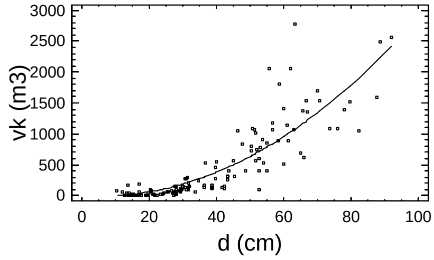


Diagram 5. *Relation of crown surface area and tree diameter*

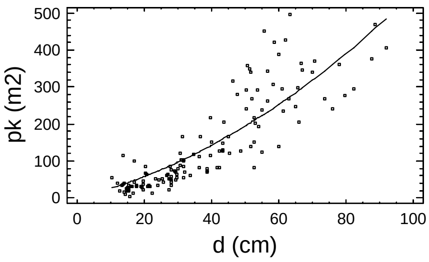


Diagram 6. *Height curve*

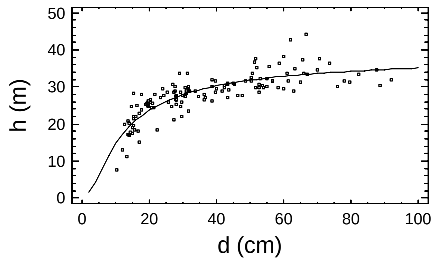


Diagram 8. *Relation of tree diameter and crown width*

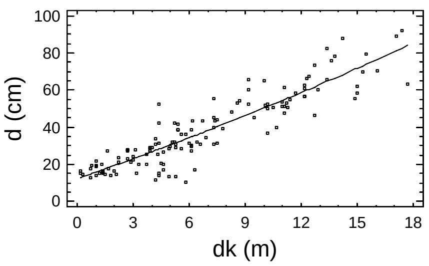
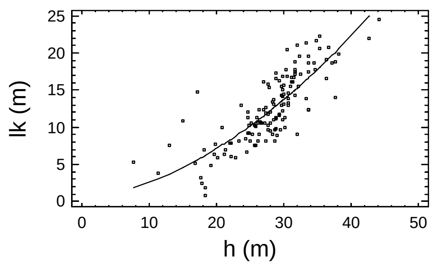


Diagram 9. *Relation of crown length and tree height*



Dependence of crown length on diameter at breast height is defined by regression equation (1) and Diagram 1.

With the increase in tree diameter up to 70 cm, crown length increases rapidly and after that it stagnates. This conclusion is in harmony with the results reported by Panić, Đ. (1966). Dubravac, T. (1998) found that crown length of common oak is in weak linear correlation, and common hornbeam in strong linear correlation with the diameter at breast height.

In the study beech stand, absolute crown length is on average about 12.6 m and relative length is about 46%. Relative crown length in a beech stand on Mt. Rudnik accounts for about 57%. A higher relative crown length indicates a more insufficient stand stocking and a poorer site class (Panić, Đ. 1966). For common oak trees, relative crown length is on average about 45% and for hornbeam trees about 59% (Dubravac, T. 1998). However, in coppice sessile oak forests, relative crown length is on average considerably lower and accounts for about 40% (Čokeša, V. 2007).

Dependence of crown width on diameter at breast height is defined by regression equation (2) and Diagram 2.

With the increase in tree diameter its crown width increases almost linearly and rapidly and in the entire range of tree diameters. This relation was confirmed by many authors (Milin, Ž. 1954, Drinić, P. 1956, Matić, V. 1959, Pavlič, J. 1966).

Crown width in the study beech stand is on average about 6.8 m, and the ratio of mean diameter and mean crown width is 1: 17.5. This ratio agrees with that reported by Brinar, M. (1952), who found that beech crown diameter was approximately twenty times larger than the diameter at breast height for trees above 30 cm. For beech on Mt. Rudnik, the ratio of diameter and crown width is from 1 : 21 to 1 : 29. The greater ratio also points to a more insufficient stand stocking (Panić, Đ. 1966). Milojković, D. (1958) emphasises the significance of the ratio of crown diameter and tree diameter and concludes that the main task of thinning is to establish the most favourable ratio between them.

Dependence of crown horizontal projection on diameter at breast height is defined by regression equation (3) and Diagram 3.

With the increase in tree diameter, the area of crown horizontal projection increases rapidly and progressively and in the entire range of tree diameters. This was also shown by other authors (Panić, Đ. 1966, Drinić, P. 1956, Matić, V. 1959, Hren, V. 1980, Dubravac, T. 1998). Also, the research in beech stands on Mt. Rudnik shows that the trees with larger crown projections regularly have also on average a greater volume increment (Panić, Đ. 1966). From the aspect of forest management, the most important taxation element of crowns in selection stands is the crown projection area (Matić, V. 1980).

Dependence of crown volume on diameter at breast height is defined by regression equation (4) and Diagram 4.

With the increase in tree diameter, the crown volume increases rapidly and progressively in the entire range of tree diameters. Dubravac, T. (2002) reports that the dependence of crown volume on diameter at breast height of common oak and hornbeam can be expressed by exponential function and that the relation is strong.

Dependence of crown surface area on diameter at breast height is defined by regression equation (5) and Diagram 5.

With the increase in tree diameter, the crown surface area increases rapidly and progressively in the entire range of tree diameters. This relation is similar by form to the relation of crown projection area and crown volume with tree diameter (Diagrams 3 and 4).

Čerman, M., Smrekar, A. (2007) report that the greatest effect on beech volume increment is exerted by total area and crown volume. This statement will be verified later on by the multiple regression method.

Dependence of height on diameter at breast height is defined by regression equation $h = a\ e^{-b/d} + 1.30$, which represents the Mihajlov's function for fitting the height curve. It is presented by equation (6) and Diagram 6.

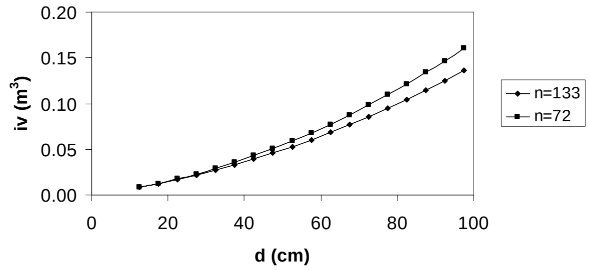
The slope degree of the height curve in the diameter interval from 10 to 50 cm is high, and then falls off. Based on the standard heights for beech in Serbia (Mirković, D. 1958), the study beech stand is classified in the second site class (II).

Dependence of volume increment on diameter at breast height is defined by regression equations (7) and (8), and Diagram 7.

Equation (7) is calculated based on 133 trees, and equation (8) is based on 72 trees, which were not marked.

In both cases, with the increase in tree diameter, volume increment progressively increases in the entire interval of tree diameters. On average, increment is higher in the sample of unmarked trees, and the difference increases with the increase in diameter. For this reason, standard error of regression of unmarked trees is significantly lower and the coefficient of determination is higher. In other words, the preciseness of increment estimation is higher and the relation is more completely explained. Of course, this must also be reflected on the results of multiple regression and correlation.

Diagram 7. *Relation of volume increment and tree diameter*



The increment of marked trees is smaller, compared to unmarked trees, because of their poorer stem and crown quality. This finding was concluded in the analysis of volume increment value and quality in high beech stands on Mt. Željin (Koprivica, M. *et al.* 2009).

Dependence of diameter at breast height on crown width. Equation (2) defines the dependence of crown width on diameter at breast height. However, the relation in opposite direction is often implemented for remote sensing purposes in forest inventory. Crown width is rather reliably measured on aerial or satellite imagery of high resolution, and it can be directly applied in the models for the assessment of tree or stand volume, or for the assessment of diameter at breast height (Koprivica, M., Jović, Đ. 2009).

This dependence is defined by regression equation (9) and Diagram 8.

With the increase in crown width, also the diameter at breast height increases almost linearly. Compared to equation (2), the coefficient of determination in equation (9) is much lower, but taking into account the strong linear relation, it should be almost the same. The difference is exclusively caused by the fact that equation (2) does not include the regression constant, like equation (9). This caused an artificial increase in the coefficient of determination. The same case also occurred in all previous equations which do not include the constant. However, standard error of regression is almost the same in both cases.

Dependence of crown length on tree height. To complete the survey of simple dependence, the dependence of crown length on tree height is also presented. This dependence is defined by regression equation (10) and Diagram 9.

With the increase in tree height, the crown length also increases progressively and rapidly. When this dependence is compared to the dependence of crown length on tree diameter (Diagram 1), it can be seen that the relation form is rather different, while the standard error of regression and the coefficients of determination are almost identical. This is the consequence of a strong correlation between tree height and diameter in the sample.

The average values of the most important crown elements were calculated based on regression equations (1-10), height and volume increment of all trees per diameter classes (Table 3).

In addition to the presented results on simple dependences between taxation elements of all trees in the sample, we also analysed separately the same dependences for unmarked trees, then for trees which belong to different crown classes, and for 20% of the trees with the greatest volume increment. However, these analyses generally did not contribute to the better explanation of the analysed relations.

Table 3. *Average values of crown and tree elements per diameter classes in the sample (n = 133)*

d (cm)	h (m)	lk (m)	dk (m)	bk (m^2)	vk (m^3)	pk (m^2)	iv (m^3)
12.5	16.70	5.41	2.06	4.54	7.74	33.20	0.00827
17.5	21.33	7.32	2.93	8.85	39.08	49.36	0.01233
22.5	24.47	9.07	3.81	14.58	86.56	67.17	0.01681
27.5	26.73	10.68	4.72	21.73	150.18	86.63	0.02173
32.5	28.41	12.14	5.65	30.30	229.93	107.74	0.02708
37.5	29.72	13.45	6.60	40.30	325.83	130.50	0.03286
42.5	30.76	14.61	7.57	51.72	437.86	154.90	0.03906
47.5	31.62	15.62	8.57	64.56	566.04	180.96	0.04570
52.5	32.32	16.49	9.59	78.82	710.35	208.66	0.05277
57.5	32.92	17.20	10.63	94.51	870.80	238.01	0.06026
62.5	33.43	17.77	11.69	111.62	1047.39	269.01	0.06819
67.5	33.87	18.19	12.77	130.15	1240.12	301.65	0.07654
72.5	34.25	18.46	13.88	150.10	1448.99	335.95	0.08533
77.5	34.59	18.58	15.00	171.48	1674.00	371.89	0.09454
82.5	34.89	18.55	16.15	194.28	1915.14	409.48	0.10418
87.5	35.16	18.37	17.32	218.50	2172.43	448.72	0.11426
92.5	35.40	18.04	18.52	244.14	2445.85	489.61	0.12476
97.5	35.62	17.57	19.73	271.20	2735.42	532.14	0.13569

3.3 Multiple dependence of tree volume increment on crown and stem elements

Multiple dependence of current volume increment was analysed in three variants:

a) separately on tree diameter and height, b) separately on crown elements, and c) mutually on diameter, height and crown elements. The analysis was made on the sample for all trees (n =133) and separately on the subsample of unmarked trees (n = 72). The objective of the analysis was to define as precisely as possible the dependence of tree volume increment on other factors. The method of stepwise multiple regression and correlation was applied.

<u>*Dependence of tree volume increment on diameter and height*</u> is defined by regression equations (11) and (12). Along with the equations, the indicators of data fitting quality are also given: standard error of regression (s_e) and coefficient of multiple determination (R^2), as well as the sample size (n).

$$iv = 0.00126688d - 0.0019944h + 0.0000526817h^2 \qquad (11)$$

$s_e = 0.02034\ m^3$, $R^2 = 83.91\ \%$, $n = 133$

$$iv = 0.000013707d^2 + 0.00000062754h^3 \qquad (12)$$

$s_e = 0.01591\ m^3$, $R^2 = 89.40\ \%$, $n = 72$

Regression equation (12) obtained for unmarked trees has better indicators of data fitting quality (lower error of regression and higher coefficient of multiple determination). The high values of coefficients of determination can partially be explained by omitting the constant in the initial models, which was also emphasised in the simple regression.

It is interesting to point out the value of relative errors of regression: $s_e\% = (0.02034/0.0358).\ 100 = 56.81\%$ and $s_e\% = (0.01591/0.0359).\ 100 = 44.32\%$. The calculated errors of regression are high, and a more precise assessment of volume increment of unmarked trees is explained by the lower variability of the value of their volume increment.

Dependence of volume increment on crown elements is defined by regression equations (13) and (14).

$$iv = 0.00377528dk + 0.0000215629vk \quad (13)$$
$s_e = 0.01965\ m^3$, $R^2 = 84.87\ \%$, $n = 133$

$$iv = 0.000117643lk^2 + 0.000109994vk - 0.0000008874pk^2 \quad (14)$$
$s_e = 0.01488\ m^3$, $R^2 = 90.86\ \%$, $n = 72$

In the initial models, crown elements are taken as independent variable: length (lk), width (šk), projection (bk), volume (vk) and surface area (pk). It is presumed that the effect of crown factors on volume increment can be expressed by the parabola of the second degree. The most influential factors are selected by stepwise regression. Regression equation (14) gives a more precise estimation of the volume increment than equation (13). However, equation (14) has three factors and their effect is significant and equations (13) has two factors.

Compared to equations (11) and (12), equations (13) and (14) give a somewhat more precise estimation of tree volume increment, i.e. the above dependence is better defined by using crown elements instead of tree diameter and height. However, taking into account the possibility of determining the values of independent variables, the equations which contain the tree diameter and height are given advantage in practice.

Dependence of tree volume increment on diameter, height and crown elements is defined by regression equations (15) and (16).

$$iv = 0.000159219pk + 0.0000064525d^2 \quad (15)$$
$s_e = 0.01976m^3$, $R^2 = 84.70\ \%$, $n = 133$

$$iv = 0.0000619446lk^2 + 0.00190979bk + 0.00000898612d^2 \quad (16)$$
$s_e = 0.01526m^3$, $R^2 = 90.39\ \%$, $n = 72$

In the initial models, as independent variables, tree diameter and height are taken together with crown elements. In this case also, it is presumed that the effect of all factors on volume increment can be expressed by the parabola of the second degree. The most influential factors are selected by stepwise regression. Regression equation (16) gives a more precise estimation of the volume increment than equation (15). However, equation (16) has three factors and their effect is significant and equations (15) has two factors. In these equations, the influential factor is tree diameter in combination with some crown elements.

The comparison of equations (15) and (16) with equations (13) and (14) shows that the preciseness of estimation of tree volume increment is similar. However, taking into account the possibility of determining the values of independent variables, the equations which contain only tree diameter and height (11) and (12) are given advantage in practice. This fact can be explained by a strong correlation which exists between volume increment and the analysed independent variables, as well as between themselves.

In addition to the presented results on multiple dependence of volume increment on other taxation elements of all trees in the sample and in the subsample of unmarked trees, the same dependences were analysed separately for trees with different crown classes and for 20% of trees with the highest volume increment. However, the above analyses did not contribute to better explanation of the analysed character.

4. CONCLUSION

The following conclusions are based on the analysis of the study results:

* There is a statistically significant correlation between beech crown elements and stem. The simple relations are most often in the form of parabola of the second degree. With the increase in diameter at breast height (10 – 100 cm) crown length increases digressively and crown width, area of crown projection, crown volume, crown surface area and volume increment - progressively. With the increase in tree height (5 – 45 m), crown length increases also progressively. In almost all cases, the parabola curvature is clearly expressed. Only the relation between crown width and diameter at breast height, i.e. diameter at breast height and crown width, is almost linear.

* There is a high correlation between beech volume increment and other taxation elements (diameter, height, crown length, crown width, area of crown projection, crown volume and crown surface area). The coefficient of multiple determination accounts for 85% – 90%. Standard error of regression is still high and amounts to 0.015 m^3 – 0.020 m^3. The high values of coefficient of determination are partially the consequence of omitting the constant in the regression models. The same models with the constant produced multiple coefficient of determination accounting for 70% – 75%, while the standard error of regression remained almost the same. The best results were obtained for unmarked trees. Theoretically, the best model is the one which includes crown length, crown volume and crown surface area as independent variables (14), and practically the best model includes the tree diameter and height (12).

* Taking into consideration the possibility of determination of independent variables in the calculated regression equations for their practical application all the results of simple regression can be applied directly for the assessment of crown elements, height, and volume increment dependent on tree diameter. Of course, the precision depends on the value of standard error of regression and on the accuracy of measured diameter. The estimation of current volume increment is performed by several models of approximately the same reliability, which include only tree diameter and height, or only some crown elements, or together the tree diameter and some crown elements. However, only the models which include tree diameter and height are practically applicable. The other models can be used for theoretical analyses of the dependence of tree increment on crown structure elements.

* The study results refer to a concrete beech stand and do not have a general validity. This would require large-scale, relatively expensive and complicated investigations. However, the form of the dependences concluded in this study would not be significantly differentiated.

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DEPENDENCE OF BEECH TREE VOLUME INCREMENT ON CROWN STRUCTURE

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Summary

The effect of crown structure on tree volume increment was researched in a beech stand in the area of Severni Kučaj, Eastern Serbia. The stand area is 22.7 hectares, altitude 410-520 m, slope gradient 7-28 degrees. The predominant aspect is north-west. Parent rock consists of dense limestones, the soil is calcocambisol, depth 40-80 cm. The stand is classified as submontane forest of beech (*Fagenion moesiacae submontanum* Jov. 1976). By silvicultural and structural form, it is a high group-selection uneven-aged beech stand of virgin forest characteristics. Site class is II, canopy 0.90, percentage of beech in volume 97%, stand quadratic mean diameter 39.4 cm, and Lorey's mean height 31.0 m. Number of trees per hectare is 274, basal area 33.4 m^2, volume 522.5 m^3 and volume increment 8.6 m^3.

Taxation elements of all trees above 10 cm were measured on circular sample plots sized 500 m². The sample included 133 trees, which were measured on 12 sample plots. All sample plots in the stand were measured as follows: diameter, total height, height of crown base and height of the maximal crown width of the trees. The area of horizontal crown projection was calculated based on eight radiuses. Volume and crown surface area were calculated using the method after Pretzsch, H. (2002) and Kotar, M. (2003). Volume increment of individual trees was estimated based on their diameter increment using the regression model. The relation between the elements of crown structure as dependent variables and tree diameter and height as independent variables was assessed by simple regression. The relation between tree volume increment as dependent variable and tree diameter, height and the elements of crown structure, as independent variables was determined by multiple regression analysis.

There is a statistically significant correlation between beech crown elements and stem. The simple relations are most often in the form of parabola of the second degree. With the increase in diameter at breast height crown length increases digressively and crown width, area of crown projection, crown volume, crown surface area and volume increment - progressively. There is a high correlation between beech volume increment and other taxation elements (diameter, height, crown length, crown width, area of crown projection, crown volume and crown surface area). The coefficient of multiple determination accounts for 85% – 90%. Standard error of regression is still high and amounts to 0.015 m^3 – 0.020 m^3.

ZAVISNOST ZAPREMINSKOG PRIRASTA STABLA BUKVE OD IZGRAĐENOSTI NJEGOVE KROŠNJE

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Rezime

U istočnoj Srbiji, na području Severnog Kučaja, u sastojini bukve izvršeno je istraživanje uticaja izgrađenosti krošnje stabla na njegov zapreminski prirast. Sastojina ima površinu 22,7 hektara i nalazi se na nadmorskoj visini 410-520 m, sa nagibom terena 7-28 stepeni. Najčešća ekspozicija terena je severozapadna. Geološku podlogu čine jedri krečnjaci, a zemljište je smeđe krečnjačko, dubine 40-80 cm. Sastojina pripada brdskoj šumi bukve (*Fagenion moesiacae submontanum* Jov. 1976.), a po uzgojnom i strukturnom obliku je visoka grupimično raznodobna sastojina bukve, prašumskih karakteristika. Bonitet staništa je II, sklop 0,90, udeo bukve u zapremini je 97%, srednji prečnik po temeljnici je 39,4 cm, a srednja visina po Loraju 31,0 m. Broj stabala po hektaru je 274, temeljnica 33,4 m^2, zapremina 522,5 m^3 i zapreminski prirast 8,6 m^3.

Na primernim površinama, oblika kruga i veličine 500 m^2, izvršen je premer taksacionih elemenata svih stabala iznad 10 cm. Veličina uzorka je iznosila 133 stabla, koja su premerena na 12 probnih površina. Na svim probnim površinama u sastojini izvršen je potpun premer prečnika, ukupne visine, visina početka krošnji i visina na kojoj se nalazi maksimalna širina krošnje stabala. Površina horozontalne projekcije krošnji računata je na bazi osam poluprečnika. Zapremine i površine omotača krošnje računate su po metodu Pretzsch,H. (2002) i Kotar, M. (2003). Zapreminski prirast pojedinačnih stabala određen je na bazi njihovog debljinskog prirasta primenom odgovarajućeg regresionog modela. Jednostavnom regresijom utvrđena je veza između elemenata izgrađenosti krošnje, kao zavisno promenljivih, i prečnika i visine stabla, kao nezavisno promenljivih. Višestrukom regresijom utvrđena je veza između zapreminskog prirasta stabla, kao zavisno promenljive, i prečnika, visine i elemenata izgrađenosti krošnje, kao nezavisno promenljivih.

Između taksacionih elemenata krošnje i debla stabala bukve postoji statistički značajna korelacija. Jednostavne veze su najčešće oblika parabole drugog reda. Sa povećanjem prsnog prečnika stabla dužina krošnje se povećava degresivno a širina krošnje, površina projekcije krošnje, zapremina krošnje, površina omotača krošnje i zapreminski prirast stabla progresivno. Između zapreminskog prirasta stabla bukve i ostalih taksacionih elemenata stabla (prečnik, visina, dužina krošnje, širina krošnje, površina projekcije krošnje, zapremina krošnje i površina omotača krošnje) postoji visok stepen korelacije. Koeficijent višestruke determinacije iznosi od 85% do 90%. Standardna greška regresije je ipak velika i iznosi od 0,015 m^3 do 0,020 m^3.

THE DEVELOPMENTAL-PRODUCTIVE CHARACTERISTICS OF THE DOUGLAS FIR CULTURES ESTABLISHED IN THE PROCESS OF AMELIORATION OF THE COPPICE AND DEGRADED FORESTS

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Abstract: *In the amelioration of the degraded coppice forests by the biological reconstruction typically the current broadleaf species were substituted by the mainly ecologically suitable conifer species which grow in this region, such as Austrian and Scots pine, spruce, common fir, and to a significantly lesser extent Bosnian pine or Macedonian pine in the high mountain regions, and from the foreign – allochthonous species, Coast Douglas fir, and Blue Douglas fir, Eastern white pine, and to a lesser extent Nordmann fir, white fir, common larch (European, Sudetic and other variances), bull pine ((Pinus ponderosa), cedar, and other species, the percentage of which is irrelevant. The Convention on Biological Diversity prohibits the introduction of the allochtonous species in the natural ecosystems, and the use of them (if they are not on the list of the invasive species) is permitted in the intensive plantations with the targeted timber production, as well as in the public urban green areas. As Douglas fir is the species which is characterized by the high productivity, the use of it in the intensive plantations is undoubted. However, there are no comparative reseaches on the productive characteristics of the Douglas fir cultures established on the different sites. Based on the comparison of the current and average volume increment, it can be concluded that the cultures reached the stage of the high productivity (in spite of the fact that the average increment have not culminated yet). Since the period of the high productive lasts for a relatively long time, in the case of the long rotations Douglas fir is able to use the productive capacity of the site, if the apppropriate care measures are applied. The results of the reseaches will enable the anticipation of the production in the intensive plantations in the dependence on the site conditions.*

Key words: Douglas fir, productivity, intensive plantations, biological diversity

RAZVOJNO-PROIZVODNE KARAKTERISTIKE KULTURA DUGLAZIJE PODIGNUTIH U POSTUPKU MELIORACIJE IZDANAČKIH I DEGRADIRANIH ŠUMA

Izvod: *U melioraciji degradiranih izdanačkih šuma biološkom rekonstrukcijom po pravilu je primenjivana supstitucija postojećih lišćarskih vrsta sa pretežno ekološki odgovarajućim četinarskim vrstama našeg podneblja kao što su crni i beli bor, smrča, domaća jela i u znatno manjoj meri munika ili molika u visoko planinskim regijama, a od stranih – alohtonih vrsta zelena i plava duglazija, Vajmutov bor, a u manjoj meri kavkaska i koloradska jela, ariš (evropski, sudetski i drugi varijeteti), žuti bor (Pinus ponderosa), kedar i druge vrste u zanemarujućem procentu. Po Konvenciji o zaštiti biodiverziteta zabranjeno je unošenje alohtonih vrsta u prirodne ekosisteme, a njihovo korišćenje (ukoliko nisu na spisku invanzivnih vrsta) dopušteno je u intenzivnim zasadima sa namenskom proizvodnjom drveta i u javnom zelenilu. Duglazija je vrsta koja se karakteriše velikom proizvodnošu, pa je njena primena u intenzivnim zasadima nesporna. Međutim, u Srbiji nema komparativnih istraživanja o proizvodnim karaktersitikama kultura duglazije podignutih na različitim staništima. Na osnovu poređenja tekućeg i prosečnog prirasta zapremine zaključuje se da se kulture nalaze u fazi visoke proizvodnosti (iako prosečni prirast još nije kulminirao). Period visoke proizvodnosti traje relativno dugo, tako da kod dugih ophodnji duglazija može, uz odgovarajuće mere nege, da iskoristi proizvodne mogućnosti staništa. Rezultati rada omogući prognoziranje proizvodnje u intenzivnim zasadima u zavisnosti od stanišnih uslova.*

Ključne reči: duglazija, proizvodnost, intenzivni zasadi, biodiverzitet

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1. INTRODUCTION

In the amelioration of the degraded coppice forests by the biological reconstruction typically the current broadleaf species were substituted by the mainly ecologically suitable conifer species which grow in this region, such as Austrian and Scots pine, spruce, common fir, and to a significantly lesser extent Bosnian pine or Macedonian pine in the high mountain regions, and from the foreign – allochthonous species, Coast Douglas fir, and Blue Douglas fir, Eastern white pine, and to a lesser extent Nordmann fir, white fir, common larch (European, Sudetic and other variances), bull pine *(*(Pinus ponderosa), cedar, and other species, the percentage of which is irrelevant. The Convention on Biological Diversity prohibits the introduction of the allochtonous species in the natural ecosystems, and the use of them (if they are not on the list of the invasive species) is permitted in the intensive plantations with the targeted timber production, as well as in the public urban green areas. As Douglas fir is the species which is characterized by the high productivity, the use of it in the intensive plantations is undoubted. However, there are no comparative reseaches on the productive characteristics of the Douglas fir cultures established on the different sites. This paper is aimed at the anticipation of the production in the intensive plantations depending on the site conditions.

2. RESEARCH OBJECT AND METHOD

On several sites in Serbia the Douglas fir plantantions, from 15 to 30 year-old, and with site indexes 26 and 30, were researched. Fifteen sample plots, located in Vidojevica, Cer, Iverak and Vidlic were set. The productivity of the Douglas fir plantations were researched by the use of the different methods of the reconstruction of the coppice and degraded forests (by the corridor method, the method of planting under the canopy cover of the parent stand by the clear felling performed in the great areas) on 15 sample plots.

The basic data on the condition of these plantations per the determined ecological units are presented in the Table 1.

Based on the phytocoenological and pedological researches of sites, on which they were established, the observed Doglas fir plantations can be determined in the following way:

Ecological unit 1 – Douglas fir plantation established on the site of Hungarian and Turkey oak with butcher's broom (Quercetum farneto-cerris Rud- aculeatetosum Jov.) on deep ilimerised extremely acid brown soil on sand sediment;

Ecological unit 2 – Douglas fir plantation established on the site of sessile oak and hornbeam with butcher’s broom (Quercetum Carpinetum Rud. aculeatetosum Jov.) on the deep ilimerised extremely acid brown soil on sand sediment;

Ecological unit 3 – Douglas fir plantation established on the site of sub-montane beech forests on acid soil on phyllite;

Ecological unit 4 – Douglas fir plantation established on montane beech site (Fagetum montanum Jov. typicum) on significantly acid brown soil on granite;

Ecological unit 5 – Douglas fir plantation established on site of Hungarian oak and Turkey oak (Quercetum farnetto - cerris carpinetosum betuli) on the deep brown acid soil on the ilimerised soil to a small extent;

Ecological unit 6 – Douglas fir plantantion established on montane beech (Fagetum moesiacae montanum silicicolum) on acid brown soil;

Ecological unit 7 – Douglas fir plantation established on montane beech site (Fagetum moesicae montanum caricetosum pilosae) on pseudogley on lime flysch.

3. RESULTS

The observed plantations are from 15 to 30 years old, which to a certain extent makes the comparison of the results more difficult. Therefore, the comparison of the results obtained in the plantations of the same age class and technique of establishment was first made, and then the comparisons of the plantations of the different age, by using the methods which generalize the data and enable the comparison of the data of this kind.

Table 1/1. *The basic characteristics of Douglas fir plantations*

Ecological unit	Plot	Age	Diameter (cm)		Height (m)		SI
			D	d	H	h	
1	III	30	26.0	19.6	21.7	20.5	30
	IV	30	26.0	20.1	21.7	20.7	30
	VI	30	26.0	19.0	21.6	20.2	30
2	IX	30	30.0	22.4	22.2	20.0	30
3	I	30	18.0	13.1	18.5	16.0	30
	II	30	21.0	14.9	19.8	17.0	30
	III	30	21.0	14.8	19.8	17.0	30
4	I	22	20.0	14.3	17.0	14.2	30
	II	22	21.0	15.4	17.4	14.6	30
5	II_2	28	23.0	18.0	18.0	16.6	26
	II_4	28	26.0	20.5	18.4	17.2	26
6	4b	15	20.0	15.9	12.3	11.0	30
7	IV_1	27	28.0	21.4	17.5	17.0	26
	IV_2	27	26.0	19.1	17.3	16.5	26
8	I	26	22.0	17.7	17.2	16.8	30

Table 1/2. *The basic characteristics of Douglas fir plantations*

Ecological unit	Plot	Number of trees		Basal area		Volume		Volume increment		% increment
		N_s	N_m	G_s	G_m	V_s	V_m	iv_s	iv_m	
1	III	912	1706	27.4	52.7	252	485	10.2	19.6	4.0
	IV	1022	1634	32.4	53.3	298	490	12.3	20.2	4.1
	VI	1094	1799	31.1	52.1	285	477	10.8	18.1	3.8
2	IX	615	1359	24.3	53.2	218	477	11.7	25.6	5.4
3	I	1147	3386	15.5	46.1	124	369	5.0	14.9	4.0
	II	1000	2720	17.4	47.4	145	395	6.8	18.5	4.7
	III	1157	2751	19.8	47.7	164	395	6.7	16.1	4.1
4	I	1826	2917	29.3	46.9	205	328	11.0	17.6	5.4
	II	525	2571	9.8	47.5	70	339	4.5	21.8	6.4
5	II_2	963	1923	24.4	50.2	185	381	6.6	13.6	3.6
	II_4	614	1543	20.2	51.2	157	398	6.9	17.5	4.4
6	4b	1354	2328	27.0	47.1	140	244	11.5	20.0	8.2
7	IV_1	720	1435	25.9	52.3	195	394	11.1	22.4	5.7
	IV_2	1074	1739	30.8	51.1	229	380	10.8	17.9	4.7
8	I	1255	2029	31.0	50.9	240	394	8.3	13.6	3.5

The majority of the observed plantations were thinned during their development (some for several times). In regard to the site indexes (Ratknic, 1996) these plantations are very similar (the ecological units 5 and 7 belong to index 26, whereas all other belong to site index 30). In the observed plantations the number of trees was determined by the method of amelioration and thinning and it ranged from 525 to 1,826 per a hectare, which points to the fact that during the treatment there were no clear criteria for the intensity and time of the thinning of Douglas fir.

By using the knowledge on the development of Douglas fir on the natural sites (in America), regression model of the dependence of the number of trees on the diameter at the breast height was constructed (for the indexes which are favourable for these circumstances). The parameters of the model of the form $y = a .b^x$ are presented in the Table 2.

The possible number of trees in the same age class ranges from 1,359 to 3,386, and it is much greater than the observed number.

In the plantation which is 30-year old, the greatest number of trees was observed in the ecological unit 3 (established by the corridor method in the form of stripes of different width). In the stripes of the same width in the ecological unit 2 the possible number of trees is by 53.9% smaller than the number of the trees in the ecological unit 3.

The mean stand diameter of Douglas fir plantations which are about 30 years old ranges from 14.3 to 20.5 cm. The mean diameters of the dominant trees are in average by 34.3% greater than the mean stand diameters.

Table 2. *Parameters of model*

Site index	Parameter	Value	Standard error	t- test
24.4	1n a	12.487592	0.056133	222.54
	b	- 1.691090	0.015809	- 106.97
30.5	1n a	12.541938	0.086176	145.54
	b	- 1.701075	0.022553	- 75.42

The mean stand diameters of Douglas fir plantantions in Italy (Bernetti) established in the similar site conditions are by about 20.6% greater than the diameters observed in the Douglas fir plantantions in Serbia. Only the ecological unit 2 is similar to the mean diameters of the stand diameters of Douglas fir plantantions in Italy.

Douglas fir plantations in Serbia were established on the best sites (site index 30) based on Bernetti tables belong to site class IV (out of V). Such great differences are the result of the use of the seedlings produced from the seeds of the unsuitable provenance, applied method of amelioration and influence of the productive site characteristics.

The sum of basal areas when the plantations are 15 years old is 27.0cm^2 , when the plantantions are 22 years old, it ranges from 9.8 to 29.3m^2, when the plantations are 26 years old it is 31,0 m^2, when the plantantions are 27 years old it is 25.8 m^2, when the plantantions are 28 years old it ranges from 20.2 to 24.4 m^2, and when the plantations are 30 years old it ranges from 15.5 to 32.4 m^2 per a hectare.

It was observed that the possible basal area (based on the determined possible number of trees) per a hectare is considerably greater than the actual.

Based on the Berrneti tables, the basal area of the main stand aged 20 year is 29.86, the basal area of the main stand aged 25 is 34.35, and the basal area of the main stand aged 30 it is 38,10 m ^{2} per a hectare. In the natural stands in America, when the site index is 30.5, the sum of basal area aged 30 is 49.79 m^2 per a hectare, which is similar to the possible basal area in these experiments.

The volume of trees per ecological units in the plantantions aged 15 is 140 m^3, when the plantations are 22 years old, it ranges from 70 do 205 m^3, when the plantations are 28 years old it ranges from 157 to 185 m^3, and when the plantations are 30 years old it ranges from 124 to 298 m^3 per a hectare.

Table 3. *The model of possible number of trees depending on the mean diameter at basal area*

d_g	Site index		
	18	**26**	**30**
15	2583	2617	2689
20	1540	1609	1649
25	1060	1103	1128
30	752	811	827
35	571	625	636

d_g	Site index		
	18	**26**	**30**
40	450	498	507
45	365	408	415
50	302	342	347

The possible volume was determined based on the observed relations between volume (V), the number of trees (N), mean diameter (d_g), mean height (h_g) and age (S):

$$V = f\ (S, N, d_g, h_g)$$

The multiplicative model of the following form was used:

$$V = S^{a1} . N^{a2} . d_g^{a3} \cdot h_g^{a4} . a_b$$

The following regression equation was obtained:

$$\ln V = 0.004898 \ln S + 0.980968 \ln N + 1.72657 \ln d_g + 1.008665 \ln h_g - \ln 9.345005$$

$R^2 = 0.9988$ $S_t = 2.1\ m^3/ha$

The possible volume is greater than the actual. The volume of the trees of the same age class in the ecological units 1 and 2 is about 100 m^3 greater than the possible volume of the trees in the ecological unit 3. When the width of the stripes is the same, the volume of the ecological unit 2 is about 17.2% greater than the volume of the ecological unit 3.

Based on Bernetti tables, the volume of the main stand aged 20, is 162 m^3, the volume of the main stand aged 25 it is 239 m^3, the volume of the main stand aged 30 it is 315 m^3 per a hectare. In the natural stands in America when the site index is 30.5 the volume of the plantation aged 30 is 427.54 m^3, which is in accord with the possible volume obtained in these experiments.

For the comparison of the productive differences between the ecological units with the different number of trees the volume of mean tree was used. This value was first used for the determination of the productive differences in the Danube and Sava riparian zones (Ratknic, 1988) and it differs from the volume of the mean stand tree, which was used by Sammi (1965). The volume of mean stand tree implies the theoretical bell-shaped distribution, which does not refer to the plantations, particularly the ones which were thinned, whereas the volume of mean tree reflects the stand structure, which depends on the soil conditions.

The volume of mean tree ranges from 0.0886 m^3 (36.5%) to 0.2427 m^3 (100%) and to a great extent reflects the applied method of amelioration and differences in the site characteristics.

By testing the differences between the volumes of mean tree, the following conclusions were made:

- There is a statistically less significant difference between the volume of mean tree when the stripes are 12 meters wide (5 rows) in comparison with the stripes of different width;
- The statistically significant differences between the volume of mean trees between the stripes which are 14 m wide, and the stripes which are 19 m in the same site conditions were not proved;
- When the stripes are of the same width, the volume of mean Douglas fir tree in the ecological unit 2 is greater than in the ecological unit 3.

The following age increment of the volume of mean tree was reported:

1	Ecological unit 6	(100%)
2	Ecological unit 1	(99%)
3	Ecological unit 2	(79%)
4	Ecological unit 5	(78%)
5	Ecological unit 7	(72%)
6	Ecological unit 4	(64%)
7	Ecological unit 3	(47%)

Based on the researches, Douglas fir plantations can be divided into three productivity classes: first, ecological unit 6 and 1, second, ecological units 2, 5 and 7, and third, ecological units 4 and 3.

Within the same site indexes the plots of the different productivity can be found, which depends on the number of trees per a hectare and type of the thinning.

The mean diameter increment ranges from 2.10 to 5.90 mm, in average 3.60 mm. The diameter increment of Douglas fir is almost twice greater than the Austrian pine diameter increment. In Austrian pine plantantions, Vuckovic (1979) reported that the diameter increment ranged from 1.86 to 2.35 mm, whereas Tomanic reported that the diameter increment ranged from 1.80 mm (IV site class) to 3.90 mm (III site class), and the diameter increment reported by Trifunovic et al ranges from 1.49 to 3.21 mm (the plantations are from 41 to 50 years old).

The diameter increment increases after the thinning in all diameter degrees (which is particularly expressed in the ecological units 13 and 14), which leads to the conclusion that the timely thinning is necessary.

The possible volume increment of Douglas fir plantantions ranges from 6 to 25.6 m^3 per a hectare. The percentage of the volume increment of the actual volume ranges from 3.5 to 5.6 (the ecological unit 6 is not taken into account).

4. CONCLUSION

Based on the comparison of current and mean volume increment, it can be concluded that these plantations are in the phase of the high productivity (in spite of the fact that the mean increment has not reached the maximum value yet). Since the period of the high productivity lasts for a relatively long time, during the long rotations Douglas fir is able to use the productive capacity of site, if the suitable tending measures are applied.

LITERATURE

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ESTIMATED EMISSIONS OF GREENHOUSE GASSES DURING FOREST ROAD CONSTRUCTION

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Abstract: *Forest roads present the infrastructural basis for most forestry operations. That is the main reason why the importance of forest road construction and research in that domain is significant. Civil engineering mechanization used in our conditions is powered with technologically aged motors. This influences the greater emission of greenhouse gasses into the atmosphere other than proposed by present day standards. Until now, research in the domain of greenhouse gas emissions during forest road construction is insufficient. This paper presents an estimation of the emission of different groups of gasses, N_2O, CO_2, CH_4, which are the main factors causing the greenhouse effect, in comparison to the volume of excavated earth during construction of a forest road and compared to references from literature. The road was built in the forest complex "Mala Albina" near Kucevo, a town in Eastern Serbia. The road length was 856m and the total excavation of earth was 8911m^3. The volume of excavated earth compared to the road length indicates specific conditions of construction. A CAT D6 caterpillar was used for excavating the earth in extreme conditions.*

Key words: *forest roads construction, CAT D6, greenhouse gasses*

1. INTRODUCTION

Forest roads are infrastructural facilities, designed and built to support forest management, whose spatial and constructive solution depends on the shape of the terrain, purpose of the forest, natural environment and composition of the forest ecosystems, planned actions in the forest, but also the socio-economic and protective functions of forests. A dense enough and properly distributed network of roads in the woodlands is a prerequisite for forest management on the principles of sustainable development. A forest roads network with adequate technical and constructive characteristics enables effective work in forestry through the application of modern machinery, timely silviculture and protection of forests, but also complex utilization of wood mass and other forest products. Good connection between a forest complex and central storage or processing facilities, creates the opportunity for a faster and more efficient offer of forest products on the market (*Стефанович Б.Ж., 2006*). In addition, the existence of a forest road network in mountainous terrain is the infrastructural base, which connects villages, local communities and individual households with urban centers, so that they are a essential living factor for people in these areas (*Stefanović B., 1999*). Funds invested in the construction of forest road networks are a long-term interest for the promotion of all sectors of society and forestry.

Civil engineering mechanization used for forest road construction in Serbia is powered with technologically aged engines whose lifetime has expired (*Ranković N., Vučković M., Stefanović B., 2002*). In addition, Serbian production standards for diesel fuel differ from European ones, which results in poor fuel quality. Technologically aged engines, poor fuel quality, use of D2 diesel fuel which the rest of the World is fazing out of use and is no longer in use in Europe, are a good base for the assumption that emissions of greenhouse gasses into the atmosphere, here in Serbia are greater than in the EU. Until now, research in the domain of

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emission of greenhouse gas emissions during forest road construction in Serbian conditions has not been done.

The aim of this paper is an estimation of the emission of different groups of gasses, NO_x, CO_x, C_xH_x, which are the main causing factors of the greenhouse effect, presented in the relation to the quantity of excavated soil during road construction.

2. MATERIAL AND METHOD

Research and calculation of the amount of emitted groups of gasses causing the greenhouse effects in the atmosphere, have been done in specific conditions of the construction of a forest road called "Mala Albina 2". This forest road has a gravel road surface and is intended for lorries and trailers with a large capacity. The road is located in a forest complex called "Mala Albina" and is part of the "Brodarica" management unit managed under the forest enterprise "Severni Kučaj" from Kučevo. The main purpose of this road is to enable rehabilitation of the forest ecosystem disrupted by a fire in 2006, on the area of 119.90 ha, with an allotted beech wood volume of 8407.09 m^3. According to the position, i.e. layout, this is a typical valley route. The height above sea level of the route beginning is 310 m a.s.l. and of the route end is 374 m.a.s.l. It was designed as an extension of the existing road "Velika Albina", which starts from the mouth of the stream *Mala Albina* into the stream *Velika Albina*, all along the stream *Mala Albina*. The road route is located on the east exposure of the right bank of the *Mala Albina* stream with an expressive terrain configuration and a very steep slopes, up to 70%. The geological base of the road consists of Amphibolites shale, with a slightly disrupted structure. The soil is cambisol and has a light-brown or acid brown color, and it is medium deep with a thickness between 40 and 80 cm. The total length of the road route is 856.54 m.

Figure 1. *The environment during the construction of the forest road "Mala Albina 2"*

Excavation of the road route was done between mid January and mid April of 2008. Excavation was conducted by a *Caterpillar CAT D6* bulldozer in very difficult conditions. During excavation 8911 m^3 of soil was removed: 6609 m^3 was third and fourth class and 2302

m^3 was fifth class soil. The *Caterpillar CAT D6* bulldozer is the property of the company "Grujić" from Kučevo, which was hired for the road construction. The bulldozer has a four stroke naturally aspirated diesel engine with six in - line cylinders and displacement volume of 10600 cm^3 that gives a nominal power of 123 kW. It was produced in 1970 and the engine general overhaul was done in 2007. Excavation of the route of the forest road "Mala Albina 2" required 168 effective working hours of the bulldozer and 2380 liters of D2 diesel fuel.

Figure 2. *Caterpillar CAT D6 bulldozer, property of the "Grujić" company from Kučevo in action*

Estimated quantities of certain groups of emitted gasses, NO_x, CO_x, C_xH_x, which are the main causing factors of the greenhouse effects, were calculated based on the volumetric mass of D2 diesel fuel, e.g. based on calculation of certain groups of emitted gasses related to the product of nominal engine power and effective working hours.

For calculation of the total quantity of emitted gasses (*AQG*), the average quantity of emitted gasses related to the road length (*MQGl*) and the average quantity of emitted gasses related to the excavated soil (*MQGv*) the following formulas have been used:

$$AQG = SQG \times NBP \times T \quad (1),$$

$$MQGl = \frac{AQG}{L} \quad (2),$$

$$MQGv = \frac{AQG}{V} \quad (3),$$

where: *AQG* – The total quantity of emitted gasses [kg],
SQG – The specific quantity of exhaust gasses [$kg \cdot kWh^{-1}$],
NBP – The nominal engine power [kW], *NBP* = 123 kW,

T – The number of engine effective working hours [h], T = 168 h,
$MQGl$ – The average quantity of gas per a meter of the road [$kg \cdot m^{-1}$],
L – The total length of the road [m], L = 856.54 m,
$MQGv$ – The average quantity of gas per a cubic meter of the excavated soil [$kg \cdot m^{-3}$] and
V – The total volume of excavated soil [m^3] V = 8911 m^3.

The specific quantities of exhaust gasses (*SQG*) are used from Table 1:

Table 1. *Gas fraction of emission gasses*

Engine generation	Engine type	NO_x	C_xH_x	CO
		$g \cdot kWh^{-1}$	$g \cdot kWh^{-1}$	$g \cdot kWh^{-1}$
1970'	Naturally aspirated	6.7-12.7	2.1-4.5	3.5-5.5

Source: *CAT, 2006*

Table 2. *Fraction of emitted solid particles*

Engine generation	Engine type	TPM*	SOF*	C	S
		$g \cdot kWh^{-1}$	$g \cdot kWh^{-1}$	$g \cdot kWh^{-1}$	$g \cdot kWh^{-1}$
1970'	Naturally aspirated	2.1-3.0	0.22-0.31	1.8-2.6	20-120

Source: *CAT, 2006*

TPM* – the specific quantity of solid particles in the emission and
SOF* – the specific quantity of soluble organic fraction in the emission.

The values from Table 1, for gas fraction of the emission, have been used for estimation of the quantity of emitted gasses which are the subject of this analysis, and the values from Table 2 have been used for estimation of the quantity of solid particles of carbon in exhaust gasses.

The quantity of emitted carbon dioxide is calculated based on the percentage of carbon in D2 diesel fuel and the quantity of CO_2 during the process of carbon oxidation. The volumetric mass of D2 in accordance with Serbian standards (****, 2009*) is maximally 850 $kg \cdot m^{-3}$. For this fuel quality emission of carbon dioxide is 3.23 kg CO_2/kg for D2 fuel, which is slightly more than the value defined by IPCC methodology, which issues 3.21 kg CO_2/kg for D2 fuel (*IPCC, 1996*). The emission of carbon dioxide is calculated based on the percentage of carbon mass in one kilogram of D2 diesel fuel, which is 88 % m/m and the fact that during oxidation of 1 g of carbon unites with 2.67 g of oxygen and gives 3.67 g of carbon dioxide in accordance to following formula:

$$E\,CO_2 = 3.67\,\frac{kg\mathrm{CO_2}}{kg\mathrm{C}} \times 0.88\,\frac{kg\mathrm{C}}{kg\mathrm{D2}} = 3.23\,\frac{kg\mathrm{CO_2}}{kg\mathrm{D2}},$$

or expressed per one liter of D2 diesel fuel

$$E\,CO_2 = 3.23\,\frac{kg\mathrm{CO_2}}{kg\mathrm{D2}} \cdot 850\,\frac{kg\mathrm{D2}}{m^3\mathrm{D2}} = 2788\,\frac{kg\mathrm{CO_2}}{m^3\mathrm{D2}} \cdot 1000^{-1}\,\frac{m^3\mathrm{D2}}{l\mathrm{D2}} = 2.8\,\frac{kg\mathrm{CO_2}}{l\mathrm{D2}}$$

3. RESULTS AND DISCUSION

Excavation during forest road construction was done in a very harsh climate, geological, pedologic and orographic conditions. Namely, excavating in winter conditions with saturation of moisture in excavated soil, very expressed steep terrain profiles with big road cuts with a height up to 10 meters, shale structure of the geological base, which results in unstable sides of road cuts and frequent occurrences of rockslides during road construction, illustrate in how specific and difficult conditions road construction was done. All this has affected that the quantity of excavated soil was much larger than the usual amount for forest roads. As mentioned before, the quantity of excavated soil was 8911 m^3 of soil, which includes 6609 m^3 of the third and the fourth classes and 2302 m^3 of fifth class soil. The quantity of excavated soil per meter of road length was 11.45 $m^3 \cdot m^{-1}$, which is a very large value, three times more than is usual for forest road construction, which is 4 $m^3 \cdot m^{-1}$. In addition, excavating was done uphill causing a greater load for the engine, and greater emission of greenhouse gasses than usual.

As the *CAT D6* bulldozer is powered by a technologically obsolete engine, its main weakness is inadequate fuel and air mixture formation in the combustion chamber because of the technologically obsolete injection system. The engine construction significantly influences the increase of fuel consumption and emissions of greenhouse gasses. The main groups of gasses, which are the product of diesel fuel oxidation in the combustion chamber, are carbon monoxide, carbon dioxide, unburnt hydrocarbons, and different nitro oxides.

The existence of carbon monoxide in exhaust gasses is a consequence of combustion in conditions of insufficient quantities of oxygen, in other words air. The nature of oxygen insufficiency could be local or global. As diesel engine combustion process mostly happens with surplus of air, carbon monoxide appears as the outcome of a local lack of oxygen, caused by inadequate fuel and air mixture formation, the main weakness of technologically obsolete engines.

The existence of unburnt hydrocarbons in exhaust gasses is a result of unfinished combustion or combustion in conditions of insufficient quantities of oxygen. The existence of this group of gasses is more obvious when the engine works in a low power working regime, as a result of imperfect conditions for mixture forming in the part of the combustion chamber close to the cold cylinder wall, and when the engine works in high power working conditions, as a result of a local lack of oxygen.

The last group of gasses consists of different types of nitro oxides produced in the reaction of nitrogen and oxygen at high temperatures. The intensity of this emission greatly depends on the concept and construction parameters of the diesel engine.

The following results for the estimated emission of harmful gasses were obtained using the results of a study *Caterpillar* has conducted for their engines (*CAT, 2006*) and consumed energy for excavation:

Table 3. *Estimated emission of greenhouse gasses during excavation of the forest road*

	Measuring unit	NO_x	C_xH_x	CO
Total emission quantity	*kg*	138.45-262.43	43.39-92.99	72.32-113.65
Emission per liter of consumed fuel	$g \cdot l_{D2}^{-1}$	58.2-110.3	18.2-39.1	30.4-47.8
Emission per meter of road route	$g \cdot m^{-1}$	161.6-306.4	50.7-108.6	84.4-132.7
Emission per cubic meter of excavated soil	$g \cdot m^{-3}$	15.5-29.5	4.9-10.4	8.1-12.8

Source: Original

Calculated values of emitted quantity of CO_2, during the excavation of soil during construction of the forest road “Mala Albina 2” are presented in Table 4:

Table 4. *Calculated values of CO_2 emission*

Total fuel quantity	*l*	2380
Maximal quantity of CO_2 emission	*kg*	6664
Road route length	*m*	856.54
Total quantity of excavated soil	m^3	8911
Average fuel consumption per cubic meter of excavated soil	$l \cdot m^{-3}$	0.267
Average fuel consumption per meter of road route	$l \cdot m^{-1}$	2.779
Average CO_2 emission per cubic meter of excavated soil	$g \cdot m^{-3}$	747.83
Average CO_2 emission per meter of road route	$g \cdot m^{-1}$	7780.10

Source: Original

4. CONCLUSION

Based on the calculation and estimated quantities of different groups of exhaust gasses, which are the main causing factors of the greenhouse effect, for concrete conditions of forest road construction the following conclusions can be made:

1. The extreme and specific conditions during excavation of the road "Mala Albina 2", which are reflected in very harsh geological, pedologic and orographic conditions, influenced the excavation of a larger than usual quantity of soil for forest road construction. Namely, the quantity of excavated soil was 8911 m^3 or 11.45 $m^3 \cdot m^{-1}$ of excavated soil per meter of road length, which is three times more than is usual for forest road construction, which is about 4 $m^3 \cdot m^{-1}$. In addition, excavation was done uphill in very harsh climate conditions. All these conditions caused a greater load on the engine, and greater emissions of greenhouse gasses than usual.
2. The *CAT D6* bulldozer, used for excavation, is powered by a technologically obsolete engine and its main weakness is inadequate fuel and air mixture formation in the combustion chamber because of the technologically obsolete injection system. This engine construction significantly influences the increase of fuel consumption and emissions of greenhouse gasses. The main groups of gasses, which are the product of diesel fuel oxidation in the combustion chamber, are carbon monoxide, carbon dioxide, unburnt hydrocarbons, and different nitro oxides, together with the fact that the existence of unburnt hydrocarbons, nitro oxides and carbon monoxide in exhausts gasses solely depend on engine conditions and technology.
3. The estimated values of emitted exhaust gasses, which are the main causing factors of the greenhouse effects, during construction of the forest road "Mala Albina 2", per meter of the road route length are in the following range: NO_x 161.6-306.4 $g \cdot m^{-1}$, C_xH_x 50.7-108.6 $g \cdot m^{-1}$ and CO 84.4-132.7 $g \cdot m^{-1}$, while the estimated values per cubic meter of excavated soil are in the following range: NO_x 15.5-29.5 $g \cdot m^{-3}$, C_xH_x 4.9-10.4 $g \cdot m^{-3}$ i CO 8.1-12.8 $g \cdot m^{-3}$.
4. The calculated emission of CO_2 during construction of the forest road "Mala Albina 2" per meter of the road route length is 7780.10 $g \cdot m^{-1}$, while emissions per cubic meter of excavated soil is 747.83 $g \cdot m^{-3}$. As the emitted quantity of CO_2 directly depends on the fuel composition - carbon content, it could be expected that in the future, using diesel fuel with lower carbon content, that emissions in Serbia will be lower.

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CHAMOIS (*RUPICAPRA RUPICAPRA BALCANICA*) MANAGEMENT IN THE NATIONAL PARK "TARA"

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Abstract: *Balkan chamois (Rupicapra rupicapra balcanica) is an insufficiently researched species/subspecies of wild ungulates in Serbia, despite the fact that it is autochthonous and rare in our region. There is an absence of more complete data on its population density and other demographic parameters, range, feeding, and also on the achieved results in the previous management. There are many factors (e.g. diseases, avalanches, predators, illegal hunting, isolation, and low density of some populations) which endanger chamois in its natural habitats all over Europe. The status of the species/subspecies at the national level (territory of Serbia) is defined as VU (vulnerable), according to a partly modified IUCN classification. It is additionally protected by the Hunting Law (1993), i.e. by the prohibition of hunting over the definite periods - males (February 1st – July 31st), females and kids (Februar1st – August 31st). At present, it exists only in a few hunting grounds. One of the best known is the hunting ground "Tara" within the National Park of the same name, where the spring density in 2009 was estimated to 354 individuals. In the past five years, the realised hunting was much lower than the planned one, and ranged from 4 to 25 individuals. This paper, for the first time in Serbia, analyses some morphological characters of chamois horns (length, height and span) on the sample of 56 individuals, hunted in the NP "Tara" over the period 2006-2009. The present population density in this hunting ground is explained, first of all, by the suitability of the general habitat conditions and by the prevention of illegal hunting, and also by the adequate management.*

The comparative analysis of habitat conditions and all planned and realised measures in the management of chamois population in the National Park "Tara" enables the identification of the main factors of chamois hazards and protection measures throughout Serbia. By all means, it is only by the analysis of a greater number of factors significant for the survival and development of populations of this susceptible species, that we can start the activities aiming at the increase of chamois density and distribution in Serbia, including also the reintroduction to the localities from which it disappeared (e.g. Kopaonik, Stolovi).

Key words: chamois, *Rupicapra rupicapra*, management, Tara, Serbia

1. INTRODUCTION

Balkan chamois (*Rupicapra rupicapra balcanica*) is one of the four autochthonous species of wild ungulates in Serbia. It is represented in only a few fragmented sites, because of which the density of its populations is the lowest. All chamois populations in Serbia are under some regime of hunting management, the strictest being in the Lazareva Reka canyon (eastern Serbia) and in the National Parks "Tara" and "Đerdap", while the scope of hunting on the mountains Prokletije, Koritnik and Šara is not known (Group of authors, 2008). Despite this, the research of chamois as a species was very scarce in Serbia which resulted in the absence of complete information on its abundance (≈600 individuals), and other demographic parameters, distribution, nutrition, and the achieved results in the previous management. At the national level (territory of Serbia), its status is defined as VU (vulnerable), according to somewhat modified IUCN categorisation (Savić *et al.*, 1995). Also, it is included in the Preliminary List of species for the Red List of Vertebrates in Serbia (Vasić *et al.*, 1990). By the current Hunting Law (1993), it is protected by the prohibition of hunting over the definite periods - males (February 1st – July 31st), females and kids (February 1st – August 31st).

Among several sites with autochthonous chamois populations in Serbia, is also the hunting ground "Tara", within the National Park of the same name. The presence of chamois in this hunting ground is reported by many written documents on the mountain Tara (1888, 1908 and 1950). However, this population was severely threatened during the war years in the neighbouring Republic B&H (1992-1995), due to permanent disturbance, chasing and poaching by the soldiers and the local population. The objective of the study was to evaluate the main causes of the current threats on the chamois population in the hunting ground "Tara" and to propose the measures for its protection, as well as to identify morphological characters of horns of the hunted individuals.

2. MATERIAL AND METHOD

The National Park "Tara" was established in 1981. It is located in the western part of Serbia, along the right bank of the river Drina, on the territory of the Municipality Bajina Bašta. It consists of several landscape units: Zvezda, Crni Vrh, Tara (in the narrow sense), Aluška Planina and Kaluđerske Bare. Hunting ground "Tara", in the present boundaries, was established in 1994 on the area of 19175 ha. Its southern and south-western parts are along the state border between Serbia and the Republic of Srpska (B&H). The dominant land uses are forests and forest lands (14247 *ha* or 74.3%), pastures and meadows (2955 *ha*), farmlands (504 *ha*), vineyards and orchards (94 *ha*) and other land uses (1375 *ha*). The relief is characterised by a frequent alteration of watercourses, gorges and canyons. The altitude ranges from 291 to 1591 *m*. Parent rock consists of limestones, schists, serpentinites and sandstones, which conditioned the formation of different soil types. Mean annual air temperature is 7.9ºC, and mean annual precipitation is 977 *mm*.

The basic data on the status and management of chamois populations, as well as populations of other game species (roe deer, wild boar, wolf and bear), were obtained from the professional service of the National Park. We also used the planning documents for the hunting ground "Tara", such as the Hunting Plan and The Annual Management Plans. Morphological characters of chamois horns (length, height and span) were analysed on the sample of 56 individuals, hunted in the NP "Tara" over the period 2006-2009. The age and sex were determined by the professional service of the National Park by standard procedure, but only for 37 trophies (21 male and 16 female). For this reason, 19 trophies were eliminated from the collective sample and the subsequent data processing. The trophies were measured and evaluated by the Commission of the National Park by the formula and directions of the International Council for Game and Wildlife Conservation - CIC (Trense *et al.*, 1981).

3. RESULTS AND DISCUSSION

Balkan chamois is one of more than 50 species of mammals whose presence is registered in the hunting ground "Tara" (1996), which also include some of the big game - bear (*Ursus arctos*) and wolf (*Canis lupus*). The area with favourable conditions for its growing covers 4250 *ha* (LPP – hunting productive area). It encompasses canyon parts of several rivers (Rača, Derventa, Drina and Brusnica) and the rocky terrains at some localities (Kozji Rid, Bilo and Aluga), as well as the boundaries of mountain areas and river canyons. The professional service of the National Park estimated the optimal spring abundance of chamois to 380 individuals (9 individuals / 100 *ha* of LPP) and the economic capacity on 472 individuals (1996, 2006).

Chamois colonizes mainly the open, stony and rocky sites. During summer, they inhabit alpine and subalpine meadows and rocky lands above the upper timberline, while in winter they retreat to lower areas covered with forests. It is an adaptable species, so the range of altitudes of it habitats is from only 150 *m* in canyons and gorges, to alpine high-mountain zone with the altitudes above 2500 *m*. Balkan chamois in Bulgaria are seen at the altitude from around 600 to 2900 *m* (Valchev *et al.*, 2006). In the hunting ground "Tara" chamois can be seen already on the banks of the lake Perućac (291 *m*), especially during winter.

The dynamics of spring density of the chamois population in the hunting ground "Tara" is presented in Diagram 1. It is evident that the number of chamois was the lowest in 1996. It is considered that the main reasons for the decrease in the density were poaching and migrations of individuals caused by the war in the neighbouring Republic B&H (1992-1995). Moreover, in the previous period (1970-1996), hunting was the secondary activity within forestry, because of which the management of chamois population was not adequate. This statement is proved by the fact that there is no reliable information on the number, sex and age of the hunted chamois in the previous period (1960-1990), and also their morphological characters were not measured.

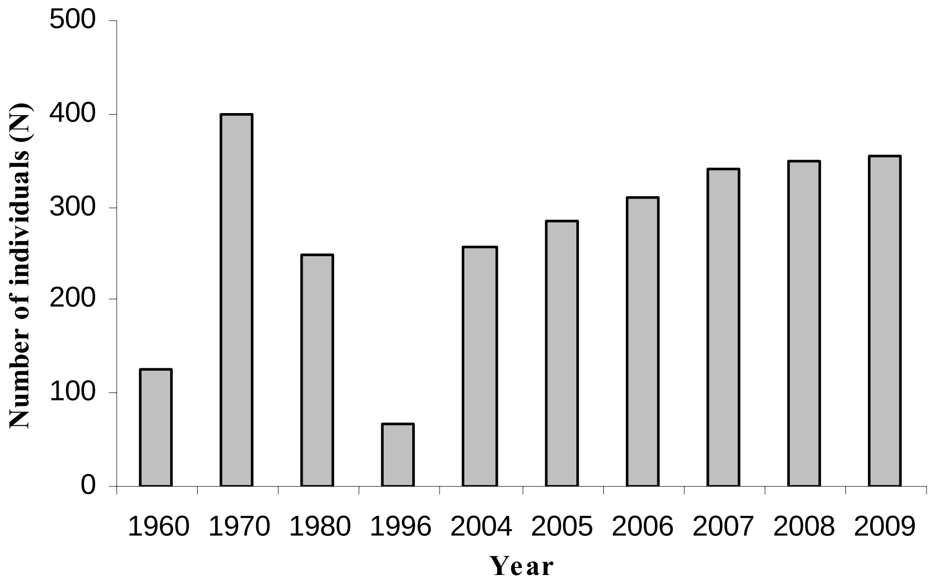

Figure 1. *Dynamics of spring density of chamois population in the hunting ground "Tara"*

The present density of chamois population in the hunting ground "Tara" (354 individuals in the spring 2009) is explained primarily by favourable habitat conditions, especially by the abundance of food, and also by significant reduction in poaching. Also, the professional hunting service was established within the National Park, and chamois hunting was prohibited over the period 1996-2002. Moreover, each year the number of hunted individuals was symbolic or significantly lower than the planned number. For example, in 2003/04 were hunted 4 individuals (3F + 1M), and 8 individuals (4F + 4M) in 2004/05. In the past three years, the number of hunted chamois was: 10 individuals in 2006/07 (16 planned), 25 individuals in 2007/08 (32 planned), and 15 individuals in 2008/09 (37 planned).

Natural predators such as lynx (*Lynx lynx*), wolf (*Canis lupus*) and golden eagle (*Aquila chrysaetos*) can in some cases affect significantly the chamois population density. Over the past decade, in the hunting ground "Tara", the lynx presence was not determined with certainty, despite some hints on its presence, but wolf is permanently present (11 individuals were shot, of which as much as 4 in 2006). In Bulgaria, the native chamois predators are grey wolf, bear, wild cat, red fox, golden eagle and feral dogs (Valchev *et al.*, 2006). However, some authors report that lynx is one of its most significant predators (Molinari-Jobin *et al.***,** 2002).

The numerical data on some morphological characters of chamois horns shot in the hunting ground "Tara" over the period 2006-2009, are presented in Table 1. Despite the relatively low number of collected samples, especially of young and old individuals, our results point to the existence of differences between the sexes, i.e. that males have larger horns than females. This is in agreement with the results reported by other authors, who determined significant differences between sexes regarding the scull and horn sizes on a much larger sample (Hrabě, Koubek, 1990), and also regarding the biomass and body growth (Garel *et al.*, 2009).

Table 1. *Morphological characteristics of chamois horns in the hunting ground "Tara"*

Age (*year*)	Sex	Sample (*n*)	Average length (*cm*)		Height (*cm*)		Span (*cm*)	
			mean	range	mean	range	mean	range
2	male	1	-	16.8	-	10.6	-	4.5
	female	-	-	-	-	-	-	-
3	male	1	-	14.3	-	10.6	-	5.2
	female	1	-	15.3	-	9.8	-	4.0
4	male	3	18.8	15.8-21.6	12.5	9.5-14.8	5.5	3.5-7.5
	female	1	-	18.3	-	12.7	-	4.0
5	male	1	-	22.9	-	14.6	-	8.8
	female	3	20.5	19.0-22.1	15.4	13.6-16.9	5.4	2.5-7.2
6	male	2	23.5	23.2-23.9	16.6	16.5-16.8	6.5	5.3-7.8
	female	3	18.8	18.0-19.9	14.9	14.1-15.8	4.6	3.2-6.0
7	male	3	24.7	23.6-26.0	17.2	16.2-19.1	9.9	6.7-11.8
	female	3	20.8	18.6-22.9	15.3	14.0-16.7	5.9	5.0-6.8
8	male	6	23.5	20.8-25.0	15.5	14.4-16.3	6.8	5.0-7.5
	female	2	21.9	20.1-23.7	16.9	16.4-17.4	3.3	3.2-3.5
9	male	3	23.3	21.1-25.6	16.7	15.4-18.8	7.9	6.5-8.8
	female	2	22.4	20.4-24.4	15.7	14.7-16.7	8.5	8.3-8.8
10	male	-	-	-	-	-	-	-
	female	1	-	23.3	-	19.0	-	6.5
11	male	1	-	21.3	-	15.6	-	6.3
	female	-	-	-	-	-	-	-

The threatening factors vary from state to state, but all are to a certain extent related to anthropogenic pressure, either poaching or excessive hunting, destruction of natural sites, domestic livestock pasture, or the increasingly intensive development of tourism in mountainous areas (Shackleton *et al.*, 1997, Group of authors, 2008). All of the above factors are active on the Balkans and in Serbia, but at the moment probably poaching has the highest impact and, to a somewhat lower degree, the domestic livestock pasturage in chamois natural habitats (Group of authors, 2008). In Bulgaria, for example, the main threats and limiting factors are: climate factors and calamities (snow, avalanches), predators and feral dogs, competition with other ungulates (red deer, roe deer and wild boar) and domestic livestock, infectious and parasitic diseases, construction of ski tracks and servicing equipments, changing the grass composition and the aspect of the grassland communities, poaching, regular hunters and local people, illegal hunting tourism, trophy hunting, disturbance and fragmentation (Valchev *et al.*, 2006). In Greece, the threats include poaching, enhanced by the dense mountain road network constructed either for livestock breeding activities or logging (Papaioannou, Kati, 2007). In Romania (Ceahlau National Park), the main causes that lead to mortality are the following: falling in pits, snow avalanches, rock falls and, to a lesser extent, the attacks of the predators - wolf and lynx (Alazaroaei, Ion, 2006). Among the negative anthropic influences, they mention: the great number of tourists that make a lot of noise (from May to September), grazing close to the biotope of chamois and poaching.

The area of the National Park "Tara" offers highly favourable conditions for the development of chamois populations, especially regarding the orographic and climate characteristics, but also the relative seclusion and inaccessibility of the canyon valleys of the river Drina and its tributaries, which are the most favourable sites. The specific ambiance of the gorges and canyons, as refugial spaces with diverse plant communities whose phenophases and biomass production alternate throughout the year along the site vertical gradient, provides a very good nutrition base for the maintenance and progress of the relatively numerous population. A greater part of the chamois habitats in the hunting ground "Tara" is covered by the first degree protection regime, which excludes all activities on the exploitation of natural resources, including hunting. Hunting activities can be realised in the zones with the II and III degree protection regime. Consequently, the areas under strict protection regime are special "population reservoirs", from which some individuals migrate by dispersion towards the peripheral zones and hunting grounds.

The main threats and limiting factors of further development of chamois populations in the hunting ground "Tara" are potential larger-scale poaching, or more significant peace disturbance in the habitat. Other potential risk factors, such as predators, greater presence of tourists, or the competition of wild and domestic animals, for the time being have a modest or insignificant effect. Possible climate changes of the global extent, which could lead to the disturbance of the natural dynamics of plant communities in this hunting ground and in the wider area, could have a significant effect both on the chamois population dynamics and on the status, and by all means also on the previous and planned management practice. We are of the opinion that future research should partly be directed towards the study of these and similar phenomena.

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BIOFUNGICIDE CONTROL DISEASE IN FOREST – FSC WAY

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Abstract: *FSC certification offers forest managers rewards for managing their forests the FSC way – following the highest social and environmental criteria there are. Powdery mildew on oak is caused by the fungus Microsphaera alphitoides Griff. et Maubl. The pathogen may retard the growth of young plants and may kill tree seedlings. The biggest damage is to the young oak, that in cases of strong attacks, must be used chemical protection (treatment by fungicides). In Serbia fungicides for control of pathogenes in forest ecosystems are not registered. Therefore, it is necessary to select ecotoxicologically favourable fungicides registered in this region and obey FSC policy in application of pesticides. Because of the desire for reducing the negative consequences of applying chemicals, biological control is becoming increasingly important. For biological control of plant disease causing fungi used biofungicides. AQ-10 is a new biofungicide that contains fungal spores of Ampelomyces qisqualis for the control of powdery mildew by parasiting and killing the fungal organisms that cause the disease. AQ-10 is approved for the efficient and biotical use of Powdery Mildew. Aim of this work is to verify the independently effect of biofungicide AQ10 and in combination with polymer Nu-film 17 in controlling powdery mildews oak. Preliminary examination were performed by standard OEPP methods PP1/69 (2) (OEPP / EPPO, 1997) on the oak seedlings infected by parasitic fungus M. alphitoides. Treatments were carried out in 4 repetitions, in the vegetation period in the 2009.*

Key words: *FSC, powdery mildew, biofungicides, efficacy*

SUZBIJANJE BOLESTI BIOFUNGICIDIMA U ŠUMARSTVU – FSC PUT

Izvod: *FSC sertifikacija šuma nudi rukovodiocima mogućnost upravljanja šumama - FSC put - po najvišim društvenim i ekološkim kriterijumima. Pepelnica na hrastu je prouzrokovana gljivom Microsphaera alphitoides Griff. et Maubl. Patogen može da zaustavi porast mladih sadnica ili ih potpuno uništi. Najveća oštećenja se dešavaju na mladim sadnicama hrasta, i u slučaju jakih napada, mora biti korišćena hemijska zaštita (tretiranje fungicidima). U Srbiji za suzbijanje patogena u šumarstvu nisu registrovani odgovarajući fungicide. Zbog želje da se smanji negativan efekat upotrebljenih pesticida biološka zaštita postaje veoma značajna. Za biološku zaštitu biljnih bolesti koriste se bioungicidi. AQ-10 je novi biofungicid koji sadrži spore gljive Ampelomyces quisqualis i koristi se za suzbijanje pepelnica parazitirajući i ubijajući patogena prouzrokovača oboljenja. AQ-10 omogućava uspešnu biološku zaštitu od pepelnica. Cilj ovoga rada je da se prikaže samostalno delovanje biofungicida AQ-10 i njegovo delovanje u kombinaciji sa polimerom Nu Film-17 u suzbijanju pepelnice hrasta. Preventivna ispitivanja su izvedena po standardnim metodama OEPP PP1/69 (2) (OEPP / EPPO, 1997) na sadnicama hrasta zaraženim gljivom M. alphitoides. Tretmani su izvedeni u četiri ponavljanja u toku vegetacionog perioda u 2009. godini.*

Ključne reči: pepelnica, hrast, biofungicidi, efikasnost

1. INTRODUCTION

The total area of forests in Serbia is 2.252.400 ha, and the most important species of oak is on the surface – 720.800 ha. Since then, forest of *Q. cerris* L. stretch of 345.200 ha, *Q. petrea* (Matt.) Liebl. forest the 173.200 ha, forest *Q. frainetto* Ten. on 159.600 ha, of *Q. robur* L. forests and 32.400 ha, of forest *Q. pubescens* Willd. to 10.400 ha (National forest inventory of the Republic of Serbia, 2009).

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Identifying biocontrol agents that can supplement conventional chemical fungicides is a valuable contribution to disease management, especially for a disease like powdery mildew of oak, caused by *Microsphaera alphitoides* Griff et Maubl. (sexual phase *Ascomycetes*) and as *Oidium quercinum* Thuem.(asexual phase *Deuteromycetes*) (Junell, 1967, Nef i Perin, 1999).This fungus generally occurs in oak of which the most sensitive *Quercus robur* (lime), and sometimes attacks and other types of genera *Fagus*, *Castanea* and *Acer* (Lagerberg, 1962, Nef and Perrin, 1999).

Mildew is a very common fungal disease on crops and tree seedlings. Powdery mildew on oak, or oak mildew, caused by pathogen *M. alphitoides*, appears on several tree genera in forests, parklands and nurseries (Lagerberg, 1962; Butin, 1995). The pathogen may retard the growth of young plants and may kill tree seedlings (Chevalier, 1997). Recurring attacks of *M. alphitoides* in combination with other pathogens or herbivory by mammals and insects may even cause older oaks to die. The biggest damage is to the young oak, that in cases of strong attacks, must be used chemical protection (treatment by fungicides). Fungicide applications are the principal management practice for this important disease ((Rajkovic, et al., 2008, 2009a).

Because of the desire for reducing the negative consequences of applying chemicals, and the possibility of resistance, biological control is becoming increasingly important. For biological control of plant disease causing fungi used biofungicides. Efficiency of biofungicides improves by adding the polymer during its application.

The biofungicide AQ10 (Ecogen Inc., Langhorne, PA) is a pelleted formulation of conidia of *Ampelomyces quisqualis* Ces. ex Schlechtend., a fungus that parasitizes powdery mildew colonies. AQ10 is intended for use as part of an integrated management program; therefore, information is needed on its compatibility with conventional chemical fungicides (Rajkovic, et al., 2009b).

The objective of this study was to examine the hyperparasitic ability of AQ10 when used alone, combined with polymers Nu Film 17 and Nu Film P.

With their proper application it is possible to repress fungi in a certain percentage without the possibility of resistance to the fungus species on active substance and on this way it will be extended action of biopreparate using polymers.

2. MATERIALS AND METHODS

The experiments were made in the nursery „Rogut" which is located in Batocina, near Kragujevac, at altitude 115m. The investigations were carried out on the oak seedlings *Q. robur* L. , aged 6 years, seed origin. The seeds from which seedlings produced comes from recognized seed stands oak, reg. no. C 02.11.01.01, which borders with the nursery. Height of seedlings are from 0.30 cm to 1.70 m (mostly about 1.20 m), because the part of seedlings were cating in the first and second vegetation period. Seedlings were planted densely in rows length of about 60m (8 rows in total, an average of 6 seedlings per m^2), with space between the row around 40 cm. For the experiment were used two rows. The control was estimate in the second row.

AQ-10 is a new biofungicide that contains fungal spores of *Ampelomyces qisqualis* for the control of powdery mildew by parasiting and killing the fungal organisms that cause the disease. AQ-10 is approved for the efficient and biotical use of Powdery Mildew. For its activation it needs 60% of air humidity therefore application should be made in the early morning or late evening when the humidity is at its highest, with the addition of some wetting agent. When spores of AQ-10 penetrate into Powdery Mildew mycelia (2-4 hours) their efficacy is depending on external influences not any more. AQ-10 is mostly preventive product but it acts also »eradicatively« and is efficient also against mycelia which passed the winter. Initial application should begin before the appearance of the symptoms and at the latest when three spots on 100 leaves have been observed. AQ- 10 has very short pre-harvest interval, only 24 hours, so it can be applied up to and including the day of harvest.

A formulated powder containing *A. quisqualis* is available from Ecogen Corporation and is marketed under the trade name AQ10. *Ampelomyces quisqualis*: Hyperparasite of powdery mildews - Powdery mildews: 256 plant species within 172 genera in 59 families; Colonizes hyphae, conidiophores, cleistothecia ; Direct penetration. Host cells are killed shortly after pycnidial formation (2-4 days after infection). Doses for use of AQ10 is 30-50-70 gr/ha.

Because of the desire for reducing the negative consequences of applying chemicals, biological control is becoming increasingly important. For biological control of plant disease causing fungi used biofungicidi. Efficiency of biofungicides improves by adding the polymer during its application.

Nu Film 17 and P are an emulsifable concentrate formulation of a specific betapinene polymer, designed for use as a spray tank additive, to be applied in combination with insecticide and fungicide pest control programe. It is used in these pest control programs, when the spray applications are made to crop foliage, during the normal growing and sprayng season. Nu Film 17 and P are a film forming polymer, which encapsulates the pesticides and biopesticides and protects it from various weathering factors, including rainfall and wind erosion. It shields the pesticide and biopesticide spray residue from heat and ultra-violet radiation, which often causes pesticide and biopesticide degradation. Pesticide volatilization is minimized by the protective film. Loss of pesticide deposit by the abrasive activity of leaves rubbing together, is also prevented. Nu Film 17 slowly realeases the pesticide at a predictable rate thus maintain biological control over a longer than normal period of time. Because of this, it has been found that the use of Nu Film 17 reduces the quantity of the pesticides needed in spray applications. It improves initial depositing of the pesticide so that lower rates of pestide can be used. It increases the normal life of most pesticides by 50 to 100 percent, again reducing the quatity of pesticide used by increasing the interval between sprays. Increasing the interval between sprays is especially advantages for aerially applied pesticides, because of the high cost of aircraft operation. Nu Film 17 is used at the rate 1-1 l.5 lit/ha, and Nu Film P is used in rate 0.3-1 l/ha.

The amount of active ingradient in the formulation doses not determine the activity. Activity is governed by the type of film which is formed and this is determined by refinement. The active ingradient in this product is Pinolene, a Terpenic polymer.
Fungicide which are used since experiments is Sulphur SC (Active ingredient: Elementary sulphur 810.50 g/l, Producer: Galenika –Phytopharmacy a.d. Belgrade-Zemun, Concentracion of use: 0.5%).

The appearance and development of powdery mildews is followed by the first appearance to the development of disease in control in the degree that it is possible to establish clear differences between control and variations where biofungicides or polymers were used.

The trials were set by the instructions of methods PP 1 / 152 (2) (EPPO, 1997) and the plan is fully randomized block design. The experiment was conducted in four repetitions. The basic plot is consist of 8 trees (1x3 m apart) 25 m^2.

Estimation on leaves by secondary infection of powdery mildew: It were selected 15 well-developed leaves on shoot from the outer zones of branched part of each tree. Recomm edations is to avoid the shoots with primary infection of powdery mildews and shoots completely infected by powdery mildews and shoots that arise from the interior foliage.

Method of application and amount of water per unit surface: Application of fungicides was performed using the backstroke sprayer “Solo”; with the consumption of 1000 l / ha of water.

Time of application of biofungicide and its combination with polymers: 07/07/2010. yr. pheno- phase: Shoots are 15-20 cm length.

The intensity of disease assessed by the method of EPPO: Guideline for the efficacy evaluation of fungicides-*Podosphaera leucotricha*, NO. PP 1 / 69 (2) in Guideline for the efficacy evaluation of Plant Protection Products, 1997, 100-102. Time of estimation: 11/07/2009. Phytotoxity is estimated by instructions of PP methods (1 / 135 (2) (OEPP, 1997).

Data processing was performed using standard statistical methods (intensity of infection by Towsend-Heuberger, the efficiency of the Abott [1], analysis of variance and Ducan test) and methods PP/181 (2) (EPPO 1997). Differences of intensity of disease was evaluated by analysis of variance and lsd-test.

Weather conditions: during the treatments there are more favorable conditions for the application of biofungicide and polymers: the wind was below 1 m / s, and the temperature 18.8-26.4 ^{0}C, with sunny intervals of 2-3 hours after treatment. Before treatment there is no rain 48h, and after 6-8 hours of treatment there was no rainfall, while the relative humidity was 80%, because the nursery is protected with old forest plantations in suroundig. Data of land: in the oak nursery soil is poorly processed. Weeds were repressed by hendly mower. Irrigation isn't done. Type of land at the tested locality was vertisoil, wet, deep 80 to 120 cm.

Other measures in the experimental field: Treteatments by insecticides and bioinsekticides were done in 07.05. 2009th year. For the suppression of gypsy moths in the variants where the product AQ10 is applied in all used concentrations, used a biological product Forey (0.3l/ha). In variants where AQ10 combined with Nu film 17 in the lower and higher doses were used applying insecticides Avaunt 15SC (200ml/ha). The variant where the AQ10 was applied in combination with Nu P film was used Coragen 20 SC (200ml/ha). On the control variants there was no application of any pesticides or biopesticides.

3. RESULTS AND DISCUSSION

In the table 1. are presented the data of realized powdery mildews infestation on the oak leaves.

In variant No. 1 where are applied AQ10 alone, we can clearly see the differences in efficacy depends of application doses. So, at the application dose of 50g efficacy was satisfactory - 75.80%. That means that this biofungicide could be included in protection program and at lower percentage of infection in nursery oak, it can be used alone,and in combination with fungicides at higher rates of infection.

When AQ10 was applied in dose of use 50g, in combination with polymer - Nu Film 17 in two doses of applying 1 l / ha and 1.5 l / ha (variants No 2-3) all variations in all combinations showed a satisfactory efficacy and a low percentage of infection of 4.65% -2.10%. Such protection is very successful and can be recommended for practice.

But, in variant No. 4-5 the AQ10 applied in dose 50 g in combination with the application of polymer Nu Film P in lower doses applying 0.3 l / ha and higher doses of application of 1 l / ha. There were expresed somewhat lower efficacy (infection intensity of 1.60% -7.80%) than in combination with Nu film 17, but still satisfactory for application in practice.

Fungicide Sulfur SC showed the efficiency of 84.43% which is low efficiency for chemical fungicides.

Infection on control variant was 29.55% which means that the presence of pathogens was significant that could be carried out this experimental essay and to properly assess the effectiveness of the investigated preparations.

Table 1. *Intensity of attacks M. alphitoides on oak leaves and efficiency of fungicides, biofungicides and polymers in the locality Batočina% - Kragujevac*

No	*Fungicide*	Conc./Doses (%), kg/ha	Infectiva (%)	*Efficacy* (%)	*Standard* (%)
1.	AQ10	50 g	7.15 a	64.07	83.33
2.	AQ10+Nu Film 17	50 g+1 l/ha	4.65 a	76.63	99.67
3.	AQ10+Nu Film 17	50 g+1.5 l/ha	2.35 a	88.19	114.71
4.	AQ10+Nu Film P	50 g+0.3 l/ha	6.35 a	68.09	88.56
5.	AQ10+Nu Film P	50 g+1 l/ha	5.70 a	71.36	92.81
6.	Sumpor SC	0.5%	4.60 a	76.88	100.00
7.	Untreated	-	19.90 b	0.00	0.00
	lsd 005		5.36		
	lsd 001		7.35		

Efficacy of biofungicide AQ10 is satisfactory, but in combination with polymers Nu Film 17 and Nu Film P is significantly improved due to the very good quality of polymers and their mechanism of action what is in this time also confirmed.

Looking at the complete experiment it can be seen that there are statistically significant differences between varieties with the lowest and highest dose application depend to the control.

In the nursery, or locality there is not noted any adverse effects of sulfur SC, biofungicide AQ10 and polymer film 17 and Nu Nu Film P on the treated plants and other organisms.

During the treatments there are more favorable conditions for the application of biofungicide and polymers: the wind was below 1 m / s, and the temperature 26.4 ^{0}C, with sunny intervals of 2-3 hours after treatment. Before treatment there is no rain 48h, and after 6-8 hours of treatment there was no rainfall, while the relative humidity was 80%.

Polymer Nu Film 17 and P are a forming film, which encapsulates the pesticide Sufur SC and biopesticide AQ10 and protects it from various weathering factors, including rainfall and wind erosion. It increases the normal life of pesticide and biopesticide by 50 to 100 percent.

4. CONCLUSION

- Powdery mildew on oak, or oak mildew, caused by pathogen *M. alphitoides*, appears on tree genera in forests, parklands and nurseries. The pathogen may retard the growth of young plants and may kill tree seedlings.
- Fungicide applications are the principal management practice for this important disease.
- Identifying biocontrol agents that can supplement conventional chemical fungicides is a valuable contribution to disease management, especially for a disease like powdery mildew of oak.
- Because of the desire for reducing the negative consequences of applying chemicals, and the possibility of resistance, biological control is becoming increasingly important. For biological control of plant disease causing fungi used biofungicides.
- Efficiency of biofungicides improves by adding the polymer during its application.

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BIOFUNGICIDE CONTROL DISEASE IN FOREST – FSC WAY

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Summary

Identifying biocontrol agents that can supplement conventional chemical fungicides is a valuable contribution to disease management, especially for a disease like powdery mildew of oak. Powdery mildew on oak is caused by the fungus Microsphaera alphitoides Griff. et Maubl The pathogen may retard the growth of young plants and may kill tree seedlings. The biggest damage is to the young oak, that in cases of strong attacks, must be used chemical protection (treatment by fungicides). Because of the desire for reducing the negative consequences of applying chemicals, biological control is becoming increasingly important. For biological control of plant disease causing fungi used biofungicides. Manufactures who have traditionally been the source of chemical fungicides will be producing and marketing biofungicides. Growers need to be aware of what products are available, the way they work and their limitations. However, under the proper growing conditions, biofungicides can be a viable alternative to chemicals. AQ-10 is a new biofungicide that contains fungal spores of Ampelomyces quisqualis for the control of powdery mildew by parasiting and killing the fungal organisms that cause the disease. AQ-10 is approved for *the efficient and biotical use of Powdery Mildew. Efficiency of biofungicides improves by adding the polymer during its application. Aim of this work is to verify the independently effect of biofungicide AQ-10 and in combination with polymer Nu Film-17 in controlling powdery mildews oak. Preliminary examination were performed by standard OEPP methods PP1/69 (2) (OEPP / EPPO, 1997) on the oak seedlings infected by parasitic fungus M. alphitoides. Treatments were carried out in 4 repetitions, in the vegetation period in the 2009.Looking at the complete experiment it can be seen that there are statistically significant differences between varieties with the lowest and highest dose application depend to the control.*

SUZBIJANJE BOLESTI BIOFUNGICIDIMA U ŠUMARSTVU - FSC PUT

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Rezime

Identifikacija biokontrolnih agenasa koji mogu da zamene konvencionalne hemijske fungicide je vredan doprinos u suzbijanju biljnih bolesti, što je posebno značajno za bolesti kao što je pepelnica hrasta. Pepelnica na hrastu je prouzrokovana gljivom Microsphaera alphitoides Griff. et Maubl. Ovaj patogen može da zaustavi porast mladih sadnica ili ih potpuno uništi. Najveća oštećenja se dešavaju na mladim sadnicama hrasta i u slučaju jakih napada, mora biti korišćena hemijska zaštita (tretiranje fungicidima). Zbog želje da se smanji negativan efekat upotrebljenih pesticida biološka zaštita postaje veoma značajna. Za biološku zaštitu biljnih bolesti koriste se bioungicidi. Proizvođači koji su tradicionalno bave hemijskim fungicidima počinju proizvodnju i marketing biofungicida. Zato proizvođači treba da budu upućeni šta im je na raspolaganju, o način rada i njihovim ograničenjima prilikom proizvodnje i upotrebe. Odnosno, odgovarajućim načinom rukovanja, biofungicidi može biti sasvim odgovarajuća alternativa hemjskim sredstvima. AQ-10 je novi biofungicid koji sadrži spore gljive Ampelomyces quisqualis i koristi se za suzbijanje pepelnica parazitirajući i ubijajući patogena prouzrokovača oboljenja. AQ-10 omogućava uspešnu biološku zaštitu od pepelnica. Efikasnost biofungicida povećava se dodavanjem polimera tokom njegove primene. Cilj ovoga rada je da se prikaže samostalno delovanje biofungicida AQ-10 i njegovo delovanje u kombinaciji sa polimerom Nu Film-17 u suzbijanju pepelnice hrasta. Preventivna ispitivanja su izvedena po standardnim metodama OEPP PP1/69 (2) (OEPP / EPPO, 1997) na sadnicama hrasta zaraženim gljivom M. alphitoides. Tretmani su izvedeni u četiri ponavljanja u toku vegetacionog perioda u 2009. godini. Posmatrajući kompletan eksperiment se može videti da postoje statistički značajne razlike izmeđutretmana sa najnižim i najvišim dozama primene u odnosu na kontrolnu varijantu.

TWO NEW SPECIES FROM THE GENUS *DUBININELLUS* WAINSTEIN (ACARI, PHYTOSEIIDAE) IN THE SERBIAN FAUNA

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Abstract: *The leaf-inhabiting mites were studied from 2006 to 2009 in artifically established stands of Alnus glutinosa***,** *Pinus nigra, P. silvestris and Larix leptolepis, on the reclaimed mine soil of the Mining-Energy Industrial Complex Kolubara, in municipality of Lazarevac, Central Serbia. Phytoseiid mites of subfamily Phytoseiinae have been fond on the plant species from the genera Rubus and Fragaria. Dubininellus maltshenkovae (Wainstein 1973) and Dubininellus ribagai (Athias-Henriot 1960) are new species for the fauna of Serbia.*

Key words: Phytoseiidae, Dubininellus, *Rubus,* New records, Serbia

DVE NOVE VRSTE RODA *DUBININELLUS* WAINSTEIN (ACARI, PHYTOSEIIDAE) ZA FAUNU SRBIJE

Izvod: Istraživanje faune epifilnih grinja sprovedeno je u periodu 2006-2009. godine u veštački podignutim sastojinama *Alnus glutinosa***,** *Pinus nigra, P. silvestris i Larix leptolepis* na rekultivisanim deposolima REIK Kolubara, na teritoriji Lazarevca, Centralna Srbija. Predstavnici kod nas malo istražene potfamilije Phytoseiinae konstatovani su samo na biljkama rodova *Rubus* i *Fragaria*. Pronađene su dve nove vrste za faunu Srbije – *Dubininellus maltshenkovae* (Wainstein 1973) i *Dubininellus ribagai* (Athias-Henriot 1960) .

Ključne reči : Phytoseiidae, **Dubininellus**, *Rubus*, novi podaci, Srbija .

1. INTRODUCTION

The diversity of the leaf-inhabiting mites from the family Phytoseiidae Berlese is only partly studied in our country. Phytoseiids are predators of several mite groups (Kostiainen & Hoy, 1996), including spider mites (Tetranychidae). Over the last two decades the phytoseiid mites in the agrobiocoenoses have been more intensively researched in Serbia, mainly in the harmony with their role in the biological control of the phytophagous mites. They can also serve as valuable bioindicators of the effects of chemicals in the plant production. Therefore, few detailed studies were carried out on phytoseiid mites, at the level of the complex of the predatory mites and the trophic groups of their prey (Radivojevic & Petanovic, 1984; Stojnic, 1993, 2001; Stojnic & Petanovic, 1994). By contrast, the research of the biodiversity and zoogeographic aspects of the mites in other ecosystems has been neglected. Thus, the researches of phytoseiid mites fauna have recently begun in numerous natural, mainly forest, and the unexplored anthropogenic sites. Due to these circumstances, by 2002 only 25 species of phytoseiid mites were reported in Serbia (Kropczynska & Petanovic, 1987; Petanovic & Stojnic, 1995; Stojnic et al., 2002), out of which five species from the genus Dubininellus Wainstein 1959: *D. canadensis* (Chant 1965), *D. echinus* (Wainstein & Arutunjan 1970), *D. juvenis* (Wainstein & Arutunjan 1970), *D. macropilis* (Banks 1909) and *D. spoofi* (Oudemans 1915). The aim of this long-term

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study is to determine the phytoseiid mite fauna in degraded habitats in post-mining reclaimed area. The paper presents some of the results of the research of the diversity of the phytoseiid mites of the subfamily Phytoseiinae Berlese in the artifically established stands of several broad-leaved and coniferous silvicultural species.

2. MATERIALS AND METHODS

The researches were conducted over the period 2006-2009 in four sampling plots in artifically established stands of *Alnus glutinosa***,** *Pinus nigra, P. silvestris* and *Larix leptolepis* on the reclaimed mine soil of the Mining-Energy Industrial Complex Kolubara, in municipality of Lazarevac, Central Serbia. It is the greatest lignite basin in Serbia. Due to the deposition of fresh waste rock, the ecological conditions, morphology of terrain and hydrological conditions changed. By the deposition of waste rock from the open-pit mines, the mine soil, reclaimed by the reforestation, were formed. The reclaimed plots are spontaneously inhabited by the species, for which the certain plot is the natural site (Drazic, 2002; Miletic, 2004; Smit and Veselinovic, 1997). The following four plots were researched:

- Lazarevac, Baroševac sample plot 5.1 (N: 44°22′49″; E: 20°22′37″; 202 m)**:** *Alnus glutinosa* plantation, 24-year-old, established on the site *Salici-Populetum;* canopy 0.9; quality, vital, straight trees, cleaned from the lower branches, the branches which are alive account for less than 1⁄3 of height; the plantation is not tended, weeded with blackberry and grass vegetation. The exposition is not well-expressed, the soil slope is not well-expressed, mine soil.

- Lazarevac, Baroševac sample plot 6.1 N: 44°25′40″; E: 20°22′57″; 230 m)**:** *Larix leptolepis* plantation with the traces of *Acer sp.* 26-year-old, established on the site *Salici-Populetum;* canopy 0.5; dry branches down to the ground, the branches which are alive account for 1⁄2 of tree height; the plantation is not tended. The exposition is not well-expressed, the soil slope is not well-expressed, mine soil.

- Lazarevac, Mirosaljci- lake, 35⁄b (N: 44°25′57″; E: 20°23′11″; 120 m)**:** Artifically established stand *L. Leptolepis* and *Pinus nigra,* in which *Robinia pseudoacacia,* regenerated in a natural way, is dominant. *Populus tremula, Salix alba,* and other hard broadleaved trees are present. Ground flora of medium density, sparse bushes, medium weed infestation. The soil slope from 6 to 10%, North-East exposition, mine soil.

- Lazarevac, Barosevac nursery, lake, 43⁄a (N: 44°25′01″; E: 20°22′55″;120 m)**:** Artifically established stand *L.leptolepis;* Ground flora of medium density, sparse bushes, medium weed infestation. The soil slope up to 5%, well-balanced, mine soil.

In each stand leaf samples were collected over the growing season on various trees, bushes and herbs. The species from 13 plant genera were sampled**:** *Acer, Alnus, Amorpha, Cerasus, Crataegus, Fragaria, Juglans, Morus, Populus, Quercus, Robinia, Rubus* and *Salix*. Depending on plant species, sample size was 50-400 leaves. They were transferred to the laboratory. To detect the presence of phytoseiid mites, the sampled leaves were previously treated with etylacetat in the laboratory for 20 minutes**,** shaken and examined under a stereomicroscope. Collected mites were cleared for one day in mixture 1:5 of 70% ethyl alcohol and lactic acid (simplified method of Evans & Browing, 1955) and mounted in Hoyer's medium (Baker & Wharton, 1964). The method of identification of mites of the family Phytoseiidae was based on Begljarov (1981) and Karg (1993), and the additional taxonomic data was obtained by DeMoraes et al. (1986). The slides of the mounted specimens were deposited in the collection of Entomology and Agricultural Zoology Department, University of Belgrade – Faculty of Agriculture.

3. RESULTS

In the present study mites of subfamily Phytoseiinae have been found only in plant species from the genera *Fragaria* and *Rubus*, although they can also inhabit the other plant species included in our investigation. Three species of subfamily Phytoseiinae have been found: *Dubininellus juvenis* (Wainstein et Arutunjan 1970) and *D. maltshenkovae* (Wainstein 1973) on *R. ceasius* i *R. fruticosus agg.*, as well as *Dubininellus ribagai* (Athias-Henriot 1960) on *F. vesca.* The latter two species were recorded for the first time for the fauna of Serbia.

The genus *Dubininellus* Wainstein 1959, belongs to the family Phytoseiidae Berlese 1916 of the superfamily Ascoidea Oudemans, 1905, as defined by Lundqvist (2009). Ribaga proposed the genus *Phytoseius* in 1902 and designated *Gamasus plumifer* Canestrini et Fanzago, 1876, as generotype. Athias-Henriot (1957) proposed the new name *ribagai,* and the species was considered as the generotype of *Phytoseius* (loc.cit. Chant & Athias-Henriot, 1960). Wainstein (1959) divided the genus *Phytoseius* in two new subgenera in the following way: sbg. *Phytoseius* Wainstein, 1959; type *P. plumifer* (C. & F.) and sbg. *Dubininellus* Wainstein, 1959, type *P. corniger* Wainstein, 1959. Given that Chant and Athias-Henriot (1960) correctly assumed that Ribaga (1902) misidentified this type of *Phytoseius*, Muma (1961, 1963) suggested that genus *Dubininellus* is a subjective synonym of genus Phytoseius.

The most important taxonomic characters of the genus *Dubininellus* are: dorsal shield with 15 pairs of setae of which there are four 4-5 lateral pairs (L), five dorsal pairs (D), four median pairs (M) and pair od setae S_1 is on the dorsal shield. Setae S_2 and D_7 are absent. Following pairs of dorsal setae are thick, thorny and pectinate: D_1, L_1, L_2, L_4, L_6, S_1, M_9 and M_{11}; setae L_4, L_6, M_9, M_{II} and S_1 are long; large setae on the dorsum are inserted in tubercles. Ventrally, sternal shield is typical for the family, bears three pairs of sternal setae (sI-sIII) and fourth pair (sIV) is on metasternal plates; genital shield with single pair of genital setae; ventrianal shield moderately narrowed behind the preanal setae, its widest part usually near the anus. Seta VL_1 thick, long and pectinate. The female with 1-3 pairs of preanal setae; the male, three. Male chelicera with an L-shaped spermatodactyl. Leg IV longer than other legs and with thick, smooth macrosetae: one on tibia and basitarsus, and frequently one on genu (Chant & Athias-Henriot, 1960); genu II with 7, genu III bears 6, genu IV with 7 setae (Wainstein, 1959). Measures of intrageneric variation are length, thickness and ornamentation of the lateral and median setae on the dorsal shield, shape of spermathecae, the number of preanal setae in the female, the relative lengths of the macrosetae on leg IV, and the ratios between the lengths of various setae.

Dubininellus ribagai (Athias-Henriot, 1960)

Material examined: Lazarevac, Baroševac, op 5.1; 08.X.2009, *Fragaria vesca* (1♀) (N: 44°25′01″; E: 20°22′55″;120 m). Comments: *Dubininellus ribagai* is a rare species, previously found only in Veneto, Italy, on *Urtica sp*. (Ribaga, 1902), in Alger, Algeria, on *Rubus ulmifolius* (Athias-Henriot, 1957) and *Vitis vinifera* in Annaba, Algeria, (Denmark, 1966), and also in Germany (Prpic, 2008), but there is no available data of host. Diagnosis: this species is characterized by having seta L2 only slightly longer than L1, and by the general relative shortness of the peripheral dorsal setae. The length of dorsal scutum is 280μm; M_{11}, L_4, L_6, M_9 70-95μm; their pectinations short, not spinelike; Leg IV with three macrosetae; Spermatheca with duct short, cylindrical, connected to vesicle by a small, subspherical thickening. (Athias-Henriot, 1957). Macrosetae on leg IV are not clubbed, macrosetae on tarsus and genu have simmilar length. L_3 = 101-107μm, L_6 = 99-111μm, M_{11} = 85-103μm, M_9 = 91-98μm, ventrianal shield bears two pairs of preanals, idiosoma of female 289-350μm (Karg, 1993). The measurements of single female found in our study are in accordance with previous descriptions: L_3=102.5μm, L_6= 100μm, M_{11}=85μm, M_9=92.5μm, idiosoma=300μm (fig.1).

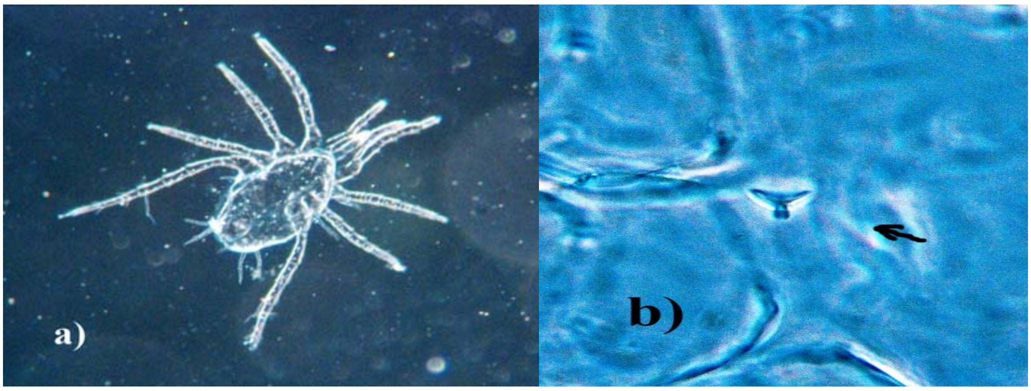

Figure 1. *Dubininellus ribagai* Athias-Henriot, 1960 (♀) : a) adult, b) spermatheca

Dubininellus maltshenkovae (Wainstein, 1973)

Material examined: Lazarevac, Baroševac, op.6.1; 08.X.2009, *Rubus caesius* (1♀) (N: 44°25′40″; E: 20°22′57″; 230 m). Lazarevac, Baroševac, op.5.1; 08.X.2009, *R. fructicosus* (2♀) *Rubus caesius* (2♀) (N: 44°22′49″; E: 20°22′37″; 202 m); Lazarevac, Mirosaljci-jezero *Rubus sp.* (1♀) (N: 44°25′57″; E: 20°23′11″; 120 m). Comments: *Dubininellus maltshenkovae* is not a frequent species, previously was found only in Sadovo, Moldova, on *Rubus sp*. (Wainstein, 1973), and also in Germany (Prpic, 2008), on *Rubus idaeus*. This species is characterized by having four slightly clubbed macrosetae on leg IV – two short macrosetae on tarsus, and one seta on tibia and genu; Calix of spermatheca ***has*** equal width and length; $L_3 = L_6 = 103$µm, $M_{11} = 94$µm, $M_9 = 90$µm; female idiosoma 310µm long and male idiosoma 210µm long (Karg, 1993). The measurements of several female found in this study are in accordance with previous description: L_3=104.2µm (100-112.5), L_6=103.8µm (100-107.5), M_{11}=94.6µm (90-97.5), M_9=91.3µm (87.5-97.5), idiosoma=310µm (297.5-315) (fig.2).

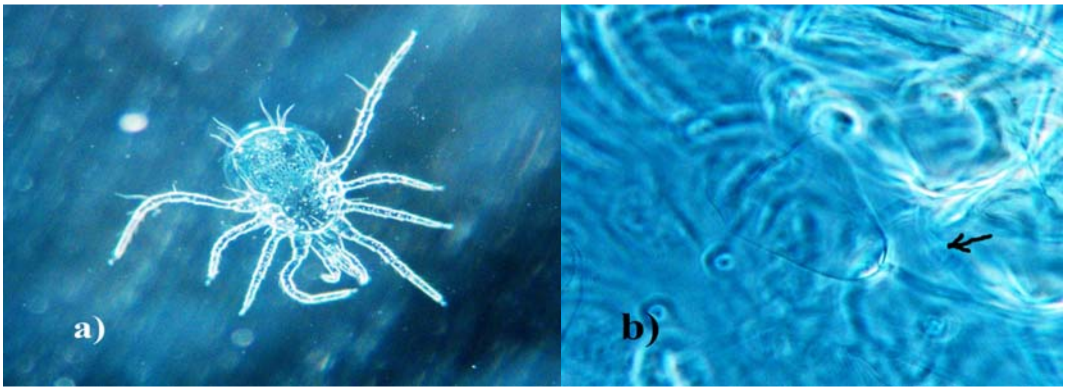

Figure 2. *Dubininellus maltshenkovae* Wainstein, 1973 (♀) : a) adult, b) spermatheca

Dubininellus juvenis (Wainstein et Arutunjan 1970)

Material examined: Lazarevac, Baroševac, op.5.1; 08.X.2009, *Rubus caesius* (1♀) (N: 44°22′49″; E: 20°22′37″; 202 m); Lazarevac, Mirosaljci-jezero 03.VIII.2009, *Rubus sp.* (5♀) 08.X.2009, *Rubus sp.* (1♀) (N: 44°25′57″; E: 20°23′11″; 120 m).

Comments: Dubininellus juvenis is a relatively frequent species (DeMoraes et al., 1986), and was collected in Armenia (*Corylus*, *Salix sp*), Crimea (*Rubus, Urtica sp.*), Kazakhstan (herbs, *Agrimonia, Malus, Salix* spp.), Moldova (*Cydonia, Rubus spp.*), Russia (*Rubus sp.*), Ukraine (*Acer negundo*, *Arctium sp.*, *Ballota nigra*, *Leonurus sp.*, *Malus sp.*, *Populus alba*, *Rubus caesius*, *Rubus sp.*, *Salix caprea*, *Salix sp.*, *Urtica sp.*), Finland (*Malus sp.*) and Serbia (Corylus avelana, C. colurna, Rubus idaeus) (Stojnić & Petanović, 1994). This species is characterized by having one short tarsal macroseta on tarsus, shorter than macroseta on genu, and three time shorter than tibial macroseta of leg IV; Calix of spermatheca ***is wide,*** bowl-shaped; $L_3 = L_6$ = 97-126μm, M_{11} = 87-111μm, M_9 = 84-119μm; female idiosoma 345μm long (Karg, 1993). The measurements of several female found in this study are: L3=100.8μm (97.5-105), L6=99.3μm (97.5-100), M11=95.8μm (92.5-102.5), M9=95.72μm (90-105), female idiosoma=343μm (337.5-350) (fig.3).

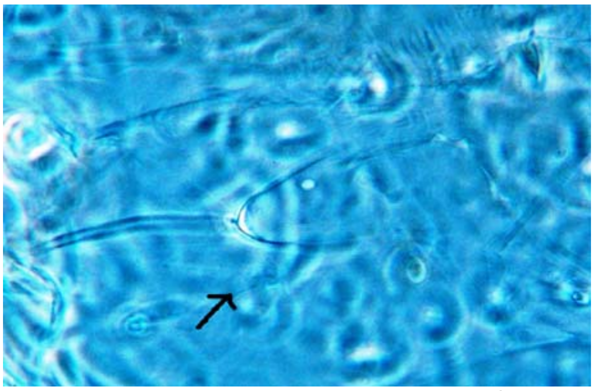

Figure 3. *Dubininellus juvenis* Wainstein et Arutunjan, 1970 (♀) : spermatheca

4. CONCLUDING REMARKS

There are more than hundred phytoseiid species already found on plants of genus *Rubus* (DeMoraes et al., 1986). The different types of blackberries and plums are the most frequently inhabited by palearctic species of the genus Dubininellus. Their presence on the other plant genera is less frequent. This observation was confirmed during these latest researches. The succession of spontaneous plant species in the artifically established stands is followed by mite species succession. Therefore, *Rubus* spp. is significant reservoir of phytoseiids in the shrub and weed layer, which is also confirmed by our previous researches (Stojnić, 2001). In the present study, two species of phytoseiid mites belonging to genus Dubininellus were recorded for the first time in Serbian acarofauna. As a result, the number of the reported species of the subfamily Phytoseiinae in our country increased to seven. This fact is is important since the biodiversity of this subfamily, according to the different sources, is proportionally small within the European fauna, with less than 20 registered species from genera Dubininellus and Phytoseius, whereas about 190 species from three known genera are found in the world. Therefore, the results obtained in our researches will enable the adding of the new faunal and zoogeographic data on the European phytoseiin mites.

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CLIMATE CHANGE, GYPSY MOTH OUTBREAK AND CHEMICAL INSECTICIDES

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Abstract: *The paper presents the results of testing the possibility of using the chemical insecticides of the third generation Avaunt ®, Alverde®, Coragen®, in forest ecosystems, in order to control gypsy moths outbreaks, when its numbers significantly exceed the threshold for use of biological insecticides. In laboratory conditions, preparations showed excellent biological efficacy.*

Key words: biological efficacy, Avaunt®, Alverde®, Coragen®, laboratory studies

INTRODUCTION

Biological insecticides based on *Bacillus thuringiensis* var. *kurstaki* (*Btk*) have been generally accepted and lately most applied pesticides in the suppression of one of the most important economically harmful species of defoliators from the order of *Lepidoptera* - the gypsy moth (*Lymantria dispar* L) during its progradation phase, when the density is low. This is in correlation with the fact that their biological efficacy is never 100% and that a part of the target population always remains alive. During the culmination phase of the outbreak, when the density of the target insect is maximal (several tens of thousands of egg masses per hectare), if biological preparations are applied even with the excellent efficacy, the part of the population which remains alive often causes the damage of such proportions that, at the first glance, it makes the efficacy of the preparation doubtful (Tabakovic-Toshic, 2005).

Btk insecticides which are used for the control of gypsy moth show the best efficacy on the younger larval instars (L_1 and L_2). The older instars require higher lethal doses, so very often the applied rates of the preparation cause sublethal effects and the loss is even greater than that caused by the larvae in the untreated areas, because one of the consequences of sublethal doses is the prolonged larval development. This fact is especially emphasised during the unfavourable meteorological conditions which lead to prolonged hatching and to washing down of a part of the applied preparation. As a consequence, the age structure of the treated population larvae is most often from L_1 to L_4, and the rate of the active ingredient is reduced so that it does not have the lethal potency (Tabakovic-Toshic, 2005).

The unfavourable meteorological conditions (precipitation, wind, low temperatures) in the optimal period for aerial suppression, often lead to its postponing. As a result, number of larvae matures when the biological effectiveness of *Bacillus thuringiensis* ssp. *kurstaki* preparation is considerably lowered or insufficient. The temperature optimum for the gypsy moth development is between 20 and 30ºC. At the lower temperatures, the susceptibility of larvae to biological insecticide is lower. Due to cold and rainy weather, immediately after the aerial application, larvae feeding intensity is lower, so the dose of the consumed bioinsecticide is sublethal, i.e. the quantity of the absorbed bacterium and its products is not sufficient to develop the lethal bacteriosis. (Tabakovic-Toshic, 2005).

Natural sunlight (the active spectrum is between 290 and 400 nm) is the most destructive environmental factor effecting the persistence of entomopathogenus. Salama et al. (1983) found that one day of the direct sunlight could inactivate over 90% of *Btk* spores on potted white

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spruce. The trees themselves in the dark can inactivate 78% of the spores in 14 days. Endotoxin activity was also reduced. However, it required about 8 times more light exposure (3.8 h) to obtain a 50% loss in insecticidal activity (Ignoffo, 1992). Wavelengths in the 300/380 nm range of the solar spectrum are largely responsible for loss of toxicity in purified *Btk* crystals. Sunlight radiation has been proved to cause tryptophan destruction in protein crystals (Pozsgay et al., 1987).

It is hypothesised that the above problems can be satisfactorily solved by using the chemical (biotechnical) insecticides of the third generation such as Avaunt®, Alverde® and Coragen®.

MATERIAL AND METHOD

During May 2009, the biological efficacy of the three chemical insecticides were tested in laboratory conditions.

Avaunt® 15 SC (active ingredient - indoxacarb) Coragen® 20 SC (active ingredient - chlorantraniliprole) and Alverde® 240 SC (active ingredient - metaflumizone) are modern chemical (biotechnical) non-systemic pesticides of the third generation, active by ingestion, less by contact. Indoxacarb and metaflumizone inhibits the sodium ions entry into nerve cells, which paralyses the larvae and causes the cessation of feeding and insect death This mode of action requires no metabolism for toxicity to target insects. Chlorantraniliprole is a diamide insecticide. The mode of action of chlorantraniliprole is the activation of insect ryanodine receptors. This activation stimulates the release of calcium from the internal stores of smooth and striated muscle which causes impaired muscle regulation, paralysis and insect death.

After foliar applications, most of the active ingredients remain on the leaf surface and a small amount penetrates into the leaf tissue. They are highly potent and active at low rates on target species, which are mainly Lepidoptera and also some Coleoptera and Diptera. The Reduced Risk Committee categorized indoxacarb, chlorantraniliprole and metaflumizone as the "reduced risk" pesticides.

Table 1. *Variants (rates) of the applied preparations in the laboratory tests of their biological efficacy*

Code	Name	Dose
1a, 1b*	Avaunt® 15 SC	250 ml /ha + 750 ml/ha white oil + water up to 1000 l/ha
2a, 2b	Coragen® 20 SC	200 ml /ha + 800 ml/ha white oil + water up to 1000 l/ha
3a, 3b	Alverde® 240 SC	100 ml /ha + 900 ml/ha white oil + water up to 1000 l/ha
4a, 4b	distilled water	1000 l/ha

*a – natural food; b – synthetic food

The experiments of biological efficacy of pesticides presented in Table 1 were established in May 2009, during the third larval instar of the gypsy moth. From the beginning of feeding till the end of the two groups of experiments the caterpillars were fed with the natural (Pedunculate oak leaves) and synthetic food, but from the third instar the food was shortly soaked in water solutions of the analysed doses of the preparation (Table 1). During the experiments, temperature and light conditions were constant (temperature 21°C, light regime - 10 hours night, 14 hours a day) The potency was controlled 26, 168 and 264 hours after the establishment of the experiments, and the individuals which survived in the treated and control groups were monitored till the end of the development.

All experiments were established in the complete random block pattern in four repetitions, where the blocks for each variant present 3 Petri dishes with the corresponding number of larvae (15).

The statistical processing consisted of the analysis of variance, the calculation of the mean value of the number of dead larvae, efficacy by Abbott (E), as well as the testing of the differences of mean values of mortality (LSD test).

RESULTS AND DISCUSSION

During May 2009, the biological efficacy of chemical insecticides of the third generation (Avaunt®, Alverde®, Coragen®), were studied in the Institute of Forestry in Belgrade, in the aim of the maximal increase of biological efficacy in the suppression of gypsy moth (*Lymantria dispar* L.) outbreak at the density when the application of the microbiological insecticide does not produce the satisfactory results. The study results are presented in Table 2.

Table 2. *Biological efficacy of the tested insecticides in the suppression of the third larval instar of the gypsy moth*

Code	Number of alive larvae per repetition								X mean		E by Abbott (%)	
	I		II		III		IV					
	a	b	a	b	a	b	a	b	a	b	a	b
26 hours after the test establishment												
1	0.0	8.3	0.0	9.3	0.0	6.3	0.0	6.3	0.0	7.6	100	47.40
2	3.0	14.0	2.7	12.7	2.0	12.0	6.0	11.7	3.4	12.6	76.41	12.76
3	3.0	11.0	1.3	14.7	0.3	14.0	3.7	12.7	2.1	13.1	85.65	9.29
4	15.0	14.7	15.0	13.7	15.0	14.3	13.0	15.0	14.5	14.4		
168 hours after the test establishment												
1	0.0	1.7	0.0	6.7	0.0	2.7	0.0	2.0	0.0	3.2	100	77.19
2	0.3	0.7	0.3	1.0	0.0	1.7	1.3	0.0	0.5	0.8	96.55	94.24
3	0.0	4.7	0.0	4.0	0.0	2.7	1.3	3.3	0.3	3.2	97.72	78.02
4	15.0	14.7	15.0	13.7	15.0	14.3	13.0	15.0	14.5	14.4		
264 hours after the test establishment												
1	0.0	0.0	0.0	1.7	0.0	0.3	0.0	0.3	0.0	0.6	100	95.93
2	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.5	100	96.53
3	0.0	0.7	0.0	1.0	0.0	0.0	0.0	0.3	0.0	0.5	100	96.53
4	15.0	14.7	15.0	13.7	15.0	14.3	13.0	15.0	14.5	14.4		

1- Avaunt® 15 SC   2 - Coragen® 20 SC   3 - Alverde® 240 SC   4 - distilled water
a – natural food   b - synthetic food

In laboratory conditions, 168 hours after the experiment was established, the best biological efficacy was attained by Avaunt® 15 SC (100%), then by Alverde® 240 SC (97.72%), and somewhat lower by Coragen® 20 SC (96.55%). All caterpillars were fed with natural food.

After 264 hours, this group showed a maximum 100% biological efficiency. Biological efficiency in the experimental group with synthetic food, was slightly lower for all insecticides (Table 2).

Generally, the tested insecticides showed slightly lower performance in the second experiments where the caterpillar fed synthetic food.

Table 3. *LSD test at the probability level 95% for biological efficacy*

** Contrast	Difference in biological efficacy		
	after 26 hours (+/- Limits: 1.84092)	*after 168 hours* (+/- Limits: 1.52068)	*after 264 hours* (+/- Limits: 0.798054)
1a – 1b	*-7.58	*-3.2525	-0.5825
1a – 2a	*-3.4175	-0.4975	0.0
1a – 2b	*-12.585	-0.835	-0.5
1a – 3a	*-2.0825	-0.3325	0.0
1a – 3b	*-13.085	*-3.6675	-0.5

** Contrast	Difference in biological efficacy		
	after 26 hours (+/- Limits: 1.84092)	*after 168 hours* (+/- Limits: 1.52068)	*after 264 hours* (+/- Limits: 0.798054)
1a – 4a	*-14.5	*-14.5	*-14.5
1a – 4b	*-14.4175	*-14.4175	*-14.4175
1b – 2a	*4.1625	*2.755	0.5825
1b – 2b	*-5.005	*2.4175	0.0825
1b – 3a	*5.4975	*2.95	0.5825
1b – 3b	*-5.505	-0.415	0.0825
1b – 4a	*-6.92	*-11.2475	*-13.9175
1b – 4b	*-6.8375	*-11.165	*-13.835
2a – 2b	*-9.1675	-0.3375	-0.5
2a – 3a	1.335	0.165	0.0
2a – 3b	*-9.6675	*-3.17	-0.5
2a – 4a	*-11.0825	*-14.0025	*-14.5
2a – 4b	*-11.0	*-13.92	*-14.4175
2b – 3a	*10.5025	0.5025	0.5
2b – 3b	-0.5	*-2.8325	2.0000
2b – 4a	*-1.915	*-13.665	*-14.0
2b – 4b	-1.8325	*-13.5825	*-13.9175
3a – 3b	*-11.0025	*-3.335	-0.5
3a – 4a	*-12.4175	*-14.1675	*-14.5
3a – 4b	*-12.335	*-14.085	*-14.4175
3b – 4a	-1.415	*-10.8325	*-14.0
3b – 4b	-1.3325	*-10.75	*-13.9175
4a – 4b	0.0825	0.0825	0.0825

** Legend in Table 2

* statistically significant differences

Table 4. *Test of the least significant differences per experiment groups*

Code*	Homogeneous groups					Code	Homogeneous groups			Code	Homogeneous groups	
After 26 hours						After 168 hours				After 264 hours		
1a	X					1a	X			1a	X	
3a		X				3a	X			3a	X	
2a		X				2a	X			2a	X	
1b			X			2b	X			3b	X	
2b				X		1b		X		2b	X	
3b				X	X	3b		X		1b	X	
4b				X	X	4b			X	4b		X
4a					X	4a			X	4a		X

* Legend in Table 2

The analysis of variance shows the statistically significant differences between the study variants 168 hours after exposure (F=140.73; p=0.000). LSD test shows that there are no statistically significant differences between three insecticides in the group with natural food and Coragen® 20 SC with synthetic food. The highest statistically significant differences are found between the control groups and other (Table 2 and 4).

In the third evaluation (264 hours after exposure), the biological efficacy of the three preparations in both groups of feeding was maximal (95.93% and 100%) (Table 2). The analysis of variance shows the statistically significant differences between the study variances on the one side, and both control groups on the other side (F=578.39; p=0.000) LSD test shows that, at the end of the experiment, the study preparations formed 2 homogeneous groups within which there are no statistically significant differences (Table 4) of biological efficacy in the suppression the gypsy moth larvae.

CONCLUSION

The results of the laboratory studies of biological efficacy of three chemical insecticides of the third generation (Avaunt®, Alverde®, Coragen®) in the suppression of gypsy moth (*Lymantria dispar* L), showed that their biological efficacy was maximal. They have all the necessary properties (high biological efficacy, mechanism of action, resistance to watering and a small amount of application) for use in forest ecosystems.

Also, these insecticides may be used as part of an Integrated Pest Management program to control pest which can include biological, cultural, and genetic practices aimed at preventing economic pest damage.

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CLIMATE CHANGE, GYPSY MOTH OUTBREAK AND CHEMICAL INSECTICIDES

Mara TABAKOVIC-TOSHIC, Snežana RAJKOVIC

Summary

In forest ecosystems in Serbia, biological insecticides based on *Bacillus thuringiensis* ssp. *kurstaki* (Btk) have been generally accepted and lately most applied pesticides in the suppression of the gypsy moth (*Lymantria dispar* L), i.e. during its progradation phase, when the density is relatively small. During the culmination phase, when the density of the target insect is maximal, if biological preparations are applied even with the excellent efficacy, the part of the population which remains alive often causes the damage of such proportions that, at the first glance, it makes the efficacy of the preparation doubtful.

Also, *Btk* insecticides show the best efficacy on the younger larval instars. The older instars require higher lethal doses, so very often the applied rates of the preparation cause sublethal effects and the loss is even greater than that caused by the larvae in the untreated areas, because one of the consequences of sublethal doses is the prolonged larval development. This fact is especially emphasised during the unfavourable meteorological conditions which lead to prolonged hatching and to washing down of a part of the applied preparation. As a consequence, the age structure of the treated population larvae is most often from L_1 to L_4, and the rate of the active ingredient is reduced so that it does not have the lethal potency.

When number is greater, it is assumed that so-called “soft“ ecotoxicologically favourable preparations Avaunt®, Alverde®, Coragen®, registered for application in agriculture, but not in forestry, can be used for inhibition of multiplication.

Results of laboratory studies of biological efficiency of above preparations showed that they have preconditions for application in forest ecosystems. The 100% biologic efficiency, mechanism of rapid inhibition of larvae feeding, and thereby inhibition of leaf mass damage, resistance to water rinsing, high selectivity, and small quantities of application, anticipated a bright future for them.

ENTOMOPHAGA MAIMAIGA – A FACTOR FOR INCREASING STABILITY AND ENHANCING BIODIVERSITY IN OAK FORESTS ON THE BALKAN PENINSULA

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Abstract: *Entomophaga maimaiga, a pathogen of Lymantria dispar in Asia, was successfully introduced in Bulgaria in 1999. The first epizootics caused by this fungus occurred in 2005 and three recent epizootics occurred in the immediate vicinity of Bulgarian borders with Serbia, Greece and Turkey (6-12 km), suggesting that the fungal pathogen has spread naturally to three of the neighbouring countries. No massive L. dispar outbreaks have been recorded recently in Bulgaria, possibly due to the impact of this entomopathogen. We believe that it is desirable to initiate a monitoring program and to augmentatively expand the range of E. maimaiga as an alternative to the use of chemical and Bacillus thuringiensis insecticides, which are a threat for the stability and biological diversity in oak forests of the Balkan Peninsula.*

Key words: *Lymantria dispar*, *Entomophaga maimaiga*, *Quercus*, biodiversity conservation

The gypsy moth, *Lymantria dispar* L. (Lepidoptera: Lymantriidae) is a Palaearctic species originating from Europe, North Africa, Asia and Japan. Currently, the species is sub-cosmopolitan because it is established in North American where it was accidentally introduced in the mid-1800s (Speare, Colley, 1912) and in New Zealand in 2003 (Barlow et al., 2000).

The gypsy moth is highly polyphagous, feeding on more than 250 deciduous and coniferous species of trees and shrubs (Liebhold et al., 1995). In Bulgaria it is mainly associated with poplars (*Populus* spp.) and oaks (*Quercus* spp.) in lowland, hilly and low-mountain areas up to 800 m a.s.l. The gypsy moth periodically causes outbreaks and, in years of high population densities, defoliations of 100-370 thousand ha are regularly observed in Bulgaria's oak forests (Georgiev et al., 2007). Defoliation of the trees in consecutive years causes physiological weakening of trees, rendering them vulnerable to attacks by pathogenic fungi and wood boring insects. Weakened trees are also affected by other stress factors and may die after a single defoliation in a subsequent year.

Entomophaga maimaiga Humber, Shimauzu & Soper (Entomophtorales: Entomophtoraceae), originally described as a fungal strain from *Lymantria dispar japonensis*, was collected in central Honshu, Japan, in 1984 (Hajek, 1999) and epizootics naturally occur in populations of *L. dispar* in Northern Japan, Eastern Russia (Primorsky Region and Sakhalin Island), South Korea, Northern China (Jilin and Heilongjiang Provinces), and in populations of the closely related *Lymantria obfuscata* Walker – in Kashmir (Hajek, 1999). The fungus was first introduced into North America (Massachusetts) in 1910-1911 (Speare, Colley, 1912) but was never reported to have been established (Hajek et al., 1995). Another isolate of *E. maimaiga* from Ishikawa Prefecture in Japan was later released in 1985 and 1986 in New York and Virginia (Nielsen et al., 2005). In 1989 the pathogen was recovered in the Northeastern US when it caused a panzootic in several states (Andreadis, Weseloh, 1990, Smitley et al., 1995). There are different hypotheses about the establishment of *E. maimaiga* in North America but the species was most probably accidentally introduced into the US prior to its detection in 1989

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(Nielsen et al., 2005; Hajek et al., 2007). During the last decade, a large scale program was implemented to monitor the spread and to redistribute *E. maimaiga* to coincide with the distribution of *L. dispar* populations in the US (Hajek, 1997). The pathogen currently occurs in gypsy moth populations in 17 states in the US (Smitley et al., 1995; Hoover, 2000; Balser, Baumgand, 2001; Hajek et al., 2005) and in Ontario, Canada (Howse, Scarr, 2002).

The life cycle of *E. maimaiga* is well synchronized with the development of its *L. dispar* host. The fungus reproduces in the hemolymph and shortly before infected larvae die, it invades other organs and tissues. After death, hyphal bodies form in the hemolymph and produce either resting spores inside the body of the host, conidiophores that grow out through the integument and actively release conidia, or both types of infective spores. Infections in early instars of gypsy moth predominantly produce conidia, and the relatively short-lived conidia are ejected from cadavers to infect new hosts. When later instar hosts are infected, resting spores are produced. *E. maimaiga* is effective in both high and low density gypsy moth populations but according to Elkinton et al. (1991), the efficiency depends only on the amount of rainfall in May and June. A series of studies were conducted over a period of years to determine the host specificity of *E. maimaiga*. The data from field and laboratory experiments characterize the fungus as a very host specific pathogen of the gypsy moth that is not harmful to non-target organisms (Hajek et al., 1995, 1996, 2000).

Bulgaria is the first country in Europe where *E. maimaiga* was successfully introduced and became established (Pilarska et al., 2000, 2006, 2007; Georgiev et al., 2007). The fungus was imported from the US and introduced on six different occasions to *L. dispar* populations in the region of State Forestries (SF) Svoge (1996 and 2001), Karlovo (1999), Assenovgrad (2001), Nova Zagora (2008), Popovo (2009) and Gorna Oriahovitsa (2009) (Fig. 1). After the first introduction in 1996, the fungus was not recovered, however after a second introduction in the region of SF Karlovo, 6.3% of collected host larvae werefound to be infected (Pilarska et al., 2000). During the period 2000-2003, infections caused by *E. maimaiga* were recorded in 6.1-15.9% of host larvae collected in the region of SF Karlovo and in 8.813.8% of host larvae from the region of SF Svoge (Pilarska et al., 2006).

One of our concerns after introducing the fungus into *L. dispar* population in Karlovo and Svoge Forestries sites was that *L. dispar* populations were at very low densities. However, our results from both sites indicate that *E. maimaiga* has persisted despite the low density of its host. In 2005, massive mortality of gypsy moth larvae caused by a fungal pathogen occurred at four sites in Bulgaria (SF Haskovo, Kirkovo, Botevgrad and Govezhda) located 30-70 km from our introduction sites in 2000 and 2001 (Georgiev et al., 2007; Pilarska et al., 2007) (Fig. 1).

Fig. 1. *Localities of Entomophaga maimaiga in Bulgaria*

In 2009, a research project funded by the National Science Fund of Bulgaria for monitoring the occurrence of *E. maimaiga* in Bulgaria and its impact on *L. dispar* and the rest representatives of the entomofauna in oak forests was initiated. Investigations showed that the fungus has spread into most gypsy moth populations in the country. In addition to the localities where it was introduced (Svoge, Karlovo, Assenovgrad, Nova Zagora, Popovo and Gorna Oriahovitsa) and the sites where epizootics were observed (Govezhda, Botevgrad, Haskovo and Kirkovo), *E. maimaiga* was also recorded in two new localities – Ravna gora and Zvezdets (Fig. 1).

Three of the localities where *E. maimaiga occurs* are in close proximity to the borders with Serbia (Govezhda, 12 km), Greece (Kirkovo, 6 km) and Turkey (Zvezdets, 8 km). There is reason to assume that the pathogen most probably has already naturally spread to the border territories of Serbia (the region of Pirot), Greece (Aegean Thrace) and Turkey (Eastern Thrace and Strandzha Mt.) and may have spread to FYR Macedonia and Romania as well. It is interesting to note that mortality of gypsy moth caused by an entomophthoralean fungus (most probably *E. maimaiga*) was recorded in Georgia in 2005 (Kereselidze and Pilarska, personal communication). *E. maimaiga* was also introduced from the US into Romania and Russia (Novosibirsk) but its establishment there has not been confirmed (Hajek et al., 2005). Although we do not yet have DNA evidence to prove that the cause of larval mortality in Bulgaria and Georgia was *E. maimaiga*, we believe this is the case because it has been estimated that this fungus can disperse widely via windborne conidia, and has spread more than 100 km in one season (Elkinton et al., 1991. According to Hajek (1999), however, long-distance spread of *E. maimaiga* conidia on the wind appears very likely but has not been proven.

From the point of view of forest protection science and practice, it is would be reasonable to detect and monitor *E. maimaiga* in Bulgaria's neighbouring countries. Biological material (cadavers of dead gypsy moth larvae) should be used for introduction into new sites where outbreaks of *L. dispar* occur. This will extend *E. maimaiga* distribution and will support its establishment in the region. The introduction and establishment of *E. maimaiga* on Balkan Peninsula enriches the natural enemy complex of *L. dispar*. The expansion of the fungal range and its adaptation to its host is a long process but this will increase stability within deciduous forest ecosystems.

Currently, pest management organizations in South and Central European countries use the bacterial pathogen *Bacillus thuringiensis* var. *kurstaki* (*Btk*) and a broad spectrum insecticides such as Dimilin and Mimic to manage damaging gypsy moth larval populations; however their use particularly that of chemical pesticides, is controversial because they are not highly specific and may affect many other non-target insect species and aquatic organisms, and thus have a negative effect on the forest ecosystems biodiversity (Miller, 1990). While *Btk* has a narrower spectrum, mortality of more than 60% of lepidopteran larvae was observed (Peacock et al., 1998).

The presence of *E. maimaiga* in gypsy moth populations would potentially allow the reduction of use of both microbial and chemical pesticides, which are expensive to apply and are toxic to various non-target organisms. Furthermore, *E. maimaiga* is very host-specific and its resting spores are known to persist in forest soils for more then 10 years, providing a source of inoculum over time. We believe that Serbia, Greece and Turkey will conduct monitoring programs on distribution of *E. maimaiga* in border areas near Bulgaria. Should epizootics occur those areas, it is desirable to augmentatively expand the range of *E. maimaiga* in oak forests newly attacked by *L. dispar*. We also suggest that other countries from Balkan Peninsula and South-eastern Europe, such as FYR Macedonia, Bosnia and Herzegovina, Croatia, Slovakia and Hungary, should consider introducing the entomopathogen as a classical biological control agent against this serious forest pest.

We believe that the establishment of *E. maimaiga* in Europe will increase stability within deciduous forest ecosystems, decrease the frequency and intensity of *L. dispar* outbreaks, and reduce the use of insecticides. In addition, this will enhance the conservation of biodiversity and will improve the recreational quality of the forests.

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ENTOMOPATHOGENIC FUNGI ASSOCIATED WITH THE GYPSY MOTH EGGS

Slobodan MILANOVIĆ[1], Dragan KARADŽIĆ[2]

Abstract: *Along with the predatores and parasitoids, the microorganisms, such as microsporodia and entomopathogenic fungi have the important role in the regulation of the gypsy moth population abundance (Lymantria dispar L.). This paper presents the research results of the entomopathogenic fungi associated with the gypsy moth eggs, which are the potential agents in the biological control.*

Several fungi, out of which three were singled out as the potentially entomopathogenic, were isolated from eggs, which originate from Bagremara (Forest Management Unit Novi Sad, Forest Administration Backa Palanka). By the determination of the fungi, which were later used in the experiment, it was determined that the first one belong to Penicillium genus, the second one to Trichothecium genus, and that the third one is the species Engyodontium aranearum (Cavara) Gams et al. The gypsy moth is known to be the host for the species of the first two gena, whereas it was found in the third species for the first time.

The entomopathogenic characteristics of the isolated fungi were studied by the experiment in which the spore and mycelial suspensions were applied to the vital gypsy moth eggs. Thirty days after the setting of the experiment, and after the hatching, the number of the non-hatched eggs was determined in each dish.

By the analysis of variance and LSD test, the significant differences among the group treated by the spore and mycelial suspensions of Engyodontium aranearum (Cavara) Gams et al. fungus, other experimental groups, as well as the control one, in the percentage of the non-hatched eggs were determined.

Keywords: Gypsy moth, eggs, pathogenic fungy

ENTOMOPATOGENE GLJIVE JAJA GUBARA

Izvod: *U regulaciji brojnosti gubara (Lymantria dispar L.), pored predatora i parazitoida, značajnu ulogu mogu imati i mikroorganizmi kao što su mikrosporidije i entomopatogene gljive. U ovom radu prikazani su rezultati preliminarnih istraživanja entomopatogenih gljiva jaja gubara koje prestavljaju potencijalne agenase u biološkoj borbi.*

Iz jajnih legal poreklom iz Bagremare (Šumsko gazdinstvo Novi Sad, Šumska uprava Bačka Planka, izolovano je više gljiva od kojih su tri izdvojene kao potencijalno entomopatogene. Determinacijom gljiva koje smo kasnije koristili u ogledu utvrđeno je da prva pripada rodu Penicillium, druga rodu Trichothecium a da je treća vrsta Engyodontium aranearum (Cavara) Gams et al.,. Gubar je za vrste iz prva dva roda poznat kao domaćin, dok je za treću vrstu ovo prvi nalaz.

Ispitivanje entomopatogenih svojstava izolovanih gljiva izvršeno je ogledom u kome su nanošene suspenzije spora i micelija na vitalna jaja gubara. 30 dana po postavljanju ogleda i posle završenog piljenja utvrđen je broj neispiljenih jaja u svakoj posudi.

Analizom varijanse i LSD testom utvrdili smo postojanje značajne razlike u procentu neispiljenih jaja za grupu tretiranu suspenzijom spora i micelije gljive Engyodontium aranearum (Cavara) Gams et al. u odnosu na druge dve eksperimentalne i kontrolnu grupu.

Ključne reči: gubar, jaja, patogene gljive

1. INTRODUCTION

In the population regulation of gypsy moth (*Lymantria dispar* L.), along with predatores and parasitoides (Ristić *et al.*, 1998), the microorganisms, such as entomopathogenic fungi,

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microsporidia (Weiser, 1964), bacteria and viruses (Martignoni and Iwai, 1981), can have an important role. Fungi can have the important role in the population regulation of the population of harmful insects during the latent period, but can also be the cause the collapse of the outbreak. The effectiveness of the microorganisms in population reduction depends upon several factors, the most important of which are the following: quantity of the pathogen inoculant, environmental conditions, the way in which the infection is performed (close contact infection, or by ingestion), host population density, the presence of the secondary or alternative hosts.

The advantage of the fungi over other microorganisms, as the reducer of the pest population, is reflected in the fact that the infection is performed by contact, i.e. the ingestion is not necessary, as in the bacteria, viruses, etc, so the increase of the quantity of inoculant also implies the increase of their effectiveness in the host population regulation if the environmental conditions are favourable. In gypsy moth, the larval development of which occurs in spring, when the relative humidity and temperature are favourable, the fungus *Entomophaga maimaiga* can cause the collapse of the outbreak (Weseloh and Andreadis, 1992).

The attention of the research scientists, who study the entomopathogenic fungi, is directed to the fungi which occur on the gypsy moth eggs, for the same reasons as the egg parasites: the long period of the exposure to the pathogen, the wide range of the different environmental conditions since the egg instar of the gypsy moth lasts for nine months and is present in every season, the prevention of the potential damages. The total of 21 fungal species was isolated from the gypsy moth eggs (Humber, 1992).

This paper presents the results of the preliminary researches of the possibilities of the use of pathogenic fungi as the potential agents in the biological control of the gypsy moths.

2. MATERIAL AND METHODS

By the laboratory tests of the gypsy moth eggs, which originate from Bagremara (Forest Management Unit Novi Sad, Forest Administration Backa Palanka), the presence of the dead eggs with the symptoms of mycosis was reported. Several fungi, out of which three were singled out as the potentially entomopathogenic, were isolated from these eggs. The entomopathogenic characteristics of the isolated fungi were studied by the experiment in which the spore and mycelial suspensions were applied to the vital gypsy moth eggs, which prior to the application were divided into four experimental groups (one for each fungi species and one as control). In the petri dishes 200 eggs were set, which after five repetitions and four treatments implies the total of 400 eggs in the experiment. Prior to the hatching the eggs were preserved at 20 ^{0}C, and the moisture necessary for the infection was provided by the everyday drenching of the cotton wool tampons in the petri dishes. Thirty days after the setting of the experiment, and after the hatching, the number of the non-hatched eggs was determined in each dish.

By the re-isolation of the applied fungi after the experiment from the treated eggs their pathogenicity was confirmed.

The statistical data procession implied the variance analysis and LSD test.

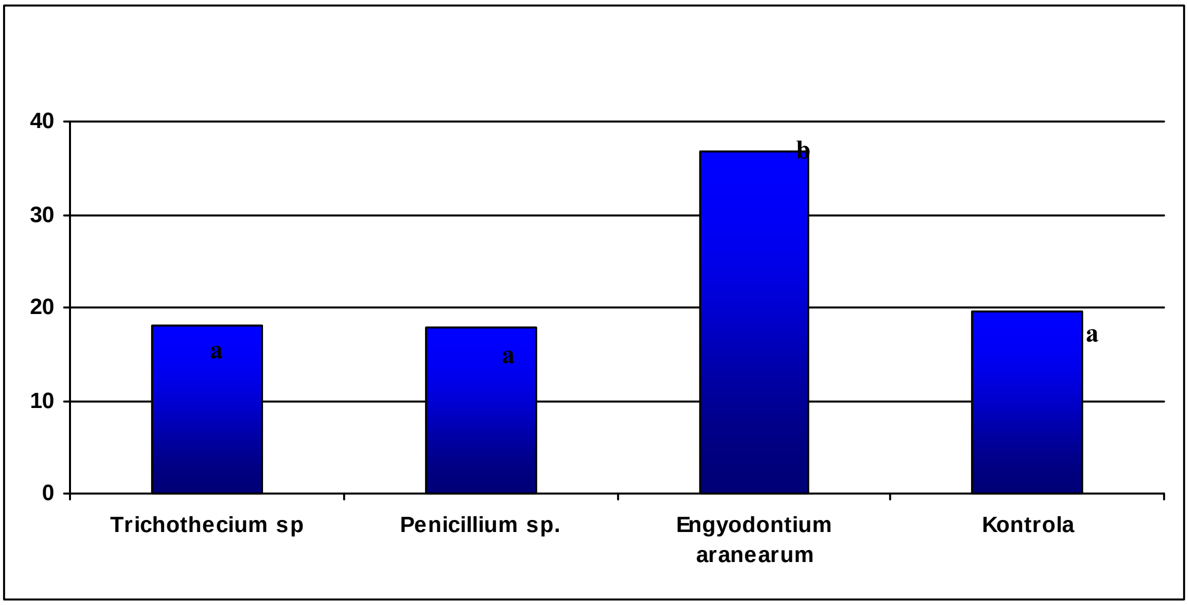
3. RESULTS AND DISCUSSION

By the determination of fungi which were used in the experiment it was determined that the first species belongs to *Penicillium* genus, the second species to *Trichothecium* genus, and the third species to *Engyodontium aranearum* (Cavara) Gams et al., and all these species belong to Deuteromycota (= Fungi imperfecti) class. It is known that the gypsy moth is the host for the species from the first two gena, whereas the third species has been found on it for the first time.

So far this species has been found on the *Pholcus phalangoides* (Pholcidae: Aranae) (Humber, 1992) species.

By the variance analysis the significant differences in the percentage of the unhatched eggs between the observed groups (F=4,70, p<0,05) were determined. By LSD test it was determined that the percentage of the unhatched eggs treated by the suspension of spores and mycelium of *Engyodontium aranearum* (Cavara) Gams *et al*. fungus, is significantly higher in comparison with two other groups and the control one. There are no statistically significant differences in the number of the unhatched eggs between the control groups and the groups treated by the suspension of spores and mycelium of *Trichothecium* sp. and *Penicillium* sp. fungi.

Graph 1: *Number of unhatched gypsy moth eggs 30 days after treatment*



Columns with the same letter are not significantly different

5. CONCLUSIONS

From the gypsy moth eggs with the symptoms of mycosis three potentially entomopathogenic fungi *Tricothecium* sp., *Penicillium* sp. and *Engyodontium aranearum* (Cavara) Gams *et al*. were isolated.

In the experiment for the study of pathogenicity of the selected fungi the most efficient was the species *Engyodontium aranearum* (Cavara) Gams *et al*.

By the re-isolation of the applied fungi after the experiment from the treated eggs their pathogenicity was confirmed.

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Summary

Along with the predatores and parasitoids, the microorganisms, such as microsporodia and entomopathogenic fungi have the important role in the regulation of the gypsy moth population abundance (*Lymantria dispar* L.). This paper presents the research results of the entomopathogenic fungi associated with the gypsy moth eggs, which are the potential agents in the biological control.

By the laboratory tests of the gypsy moth eggs, which originate from Bagremara (Forest Management Unit Novi Sad, Forest Administration Backa Palanka), the presence of the dead eggs with the symptoms of mycosis was reported. Several fungi, out of which three were singled out as the potentially entomopathogenic, were isolated from these eggs. By the determination of the fungi, which were later used in the experiment, it was determined that the first one belong to *Penicillium* genus, the second one to *Trichothecium* genus, and that the third one is the species *Engyodontium aranearum* (Cavara) Gams et al. All these fungi belong to Deuteromycota (= Fungi imperfecti) class. The gypsy moth is known to be the host for the species of the first two gena, whereas it was found in the third species for the first time.

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ENTOMOPATOGENE GLJIVE JAJA GUBARA

Slobodan MILANOVIĆ, Dragan KARADŽIĆ

Rezime

U regulaciji brojnosti gubara (*Lymantria dispar* L.), pored predatora i parazitoida, značajnu ulogu mogu imati i mikroorganizmi kao što su mikrosporidije i entomopatogene gljive. U ovom radu prikazani su rezultati preliminarnih istraživanja entomopatogenih gljiva jaja gubara koje prestavljaju potencijalne agenase u biološkoj borbi.

Laboratorijskim pregledom legala gubara poreklom iz Bagremare uočeno je prisustvo uginulih jaja sa simptomima mikoze. U jednom leglu procenat jaja sa simptomima mikoze bio je 23,6. Ovo nas je podstaklo da počnemo istraživanje ove pojave, što je podrazumevalo izdvajanje jaja sa simptomima mikoze, njihovu površinsku dezinfekciju, stavljanje na MEA hranljivu podlogu i izolovanje čistih kultura, posle razvoja micelije. Izolovano je više gljiva od kojih su tri izdvojene kao potencijalno entomopatogene. Determinacijom gljiva koje smo kasnije koristili u ogledu utvrđeno je da prva pripada rodu *Penicillium*, druga rodu *Trichothecium* a da je treća vrsta *Engyodontium aranearum* (Cavara) Gams *et al*., sve iz klase Deuteromycota (= Fungi imperfecti). Gubar je za vrste iz prva dva roda poznat kao domaćin, dok je za treću vrstu ovo prvi nalaz.

Ispitivanje entomopatogenih svojstava izolovanih gljiva izvršeno je ogledom u kome su nanošene suspenzije spora i micelija na vitalna jaja gubara, koja su pre aplikacije podeljena u četiri eksperimentalne grupe (po jedna za svaku vrstu gljiva i jedna kao kontrolna). U Petri posude je stavljano po 200 jaja što je sa pet ponavljanja i četiri tretmana činilo ukupno 4000 jaja u ogledu. Jaja su do završetka piljenja držana na temperaturi od 20 ^{0}C a neophodna vlaga za infekciju obezbeđena je svakodnevnim kvašenjem tampona vate u Petri posudama. 30 dana po postavljanju ogleda i posle završenog piljenja utvrđen je broj neispiljenih jaja u svakoj posudi.

Analizom varijanse i LSD testom utvrdili smo postojanje značajne razlike u procentu neispiljenih jaja za grupu tretiranu suspenzijom spora i micelije gljive *Engyodontium aranearum* (Cavara) Gams *et al*. u odnosu na druge eksperimentalne grupe i kontrolu.

THE INFLUENCE OF TEMPERATURE AND CONCENTRATION OF H-IONS ON THE GROWTH AND MASS PRODUCTION OF MYCELIUM *FOMITOPSIS PINICOLA* (SW.:FR.) P. KARST. ISOLATED FROM BEECH AND FIR

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Abstract: *Special importance is the impact of research more destructive fungi that cause a form of corruption - prismatic brown rot. Among these species, in our climate is one of the most common fungus Fomitopsis pinicola (Sw.: Fr.) P. Karst, which attack broadleaf and larch wood, and is being developed as a parasite and a saprophyte. Testing was done on influence of temperature and concentration of H - ions on the growth and mass production of mycelium and pH substrate change under the influence of this fungy. It was found that the range of development of both strain F. pinicola from 5 to 34^{0}C, while the optimum for its development is 29^{0}C, which coincides with the literature data. At constant pH values of the substrate mycelium of both strains F. pinicola had a maximum increase of the weaker acid substrate (pH 4.8). Tests on unpufered substrates showed that the mycelium F. pinicola weighing pH 2.3, where it recorded the largest weight of dry mass of mycelium.*

Keywords: temperature, pH, wood decay ing fungi, beech, fir

UTICAJ TEMPERATURE I KONCENTRACIJE H - JONA NA PORAST I PRODUKCIJU MASE MICELIJE *FOMITOPSIS PINICOLA* (SW.:FR.) P. KARST. IZOLOVANE SA BUKVE I JELE

Izvod: *Naročit značaj ima istraživanje uticaja gljiva koja izazivaju najdestruktivniji oblik truleži – mrku prizmatičnu trulež. Među ovim vrstama, na našem podneblju jedna od najčešćih je gljiva Fomitopsis pinicola (Sw.:Fr.) P. Karst, koja napada i lišćarsko i na četinarsko drvo, a razvija se i kao parazit i kao saprofit. Vršeno je ispitivanje uticaja temperature i koncentracije H – jona na porast i produkciju mase micelije, kao i promene pH supstrata pod uticajem ove gljive. Konstatovano je da je dijapazon razvoja oba soja F. pinicola od 5 do 34^{0}C, dok je optimum za njeno razviće 29^{0}C, što koincidira sa literaturnim podacima. Na konstantnim pH vrednostima supstrata micelije oba soja F. pinicola imale su maksimalan porast na slabije kiselom supstratu (pH 4,8). Ispitivanja na nepuferovanim podlogama pokazala su da je micelija F. pinicola težila pH vrednosti 2,3, gde je zabeležena i najveća težina suve mase micelije.*

Ključne reči: temperatura, pH, truležnice drveta, bukva, jela

1. INTRODUCTION

Familiarity with the basic physiological characteristics of the destructive agent in wood is a good base for the rational fight against the factors of destruction. Special importance belongs to the investigation of the impact of fungi on the decay of the most valuable part of the stem-heartwood. Among these species, in this region one of the most common fungi is *Fomitopsis pinicola* (Sw.:Fr.) P. Karst which causes the most destructive type of decay- brown cubical rot.

In order to reveal more about the nature of the fungus *Fomitopsis pinicola* (Sw.: Fr) P. Karst, as the destructive agent in wood investigations of the basic conditions which determine and enable the fungi to perform the infection were carried out. In natural conditions the main

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determinants of this process are temperature, ph of substrate, the level of inoculum, virulence and competition from other microorganisms (Cartwright, Findlay, 1946). In that sense, the impact of the temperature and hydrogen ions concentration in the substrate were studied as the basic parameters of the environment in which all processes of the infection and the rot development are performed during the certain period of time.

2. MATERIAL AND METHOD

Dikaryotic mycelium of the fungus *Fomitopsis pinicola* (Sw.: Fr.) P. Karst, which was used in the experiments was isolated using standard methods from the fruiting bodies taken from the beech and fir trees, from the national park Tara, at the locality Predov krst, Zvezda. Isolates were subcultured after every two months and they were cultivated in the mycotheca of the Institute for Forestry.

2.1. The influence of temperature on the growth of mycelium *Fomitopsis pinicola*

The experiment was set in a polythermostat on temperatures of 5, 8, 12, 16, 21, 25, 29 and 34°C. The base of malt and agar of standard concentration was used as the nutritive substrate. Inoculation with the fungus *F. pinicola* (isolates from beech and fir) was performed in a laminar chamber, with mycelium fragments of circular shape (D= 11mm), taken from the growing part of mycelium and set by the rub of a petri dish with a base. The growth of the mycelium was marked after every 24 hours and the average daily growth was calculated as the mean value of the daily growth lengths in three directions- in the direction of the radius of the dish and to the left and right under the angles of 22.5°C. For each fungus and each investigated temperature three replications were used. At the temperature of 34°C petri dishes were wrapped with paraffin film to slow down the drying of the base.

2.2. The influence of the substrate pH value

2.2.1. The influence of pH substrate on the growth of mycelium *F.pinicola* on buffered bases

For the investigation of the influence of different constant pH values on the development of mycelium *F.pinicola* (isolates from beech and fir), the buffered media was prepared. In order to equalize the quantity of nutrients in the certain parts of buffer, the buffered system was prepared according to the illustrated recipe, by Wolpert method, which was used by several authors (Miric, 1993, Rypachek, 1957). By mixing the 3 different volumes 0.3 molar suspensions of phosphates – phosphoric acid (H_3PO_4), potassium-hydrogen-phosphate (K_2HPO_4) and Potassium-dihydrogen-phosphate the basis with the different pH values were obtained, but with the same quantity of phosphate, so that their different quantity would not influence the results. In this way five series of phosphate of 187.5 ml which were poured into 5 erlenmayers, the volume of which was 300 ml were obtained.

2.2.2. The influence of mycelium *F. pinicola* on the change of pH nutrient substrate on unbuffered bases

For the study of the influence of fungus *F. pinicola* on the change of the pH value of the nutritive substrate, the unbuffered (liquid) media was prepared, according to Schmidt and Liese method (Miric, 1993). The quantity of 2.600 ml of the double concentrated malt base (10 Bé sugar) was prepared with the distilled water. Of this quantity 408 ml were poured into 6 erlenmayer bottles, 500 ml volume (for 6 series) in the defined quantity the suspension of distilled water and 1M HCl, or 1M NaOH was added. In this way the needed quantity of the liquid nutritive malt base of the standard concentration (5 Bé sugar) was obtained. Before the sterilization pH values if each series were measured. From each series 120 ml of base were poured into 12 erlenamayers 300 ml volume (for each of the four fungus, in 3 replications), so from 6 series the base was poured into 72 erlenmayers, which were sterilized in the autoclave for 20 minutes at 120 ± 1^0 C temperature and 1.4 b pressure. After the sterilization pH values were re-measured and they were treated as initial.

3. RESULTS AND DISCUSSION

The basic precondition for the understanding of the conditions which make it possible for the fungus to colonize the wood is the knowledge of its main physiological characteristics (Miric, 1993). The fungi isolated from the natural habitats, and then moved and grown in the laboratory conditions, are found in the unusual conditions of existence, which causes their rather different physiological activity (Vuchetic, 1985). It happens because it is hard to make conditions in the laboratory which adequately reflect the environmental conditions and variation in only one factor without the mutual influence. Therefore, the results obtained by the most accurate laboratory methods cannot be directly applied for the natural conditions, and they should be accepted only as the probable indicators of the possible phenomena (Miric, 1993).

3.1. The influence of temperature on the growth of mycelium *F.pinicola*

Results of the laboratory testing of the influence of different temperatures on the growth of mycelium *F. pinicola* from fir and beech, it can be concluded that the lower boundary temperature for the development of mycelium *F. pinicola* is 5°C (the growth was only 0.31mm /day). In the range between 5° and 21° there is an almost linear acceleration of growth, and at 21° and 25° the growth is almost the same (in isolates from fir there is only a slight increase from 4.3 to 4.39 mm/day; in isolates from beech the growth is slightly more distinguished and grows from 3.67 to 4.39 mm/day), whereas between 25° and 29° there is a sudden increase to 5.54 or 6.11 mm/day, respectively. The upper boundary temperature (maximum) is at about 34°C (at this temperature the growth is suddenly reduced to only 1.25 or 1.20 mm/day, respectively). The minimum temperature for the investigated fungi is about 5°C. The maximum temperature is about 34°C. The optimum temperature is at about 29°C.

3.2. Influence of pH values of substrate

The concentration of H- ions influences the growth and metabolism of the rot fungi, as well as the development of all plant species (Rypachek, 1957). Substrate acidity can influence the stimulation or inhibition of the growth of epixylous fungi, and the change of pH value has the important influence on the velocity of consumption of nutrients and substrate decomposition (Miric, 1993). According to Rayner and Boddy (1988) the lower threshold of growth of wood rotting fungi is in the region of pH 2 to 3, optimum between 4 and 6, and the causal agent of brown rot requires lower pH values than the causal agent of white rot. Jačevski (1933) noted that epixylous fungi develop in a substrate whose pH value is between 2 and 8.5 with an optimum between 4 and 6 which is the natural value of pH of most tree species.

3.2.1. The influence of pH values of the substrate on the growth of mycelium *F. pinicola*

On the basis of the results shown in table 1 it can be seen that mycelium of all investigated fungi developed on all bases with different investigated values of pH substrates, and that the growth on bases of certain, constant pH values was different.

Table 1. *Average daily growth of mycelium F. pinicola on buffered bases (mm/day)*

Number of series	pH of the base			Average growth of mycelium (mm/day)	
	Initial pH (after sterilisation)	pH at the end of the experiment			
		***F. pinicola* (fir)**	***F. pinicola* (beech)**	***F. pinicola* (fir)**	***F. pinicola* (beech)**
1	3,2	2,8	2,8	2,14	2,11
2	3,8	2,9	3,0	2,67	2,34
3	4,8	2,9	3,8	2,46	2,39
4	6,0	5,0	5,7	1,86	2,34
5	7,2	6,9	6,9	0,89	0,00

Mycelium *F. pinicola* from beech had maximum growth on a less acid substrate (pH 4.8), whereas the isolate *F. pinicola* from fir had maximum growth in a slightly more acid environment pH 3.8. Decrease of growth is even more distinguished on the weak acid substrate, whereas on the week base substrate (pH 7.2) the growth is almost completely reduced, so that it is absent for the isolate *F. pinicola* from beech, and for the isolate *F. pinicola* from fir it amounts to only 0.89 mm/day. On the strong acid substrate (pH 3.2) the growth of isolate *F. pinicola* from beech is highly reduced and amounts to 2.11 mm/day. Isolate *F. pinicola* from fir has faster growth on a stronger acid substrate (pH 3.2) which amounts to 2.14 mm/day.

3.2.2. Influence of mycelium *F. pinicola* on the change of pH nutritive substrate

Table 2 shows the changes of pH of the nutritive malt base of standard concentration under the influence of mycelium *F. pinicola* from fir.

Table 2. *Change of pH values of base under the influence of mycelium F. pinicola (isolate from fir), regarding the time of action*

Number of series	Initial pH (after sterilisation)	Change in pH of the base				Weight of the dry mass of mycelium (gr)
		After 7 days	After 14 days	After 21 days	Total change of pH	
I	2,2	2,4	2,1	2,1	-0,1	0,328
II	2,8	3,0	2,3	2,2	-0,6	0,387
III	4,2	4,5	2,2	2,2	-2,0	0,571
IV	4,8	4,2	2,5	2,3	-1,5	0,578
V	5,4	5,4	2,7	2,3	-3,1	0,451
VI	6,2	5,5	3,2	2,3	-4,1	0,366

On the basis of the results shown in table 2, it can be seen that in the base with the initial pH value of 2.2 there was actually no change in pH until the end of the experiment (pH was reduced by only 0.1). The greatest changes in pH were recorded in bases with initial values of 6.2 and 5.4 (pH was reduced by 4.1 and 3.1 in 21 days). Except in case of the initial value of 2.2 on which mycelium *F. pinicola* from fir had almost no influence, in case of all other initial pH values, pH was reduced to the values from 2.2 to 2.3 at the end of the experiment.

Table 3. *Change of pH values of base under the influence of mycelium F. pinicola (isolate from beech) regarding the time of action*

Number of series	Initial pH (after sterilisation)	Change of pH of the base				Weight of the dry mass of mycelium (gr)
		After 7 days	After 14 days	After 21 days	Total change of pH	
I	2,2	2,6	2,0	2,1	-0,1	0,413
II	2,8	2,9	2,3	2,3	-0,5	0,358
III	4,2	4,3	2,2	2,3	-2,1	0,493
IV	4,8	4,7	2,4	2,1	-2,7	0,534
V	5,4	5,3	3,4	2,3	-3,1	0,417
VI	6,2	5,2	2,4	2,4	-3,8	0,352

After 21 days pH of the base for all the initial pH values (from 2.2 to 6.2) was reduced to the narrow diapason- between 2.1 and 2.4, with 2.3 being the most frequent final pH value of the substrate, which can be considered close to the optimum value for the development of the isolate. That can also be seen according to the dry mass of the mycelium which is also the largest in series 3 and 4, in which pH of the substrate is reduced to 2.1 and 2.3, respectively after 21 days.

4. CONCLUSION

Temperatures which are optimal for the development of the investigated fungus are at the same time favourable for the growth and development of the numerous species of rot fungi. Therefore, one has to take into account that *F. pinicola* has a great number of rivals in food and environment, which also develop at temperatures which are more favourable for it.

The change of the pH value of substrate on which the cultures *F. pinicola* moved into the direction of the mildly acid reaction, which points to the fact that it, like the majority of rot fungi, prefers the weak acid base. This fact, as well as the former one – regarding the temperature, implies that *F. pinicola* in the competitive relations with other rot fungi conquer the substrate with the equal chances for success, at least regarding the temperature and H- ions concentration.

Given the results of the study of the influence of the temperature and H-ions concentration on the growth and production of mass of mycelium of fungus *F. pinicola*, as well as the change of pH substrate under the influence of this fungus, regarding the possibility for the successful colonisation of the nutritive base in the nature conditions, it can be concluded that the studied species is neither favourised nor inhibited by the environmental factors in comparison with the rival rot fungus. Not only the speed, course and consequences of the wood decomposition as substrate and food source do directly depend upon this phenomenon, but also the wood as the very important raw material for procession in the industries of all countries and which is, because of its organic origin, food for a great number of organisms and microorganisms. For this reason it is necessary to investigate the competitive relations of this and other competitive rot fungi in the controlled conditions, in so-called mixed cultures, in the conditions of moisture, temperature and H-ions concentration which are convenient for all species of the competitive fungi.

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THE INFLUENCE OF TEMPERATURE AND CONCENTRATION OF H-IONS ON THE GROWTH AND MASS PRODUCTION OF MYCELIUM *FOMITOPSIS PINICOLA* (SW.:FR.) P. KARST. ISOLATED FROM BEECH AND FIR

Miroslava MARKOVIĆ, Milenko MIRIĆ, Snežana IVKOVIĆ, Snežana RAJKOVIĆ

Summary

Knowledge of basic physiological characteristics causers of the destruction of wood is a rational basis in order to fight against the factors of destruction. Special importance is the impact of research more destructive fungi that cause a form of corruption - prismatic brown rot. Among these species, in our climate is one of the most common fungus Fomitopsis pinicola (Sw.: Fr.) P. Karst, which attack broadleaf and larch wood, and is being developed as a parasite and a saprophyte. Testing was done on influence of temperature and concentration of H - ions on the growth and mass production of mycelium and pH substrate change under the influence of this fungy. The trials were made with dicarion mycelium F. pinicola isolated from the mushroom body taken from fir and beech trees, from the Tara National Park. It was found that the range of development of both strain F. pinicola from 5 to 34^0C, while the optimum for its development is 29^0C, which coincides with the literature data. At constant pH values of the substrate mycelium of both strains F. pinicola had a maximum increase of the weaker acid substrate (pH 4.8). Tests on unpufered substrates showed that the mycelium F. pinicola weighing pH 2.3, where it recorded the largest weight of dry mass of mycelium.The aim of this study was to determine if they are and how many extent environmental factors influence the successful colonization of nutritive surfaces in natural conditions by F. pinicola, compared to competitive destructor fungy. Not only the speed, course and consequences of the wood decomposition as substrate and food source do directly depend upon this phenomenon, but also the wood as the very important raw material for procession in the industries of all countries and which is, because of its organic origin, food for a great number of organisms and microorganisms. For this reason it is necessary to investigate the competitive relations of this and other competitive rot fungi in the controlled conditions, in so-called mixed cultures, in the conditions of moisture, temperature and H-ions concentration which are convenient for all species of the competitive fungi.

UTICAJ TEMPERATURE I KONCENTRACIJE H - JONA NA PORAST I PRODUKCIJU MASE MICELIJE *FOMITOPSIS PINICOLA* (SW.:FR.) P. KARST. IZOLOVANE SA BUKVE I JELE

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Rezime

Poznavanje osnovnih fizioloških karakteristika uzročnika destrukcije drveta predstavlja osnovu u cilju racionalne borbe protiv faktora destrukcije. Naročit značaj ima istraživanje uticaja gljiva koja izazivaju najdestruktivniji oblik truleži – mrku prizmatičnu trulež. Među ovim vrstama, na našem podneblju jedna od

najčešćih je gljiva Fomitopsis pinicola (Sw.:Fr.) P. Karst, koja napada i lišćarsko i na četinarsko drvo, a razvija se i kao parazit i kao saprofit. Vršeno je ispitivanje uticaja temperature i koncentracije H – jona na porast i produkciju mase micelije, kao i promene pH supstrata pod uticajem ove gljive. Ogledi su rađeni sa dikarionom micelijom F. pinicola izolovanom iz plodonosnih tela uzetih sa stabala bukve i jele, iz nacionalnog parka Tara. Konstatovano je da je dijapazon razvoja oba soja F. pinicola od 5 do 34^0C, dok je optimum za njeno razvoće 29^0C, što koincidira sa literaturnim podacima. Na konstantnim pH vrednostima supstrata micelije oba soja F. pinicola imale su maksimalan porast na slabije kiselom supstratu (pH 4,8). Ispitivanja na nepuferovanim podlogama pokazala su da je micelija F. pinicola težila pH vrednosti 2,3, gde je zabeležena i najveća težina suve mase micelije. Cilj rada je bio da se utvrdi da li i do koje mere osnovni parametri spoljne sredine utiču na uspešnu kolonizaciju hranljive podloge od strane gljive F. pinicola, što je verovatan pokazatelj ostvarenja infekcije u prirodnim uslovima, u odnosu na konkurentske gljive truležnice. Fenomen kompeticije mikroorganizama na istom supstratu, inhibicije rasta ili pojave antagonizma može biti posledica metabolizma suprotstavljenih vrsta gljiva, lučenja mikotoksina ili antibiotika ispred rastućeg fronta micelije i senzitivnosti, odnosno reakcije konkurentskih vrsta na njih. Od ovog fenomena direktno će zavisiti brzina, tok i posledice razlaganja drveta kao supstrata i izvora hrane, ali i drveta kao, za ekonomiju svake zemlje, veoma važne sirovine za preradu koja zbog svog organskog porekla i predstavlja hranu za veliki broj organizama i mikroorganizama. Iz tog razloga potrebno je istražiti kompetitivne odnose ove i drugih konkurentskih vrsta truležnica u kontrolisanim uslovima u tzv. smešanim kulturama, pri uslovima vlage, temperature i koncentracije H – jona koje odgovaraju svim vrstama suprotstavljenih gljiva.

BARRIERS AND OPPORTUNITIES OF SUPPORTIVE POLICY OF FOREST ENTERPRISES IN THE SLOVAK REPUBLIC UNDER THE CONDITIONS THE EU

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Abstract: *Analysis of the results of supportive policy- NATURA 2000 impact on the economics of forest enterprises in pre-accession period and after the accession into EU demonstrates mainly for small agrarian enterprises their efforts to diversify own activities. This trend has been possible also by adoption of current supportive forest policy. The paper presents an overview of current supportive policy of forest sector in the framework of whole agrarian sector as well as other sectors of the national economy. Problems connected with the implementation of this policy are described. They are mainly barriers in enterprising in forestry and related activities. Overview of supportive policy is compared with the results of expert questionnaires survey. The overview presents also prediction of the needs of supportive forest policy by state forest sector and non-state forest sector according to present leaders of interest groups in forest sector. Barriers and opportunities of supportive policy with considering changed conditions due to economic and financial crisis as well as chances for forest enterprises to use opportunities of adopted tools of economic policy, which solve current unfavourable situation, are given in the paper.*

Key words: support policy, NATURA 2000, SWOT analysis, forest enterprises, activities, diversification

1. INTRODUCTION

Restructuring of economy has been going on in forest sector like in other sectors of the Slovak economy. This restructuring is connected frequently with reduction of jobs, creating of unequally distributed new jobs and concentration of social and economic problems in certain areas. Supportive policy being aimed at elimination of the mentioned problems has been in case of being the member of the EU, influenced by current trends of European policy. EU policy is aimed mainly at increasing the quality of human potential. Cohesion policy of the EU enforces by integrated way the development of individual member states, including considering the effects of globalisation, climate change and it is sensitive to demographic changes. It gives coherence to sectors' policies as well. Integrated approach means utilization of synergy among policies fields and regulation of their various effects. This policy prefers dialogue rather administration direction and is capable of better adaptation to the effects of socio-economic characteristics of regions and territories.

Other not less important effect is currently despite ongoing programming period an effort to make more effective common agrarian policy through the changes in supportive policy of EU. It should be mainly reduction of direct payments on area in case of large agricultural farms. The saved money should be shifted to concrete projects of rural development. The planned change of common agrarian policy is a big chance for forestry, as it will enable development of activities aimed at nature and landscape conservation, ecological forms of management and diversification of activities.

The paper evaluates current situation in supportive policy of the state – Slovak Republic in relation to forest sector. It presents an analysis of the potential of support for the owner and user of forest land. Possibilities of obtaining subsidies from national supportive policy being applied in Slovakia, which is being enhanced in supportive EU policy by their actors, are given as well.

2. FOREST SUPPORTIVE POLICY

Current supportive forest policy is dependent not only on the possibilities being provided by supportive system in agrarian sector but forest enterprises have a possibility to use finances also from other sources of state policy support. At present they are mainly following operational programmes:

- Environment,
- Education,
- Employment and social inclusion,
- European programmes as Interreg, Progress and others.

In agrarian sector they may use also national supportive policy of this sector as well as to some extent supportive programmes of employment services. The state may adopt especially by means of own economic instruments indirect support of some activities, through taxes, transfer payments, and so on.

Supportive system is outlined in detail in figure 1.

This period of the programme is characteristic for:

- Securing consistent implementation of the assessment of effects on the environment;
- Support to the integration of financial means on horizontal as well as vertical level (associations of microregions, establishment of PPP etc.),
- Consistent checking and assessment of the sustainability of the activity being supported,
- Creating of synergic effect on the level of region with determination of entitled operations in a way to maintain balance of local regional and sub-regional effects and other.

One planned action may be supported via integrated project from two funds of the EU and state budget. It is namely:

- ESF – supporting education and creation of new jobs;
- ERDF – support to investments.

Employees of forest enterprises decide how they are able to use the mentioned supportive system. It depends on the professional in forest enterprises whether we will pay or get support. It is valid also in national level and thus we may increase potential of our national economy with help of funds from the EU.

Opportunities for the support of rural regions are very little discussed in the forest industry nowadays. The forest policy did not become the part of rural policy in Slovak republic. The forest policy should encourage the development of tourism currently and in the near future. The tourism can not exist without the whole rural area. The topics on the tourism, the engagement of human sources into development of rural activities and on the current situation of tourism which can not exist without the forest industry were elaborated by Jarábková,J. (2000, 2002) a Fáziková, M. (2009), Fáziková, M.and Milotová, B.(2009). The forest industry shall be integrated into the rural area and all kind of support shall be used in order to achieve the synergic effect. The social sources within this field may not be shared by the fields of activities (agriculture, tourism, forestry, crafts…) but it shall cover all capacity of rural sources.

3. AGRARIAN SUPPORTIVE POLICY

At present we have had in effect in Slovakia following legislative framework for supportive policy in agrarian sector:

- Act no. 274/2006 of the Digest in the version of later regulations on the support for agrarian sector and rural development
- Regulation of the Government no. 369/2007 of the Digest on some supportive measures in agrarian sector
- Forest Act no. 326/2005 Z z. in the version of later regulations.

Supportive policy is facultative for forestry. It means there does not exist claimable legal framework for subsidies granting. Even special act for forestry no. 326/2005 of the Digest does not specify obligatory titles that would be supported in accordance with this act.

Forest Act (no. 326/2005 of the Digest) contains directly or indirectly following titles for the support:

§ 20 – Forest regeneration (direct support is not specified)

§ 21 – Forest tending

§ 55 – Financing public beneficial activities

- Loss in forest management and professional administration with applying lien,
- Elaboration of forest management plan,
- Education and consultancy in forestry.

Other supported activities have not possibility to finance managers of forest lands directly. Supportive activities are intended mainly for enterprises in forestry of non-commercial character, providing "services" in science and research, elaboration of forest management plans and others.

Next legal norm specifying the kind and preconditions for the support to forestry is the act no. 274/2006 of the Digest.

(1) The purpose of subsidies in forestry is to support management in forests, forest regeneration, forest protection and tending of forest stands and thus to secure sustainable forest management and sustainable forest development.

(2) Subsides may be provided in accordance section 1 for following purpose:

a) Sustainable forest management and sustainable forest development and for afforestation of agricultural lands,
b) Professional management of forests,
c) Restoration of forests damaged by injurious agents and for adoption of protective, remediation and prevention measures,
d) Investments for the development of production and processing of raw timber before industrial processing and implementation of forest production,
e) Associating of forest owners with the area of forests within 50 hectares into associations as legal entities,
f) Forest extension and education, foundation and activity of regional associations of forest users and forest owners,
g) Participation in exhibitions, fairs and competitions,
h) Insurance payments,
i) Preservation of endangered gene pool of forest tree species.

The act is primary legislative framework determining mainly kind of forestry activities that are supported.

The latest legal norm on supportive policy in agrarian sector is the Regulation no. 369/2007. It specifies respective subsidized titles as well as includes instructions for submitting the application also with the calculation of the required subsidy.

Regulation no. 369/2007 specifies support to following forestry activities:

- Subsidies for silviculture and forest protection,
- Subsidies for enhancement of recreational forest functions,
- Subsidies for the insurance payments for forests,
- Subsidies for plant-medical care in forests,

– Subsidies pre for forest enterprise to participate in exhibitions,
– Subsidies for the reimbursement of loss due to negative impact of natural disasters and unfavourable weather on forest stands and reproductive material in forest nurseries.

What are the possibilities of the forest owner, entrepreneur in forestry or the manager of forest land in applying for the support?

Regulation no. 369/2007 has been in effect since 15.08.2007. The owners and forest managers are being informed minimally. Despite that fact the regulation has been in effect there were not secured consultancy services for its successful implementation. Even a basic information campaign has not been organized yet.

The most interesting subsidies for an applicant are following ones:

- Silviculture and forest protection (request are being submitted until 31.1. of respective calendar year),
- Reimbursement of loss due to natural disasters (request/applications are being submitted until 31. 10. of respective calendar year),

In this case it is necessary to proceed as follows:

- Written notice within 10 days,
- Calculation of loss in expert's opinion.

How to calculate loss in production being contained in the expert's opinion? Must it be in respective calendar year? Is it important from that aspect if some calamity occurs we do not know even the extent of the calamity?

With aim to objectify the procedures of state administration of forestry in subsidy policy it will be necessary to set a methodology for all actors of the implementation of the regulation of Slovak government. Methodologies for the calculation of reimbursement in expert's opinion should unify procedures for deriving wood production.

Wood production:

– Loss due to lower quality of assortments in salvage felling,
– Loss in production (total current increment, total average increment)
– Loss due to unplanned costs arising due to restoration and subsequent protection of forest.

In EU countries similar projects of support are being adopted for 10-20 years. Thus they may eliminate lack of initial information on calamity as well as it is possible to perform supported activities after calamity removal.

At present supportive policy in forestry:

– Has not interlinking with the system of economic instruments of the state (tax policy, employment policy and others)
– Has not a system of indicators of income for the management of forest.

The state regulates national supportive policy at present in accordance with the act on state assistance. Supportive policy of the EU is being regulated by the policy adopted by the member states.

In general it is valid:

– EC supports institutional structure of the state, including mainly state sector (state administration, consultancy),
– EC does not support enterprising of the state, as the state has its own instrument of assistance to own enterprises.

4. CONCLUSION

Programme policy of the EU for seven years improves considerably long-term planning in member countries. It influences identification of priorities in decision-making on public investments and thus affects not only investment activities being supported by the Community but also the use of public investments and subsidies in general in respective member country. In Slovakia it means the first stable period of big investments in the national economy for the period of seven years that should not be connected with political cycles due to change of the government and ruling political groups. In that way a chance for forming more favourable entrepreneurial environment is created.

The rule of consultancy is currently a basic policy that is being accepted as a key element of good administration of public issues. This principle is a change for forestry that plays in our regions an important role. In case of establishment a partnership between the Community, national, regional and local organs (e.g. associations of owners, interest organizations) it is possible the supported activities to adapt to the situation in concrete place to secure the success of outputs and results of the supported projects.

Present change of Common Agrarian Policy is for foresters a big change to obtain development funds for forest sector. Current support of NATURA 2000 means that our primary objective must be as follows:

– Preserve and improve current state of our forests,
– Individual approach to the support for projects,
– Enforce forestry development.

NATURA 2000 does not mean a stop for development. On the contrary ecological management for example also approved by certification is connected with better sale of raw timber.

The paper indicates potential for the development of forestry on the basis of improving the quality of procedures in supportive policy. Slovak Republic is rural country and the policy of rural development is decisive for forest enterprises with regard to a possibility of obtaining non-returnable financial means. The same is valid for obtaining good credit conditions in commercial banks. Good knowledge of the mentioned issues help the development of forestry as a whole and in that way increase possibilities for the management of forest on the required level of forest protection and improvement of its current state.

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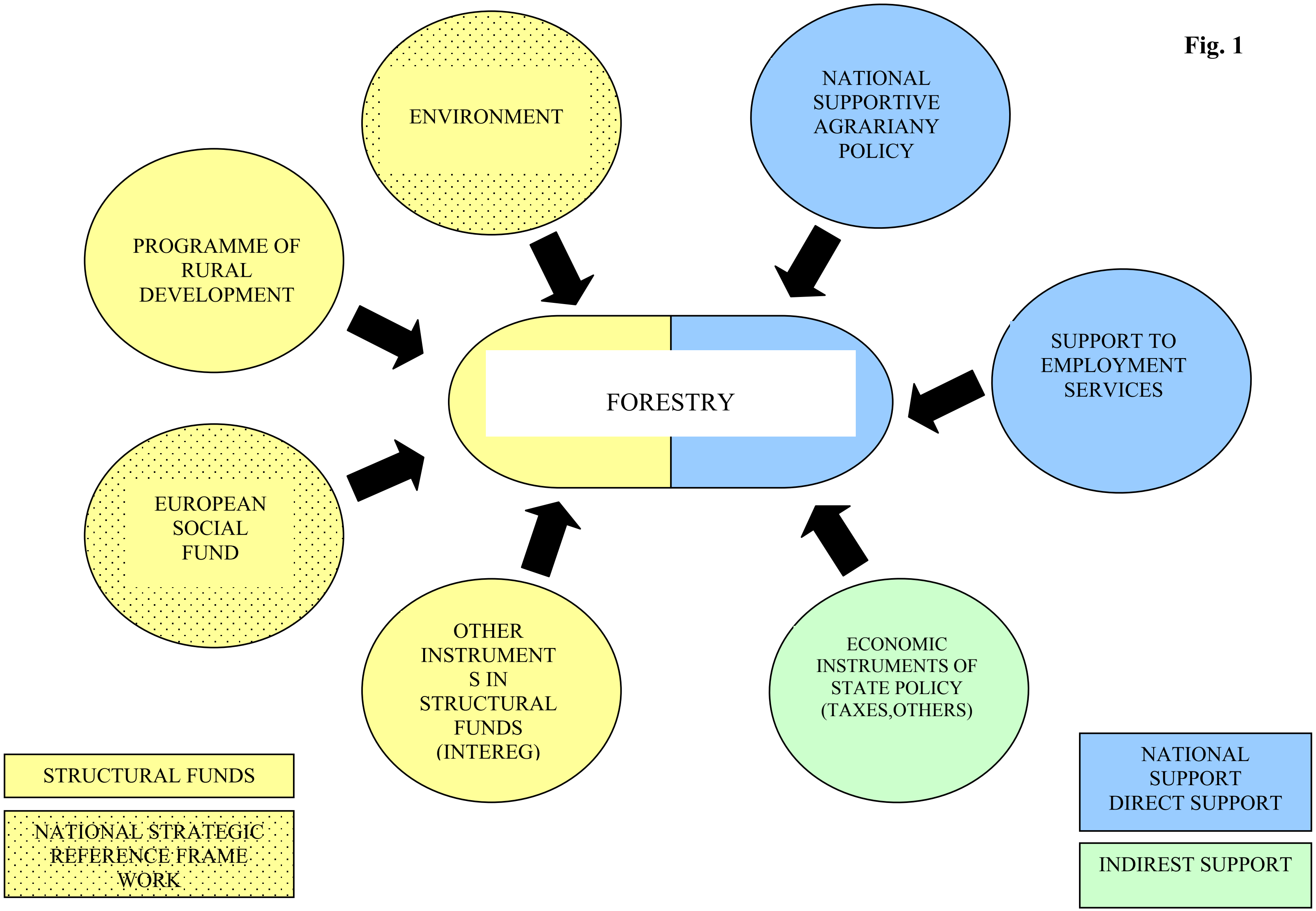
7. Plán rozvoja vidieka [Plan of rural development]

Supportive system of forestry for SR –2008-2013

Fig. 1



ON THE PATH OF THE SUSTAINABLE AND UNSUSTAINABLE DEVELOPMENT FROM STOCKHOLM TO COPENHAGEN

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Abstract: *The Stockholm Conference on the Human Environment in 1972 pricked the human conscience and marked the beginning of the "ecological age". „The Earth Summit*" in Rio de Janeiro was the starting point in the world response to the climate change and increase in the temperature on our planet.*

Almost 150 world leaders at this summit signed the agreement called "The United Nations Framework Convention on Climate Change". This conference was aimed at the reduction of the emission and stabilization of the quantity of gases, which in the atmosphere cause the glass house effect, to the level which would prevent their adverse effect on the climate change, which can be the result of the changes caused by the human activities.

After 17 years, The International UN Conference on Climate Change - 15th United Nations Climate Change Conference, should have been the most important chapter of the "story" called climate change.

The Copenhagen Conference is aimed at reaching the new global agreement on the fight against the climate change, which would replace the current Kyoto Protocol, which expires in 2012.

Key words: Conference, Copenhagen, environmental protection, sustainable development, climate change.

1. INTRODUCTION

United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro (Brazil) in June 1992 has been the greatest conference organized by the UN ever. Almost 10.000 official representatives from about 150 countries, including 116 national political leaders, took part in it. However, as it was expected, the participants did not succeed in reaching the solution and consensus on many issues. Namely, it was hard to bridge the gap between the countries on the issues which endangered the different economic interests or widely accepted values. The Earth Summit in 1992 was successful, since for the first time the issues concerning the development and environmental protection were integrated. The sustainable development should integrate the economic growth, social development, and the human environment protection.

Unfortunately, over the next decade these expectations were denied, the poverty was additionally aggravated, particularly among the the lowest social classes, and the degradation of the natural environment and pollution continued at the same speed.

After 17 years, in December 2009, in the capital of Denmark, Copenhagen, The International United Nations Conference on Climate Change (UN) was held, which by the number of the delegates exceeded the Rio Conference in 1992, which had been the largest up to this point of time. At the summit in Copenhagen, during two weeks, the delegations from 192 countries, held the disscussions on the new agreement, i.e. on the conditions which their government would oblige to meet within the fight against the climate change and against the atmosphere pollution.

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The officials of the World organization proclaimed that the emission of the harmful gases in the atmosphere must be reduced in order to avoid the danger of the increase in temperature on the Earth.

The main topics of the discussions held at the International Conference on Climate Change were the following:

- Setting the goals for the decrease of the quantity of the harmful gases (CO_2) which each individual country releases into the atmosphere, particularly the developing countries. In essence, the issue concerning the decrease of CO_2 emission refers to the development of industry, the share of the profit on the market, and, of course, to the power sharing.
- Finding of the sources of the financial support for the mitigation of the results of the climate change and adaptation to these results in the developing countries, as well as
- Definition of the programmes of "trade by the carbon emission", aimed at stopping of the destruction of the world forests until 2030.

One scientific UN comission recommended that the developed countries should reduce the emission of the harmful effects between 20 and 40% until 2020. In this way the following phenomena would be avoided: destructive storms and droughts, the catastrophical increase of the sea level, as well as the climate disturbances all over the world.

2. FROM STOCKHOLM CONFERENCE TO CONFERENCE IN COPENHAGEN

The world was much different in 1970^{s} than today, since it was still polarized The Cold War raged, placing the clear demarcation line between the East and West. The problem posed by the global warming was merely mentioned, there was the little knowledge on the problem posed by the ozone holes, i.e. it was known that the main cause of it are the engines of the supersonic airplanes.

The transnational companies gained the momentum and became more and more powerful, and the concept of the globalization had not been on the horizon yet. Given such constellation of powers, the idea of the organizing the Conference on Human Environment, which was held in Stockholm in 1972, and which started the process later called „compromising spirit of Stockholm“, was suprising. At this conference the representatives of the developed countries looked for the path of the reconciliation of very different interests. Sweden was very worried about the adverse effects of the acid rains on its forests, and was not able to solve the problem on its own, since the air pollution originated from West Europe.

The Stockholm Conference adapted the Declaration with 26 principles and Action Plan with 109 recommendations, and it made special decisions such as 10-year moratorium on whale hunt, and on the release of the oil waste in the sea. The Stockholm Conference recommended the creation of one United Nations Secretariat which would focus on the ecological problems, which was materialized shortly, and named UNEP (United Nations Environmental Programme). It was aimed at encouraging, enabling, informing, improving the environmental conservation, as well as at improving the quality of life of the current generations and, at the same time, not disturbing the future ones.

It would not be wrong to say that Stockholm was the corner stone and articulated the wish and the right of people to live in the environment which would provide the dignified and prosperous life to them. Stockholm is the reflection of the general mood of the time, and, relying on its bases, more than fifty governments and countries incorporated the environmental conservation into their Constitutions or other official documents, as the fundamental human right. The Law on Environmental Protection was adopted by numerous countries, and more than 110 countries founded the Ministries or Secretariats.

After the Stockholm Conference in 1972 the history of the development of the „story" about the climate change can be briefly summerized in the following way:

- American scientist Wallace Brecker popularized the term global warming in one of his scientific papers in 1975.
- The first international climate conference in 1979 asked the governments to: predict and prevent the potential climate change caused by man.
- The Montreal Protocol was signed in 1987, which limits the emission of the chemical substances which make the ozone layer thinner. Although it was not adopted in order to limit the climate change, it is very important to the emission of gases with the glass house effect.
- In 1988 the UN founded the Intergovernmental Panel on Climate Change (IPCC), aimed at the collection and analysis of the proofs on the global warming.
- The UN Earth Summit in Rio de Janeiro in 1992 adapted the The United Nations Framework Convention on Climate Change: the developed countries agreed to reduce the emission of gases to the level from 1990.
- In 1997 the Kyoto Protocol set to the industrial countries the compulsory quotas for the reduction of the emission of gases by 5% in comparison with the level from 1990 over the period 2008-2012.
- The powerful El Nino in 1998 (Spanish: El Niño, is the global atmospheric-oceanic phenomenon which occurs as a result of the fluctuations of the directions of winds and water temperature in the tropical part the Pacific) in the combination with the global warming brought the warmest ever recorded year on the Earth from the beginning of the temperature measurement.
- President George Bush withdrew the USA from the Kyoto Protocol in 2001. The Kyoto Protocol was compulsory to the industrialized countries, but there were no limits for the countries such as India and China. The USA withdrew from the Protocol, stating that China, India and Brazil must also participate in the reduction of CO_2 and that the implementation of the Protocol has an adverse effect on the competitiveness of the American industry.
- In September 2002, at Summit on Sustainable Development held in Johanesburg, the world gathered again in order to overcome obstacles to the achieving of the sustainable development, as well as to intensify the initiatives which will bring results in the improvement of the conditions and standard of living, and, at the same time, preserve the environment.
- The Kyoto Protocol came into force in 2005. The Kyoto Protocol is the obligation of thirty-seven leading industrial countries, which implies that they have to reduce the emission of the carbon-dioxide and other gases of glass house, by 2012, by more than five percent in comparison with the level from 1990.

The most important chapter of the story called climate change, 35-years old, should have been exactly 15th The International UN Climate Change Conference (*15th United Nations Climate Change Conference)* in 2009. The governments of 192 countries, with more than 1.500 delegates from the whole world, met in Copenhagen at UN summit to discuss the new agreement on the climate change.

3. ECOLOGICAL SYSTEMS AND GLOBAL ECONOMY

The global warming, climate change, ozone layer destruction, glass house effect, acid rains nowadays endanger the developed and undeveloped countries to the same extent, requiring the solutions of the international scale.

Poverty, illnesses, high mortality rate, lack of the basic hygienic conditions are the problems of the poor and developing countries. The ecological problems of some countries or regions are less frequently talked about, since they acquire the global character.

The ecological systems, even if they are significantly damaged, show the greater degree of the sustainability than the global economy, regardless of the fact they are limited by the living forms and their ability to adapt to the conditions (desert, water, elevation, the quantity of light), which are the limiting factors for the expansion of an ecological system.

The rich nations used the disproportionately more energy and matter for their development, not taking into account the soil, air and water pollution. The growth at any cost is one of the causes of the unsustainable development, and the main indicator of it is pollution.

In order to reduce the cost of the production, these nations deposit the toxic matters and waste materials in an inadequate way at the unsuitable places, so that the agent cannot be traced. It is much more profitable for the polluter to leave this task to the future generations.

In the context of the sustainable development, all inputs and outputs, matter, energy, time, knowledge, must be taken into consideration. The sustainable development requires that in the preservation of the entire biosphere the influence of the future generations should also be taken into account.

From the current perspective, it is visible to which extent the contemporary economic is toxic and unsustainable. In the recent times, one type of the industrial economy based on the market principles and private initiative, the activity of which should support the sustainable development, has been suggested.

The natural ecosystems function on other bases, the energy and material costs have been already included, the system has one hundred percentage of the recycling, the net results of one ecosystems are almost perfectly balanced and sustainable. The total activities of one ecosystem are coded in the form of the equalization of the sum – time, energy, matter, and the degree of equalization is obvious.

Economy and ecology are not in conflict, the preservation of the environment is not in opposition with the interests of the economic development and growth, of the standard of living, and of the opening of the new work places. The traditional concept of the economic and industrial development based on the increase of the exploitation of the renewable, slowly renewable and non-renewable natural resources reaches its ultimate limits.

The products of this way of production, i.e. ecological costs, soil, air and water pollution, the exhaustion of the resources, decrease of the biodiversity, and disturbance of the human health, increasingly exceed the benefits of the further growth.

As a result of the understanding of the catastrophic consequences, there is the increasing investment in the environmental protection, energy saving and in the development of the new technologies, which are eco-friendly. In this domain exactly at the same time the differences and similiarities clash and reconcile, and the new synthetized science occurs.

The ecological economy is the trans-discipline science which results from the need to explain the whole series of interactions between the ecological and economic systems, including their evolutionary and co-evolutionary development.

Ecology explains the relation between plant and animal world, humans and their attitude towards the natural environment, balance and coexistence.

The ecological economy is the attempt to synthetize the attitudes and relations between nature and human activities, by insisting on the social, ethical and spiritual aspect of this relation.

The important improvement in this attitude refers to the synthesis of the ecological and biocentric principles, by contrast to the previous anthropocentric attitude, in which the quality of the relation man-nature is more improved.

The basic principles of this attitude are the right to the survival of all living species, reduction of the growth of the human population, promotion of the biological differences, decentralization of planning and implementation of the multi-beneficial systems and orientation to the more sustainable economic activities and processes, which implies the implementation and development of the new and more advanced technologies. The process of globalization to which economy, culture, information and media are already subject, is also increasingly present in the politics as the frequent phenomenon, but the globalization should integrate the principles of the sustainable development as well, and if this goal is not achieved, the humankind is heading to the inevitable economic and ecological catastrophy.

4. GLOBAL CLIMATE CHANGE

Air pollution affects the human health and the ecosystem in general in many ways. The physical consequences of the global air pollution are various, very complex and inextricably bound, the harmful matters are transported with the air to the most distant sites, thereby polluting both mainland and water. The main sources of pollution are the excessive combustion of the fossil fuels, industry, and the exhaust gases of the motor vehicles. Carbon and sulfur dioxide, carbon monoxide are the gases which naturally occur in the atmosphere, but their increasing presence causes the changes of the chemical composition of the air, which are reflected in the climate change, in the glass house effect and in the acid rains.

The increasing activity of the anthropomorphic and technogenic gases causes the holes in the ozone layer of the Earth, and the essential changes in agriculture and fertilization cause the increasing emission of the nitrogen oxides and suboxides, as well as methane.

The global climate change, glass house effect, global warming, are the results of the previous increase of the concentration of gases, which has been increasingly visible, since the second half of the twentieth century.

The concentration of carbon dioxide, the gas which is the main cause of the glass house effect, is the natural phenomenon of the increased absorption of the solar radiation, which re-asorbs owning to the belt of the poisounous gases in the atmosphere, since it can not reach the space again.This process causes the effect of the additional warming. The results show that the mean annual air temperatures measured in the late 20th century are by one degree higher than the temperatures measured in the late 19th century. Based on the forecasts by the end of the 21 century, the mean temperatures can increase by 1,5-4,5 °C in comparison with the current ones, and have many negative effects.

As early as nowadays the melting of the earth ice caps, with the tendency of the further reinforcement, which will cause the increasing of the sea and ocean levels, as well as the sinking of the vast riparian territories has been reported.

The decrease of the ozone layer, which is very important for the temperature regulation and protection from the intensive ultra-violet radiation, is mainly caused by the anthropogenic gases chlorine-flourine-hydrocarbons, better known as freon. These gases are widely used in the chemical industry, and the industry of the refrigirating devices. By their nature, these gases are inert and harmless to the health, but when they reach the higher layers of the atmosphere, owning to the ultraviolet radiation they decompose and thereby destroy the ozone molecules.

Along with the reinforcement of the glass house effect, the reduction of the ozone layer has the adverse effect on the health since the increaseed ultraviolet radiation is the additional cause of the skin cancer, eye cataract, the weaking of not only human immunity but also the immunity of numerous animal species.

The increased ultraviolet radiation affects the soil degradation and causes the decrease of the fertility of the agricultural crops.

The emission of the acid substances, sulfur and nitrogen dioxide cause the combustion of the fossil fuels and the industrial processes, and these gases remain in the atmosphere for several days and expand. Transformed into the sulfurous and nitrogen acids, they are transfered to the land, in the form of the acid rains and increase the acidity with the very negative consequences. Water flora and fauna are very sensitive to the increase of pH and other toxic substances. The land plants are also very sensitive to the increased soil acidity, and by consuming these plants animals and humans become only one more link in the chain of pollution.

The limitation of the emission of gases is important for the solving of these problems. As early as in Berlin and at the Climate Conference it was concluded that this step is not sufficient and that the action should be directed not only to the limitation but to the reduction of the emission of the harmful gases as well.

The United Nations Framework Convention on Climate Change in Kyoto was signed by 50 countries in 1997, thereby obliging themselves to reduce the emission of the harmful gases by 2020, by 5%, in comparison with the level from 1990.

The international regulations in the domain of the environmental protection have not yer reached the level which would enable the peaceful life to all inhabitants and all living forms on our planet. The various protocols, conventions, declaration and agreements are being adopted, but, as a rule, this step is taken when the environment is already endangered, and less frequently, when it is needed in order to prevent its endangerment (D. Stankovic, 2008).

Nowadays, the ecological situation does not improve, but it aggravates worldwide, and it will increasingly aggravate if the current trends are continued. The arable land is increasingly degraded by the excessive use of the chemical preparations, the problem posed by the lack of drinking water and water needed for watering of crops increases, and in the next thirty years the doubling of the adverse influences is anticipated.

Thousands of cities already have the unhealthy atmosphere which causes the numerous health disturbances, in spite of the fact that it can be considerably reduced by the relatively acceptible material costs.

5. CONCLUSION

The delegates of UN Climate Change Summit in Copenhagen finished their work after the multi-hour blockade, after the Vice Chairman of the Summit announced that the participating countries agreed to take into account the final document of the Summit, the Copenhagen Declaration.

The final document was brought into harmony by 27 countries, including the USA, China, India, Brazil, South Africa and the leading EU countries, whereas the other participating countries at the Summit agreed to submit the notice on whether they accept the Declaration over the next period.

"Copenhagen Agreement" is legally unbiding, does not contain the concreate figures related to the obligations of the countries in regard to the reduction of the emission of harmful gases, or the goal to reduce the carbon dioxide emission by 50 percent by 2050.

The document anticipates that, during January 2010, the countries will on their own set and declare the national goals in regard to the reduction of the emission of the harmful gases, as well as the organisation of the new climate meeting in the net six months, which would be hosted by Germany.

It seems that the only issue on which all delegates agreed, without any conditions, in regard to the solving of the problem posed by the pollution and climate change, at the Conference in Copenhagen, is that the „multidimensial corporation“ of all countries is the essential and only possible method.

To sum up, Copenhagen was characterized by the protests, riots, interesting comments, and ended in the same way, without the final agreement, and such an outcome did not suprise anyone.

On the eve of the Conference, Copenhagen was called **Hopenhagen** (eng. **Hope). *However, as in many other instances, this hope was betrayed.***

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* www.bbc.co.uk/serbian/news/2009/.../091206_copenhagen.shtml
* www.pregled.com/nauka.php?tmpl=nauka_tmpl&id...1118
* www.UN-konferencija-o-klimatskim-promenama-u-Kopenhagenu.html
* UNESCO Education for Sustainable Development, http://portal.unesco.org
* World Summit on Sustainable Development, http://www.johannesburgsummit.org

FOREST RESOURCE AND SPATIAL IMPACT ANALYSES

Radovan NEVENIC[1]

Abstract: *Island forest coverage – former island Ada Ciganlija has 265,5 ha. The research area of the island forest coverage impact lower part of the Ada plate, position where just now Belgrade Sava bridge is in construction. The spectacular bridge over the Sava will be 929 m long and 45 m wide. It will have a distinctive 200 m pylon erected on the lower tip of the Sava island, with a fan of steel cables on both sides of the pylon holding the structure together. There will be six lanes for vehicles, two tracks underneath for the planned underground railway, and two lanes for bicycles and pedestrians.*

In this paper, second phase of previous investigation, research of possible impact on forest coverage is done only at corridor where the bridge route is wriggled over Ada lower part, which comprise forest, vegetation coverage close to the bridge. Overview and global recognizing of the imperiled vegetation coverage as a part of recreation zone, urban forests, will be analyzing issue as well as comparing previous vegetation condition with present area in construction.

Key words: spatial data, forest, impact, GIS.

1. INTRODUCTION

Bridge construction over River Sava and Ada Ciganlija lower part (Figure 1.), natural resource and recreation complex is in progress this days. Bridge and future traffic activities will have several negative ipact influences on forest coverage and ground vegetation.

Basic indicator in the process of analyzing the forest coverage impacts on the lower part of Ada Ciganlija was a map of the present vegetation with slightly changed primal vegetation community as a result of the anthropogenic impacts as well as entering the domicile and exotic plant species in the past, what was the main step in couple of years first anlayses too.

The important factors are undoubtedly orography factors influencing the flooding waters and edaphic humidity. Present form of the vegetation communities, several hygrophyte types of the forest groups and phytocenosis is closely connected and limited with the flood regime and level of ground water. Underground waters are very active so the influence of the river level is very significant on the continental part of the Ada as well. Ada Ciganlija terrain is a part of the large alluvial terrain originated by Sava River and it represents a plain. Absolute terrain heights varies from cca 70 til 73,5 m.

Ada Ciganlija foreland flooding and underground water regime depends on the Sava River water level regime. The highest water levels are occurring in April and June, the lowest in September and October. Such water levels are influencing the soil processes as well as the vegetation, especially on the parts that are not protected with the riverbank. Influence is firstly visible in appearing of the different plant species under certain soil moist regime and with flooding. In spite of that, it is important to emphasize that the River Sava level, underground waters (beside the riverbank and protection canals) effects the life of the vegetation coverage plants so that only certain species can exist like that in the optimal conditions.

Vegetation coverage sorts of the Ada area are developing in a scope of the existing ecosystems, systems that are adapted on the certain environment conditions ruling. Drastic raid

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of the new content (bridge) with large metal construction, which absorbs more heat, is permanently radiating and heating the environment even during the night when the temperature amplitudes are expected to descend. Intensity of such oscillations varies in relation to the object distance from potential forest resource stands. Buffer zones from the bridge and negative impact analisys should be the tool for recognizing environment desturbances.

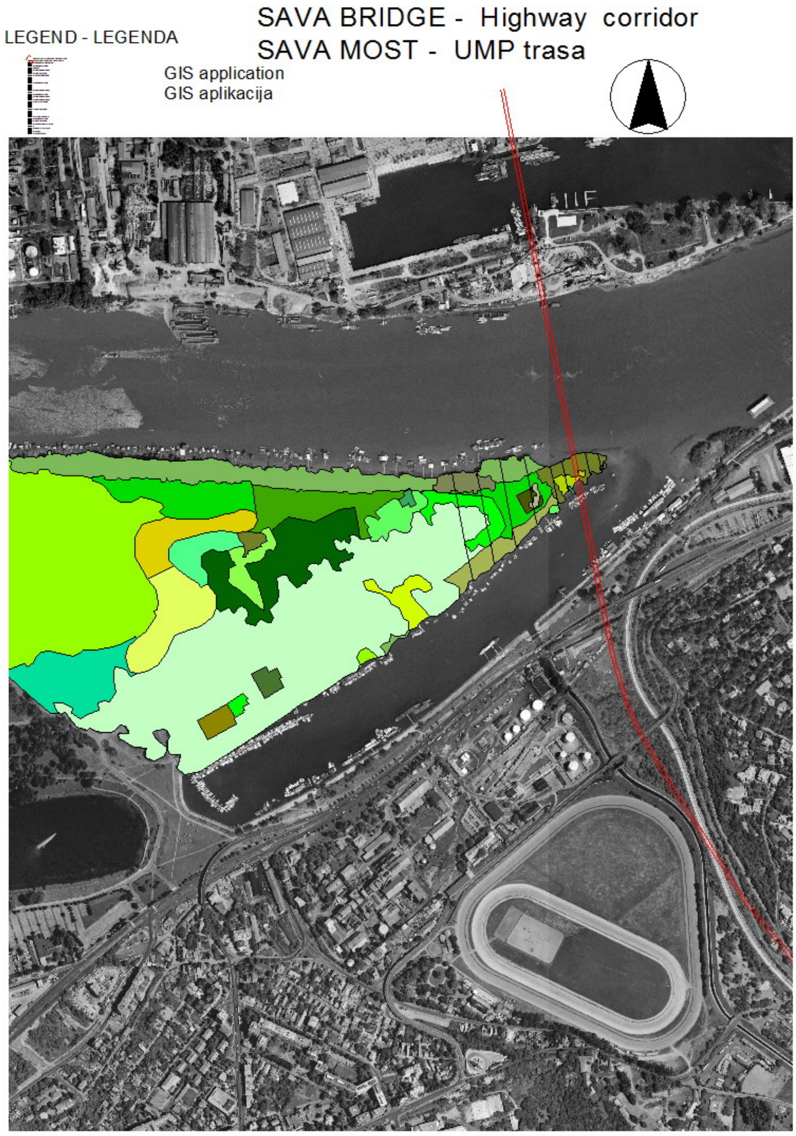

Figure 1. *New Sava Bridge in Belgrade – Highway corridor*

2. MATERIAL AND METHODS

Impact analyses calculated by GIS buffer zones, condition of vegetation coverage mostly depend from the distance of the beginning action place. The bridge, highway, which is just in the construction over Ada Ciganlija island lower part could be with great impact in zones of 50m.

Impute dates as preparing material for GIS analyses, applications and models are collected from following sources:

- Topographic maps 1:25 000 and 1: 50 000 for Belgrade region
- Digital layouts, Belgrade Master Plan

- Hydro geological maps
- Pedological - Geological maps, Belgrade region
- Case Study: UMP Environment Impact Analyses, Belgrade Ring
- Case studies “Vegetation of Ada Ciglanlija”, worked out by colleagues from Faculty of Forestry Belgrade.
- Digital Ortho-Photo, Ada Ciganlija area
- Photo documentation (Author data base)
- Thematic maps
- Terrain works, earning dates, observations.

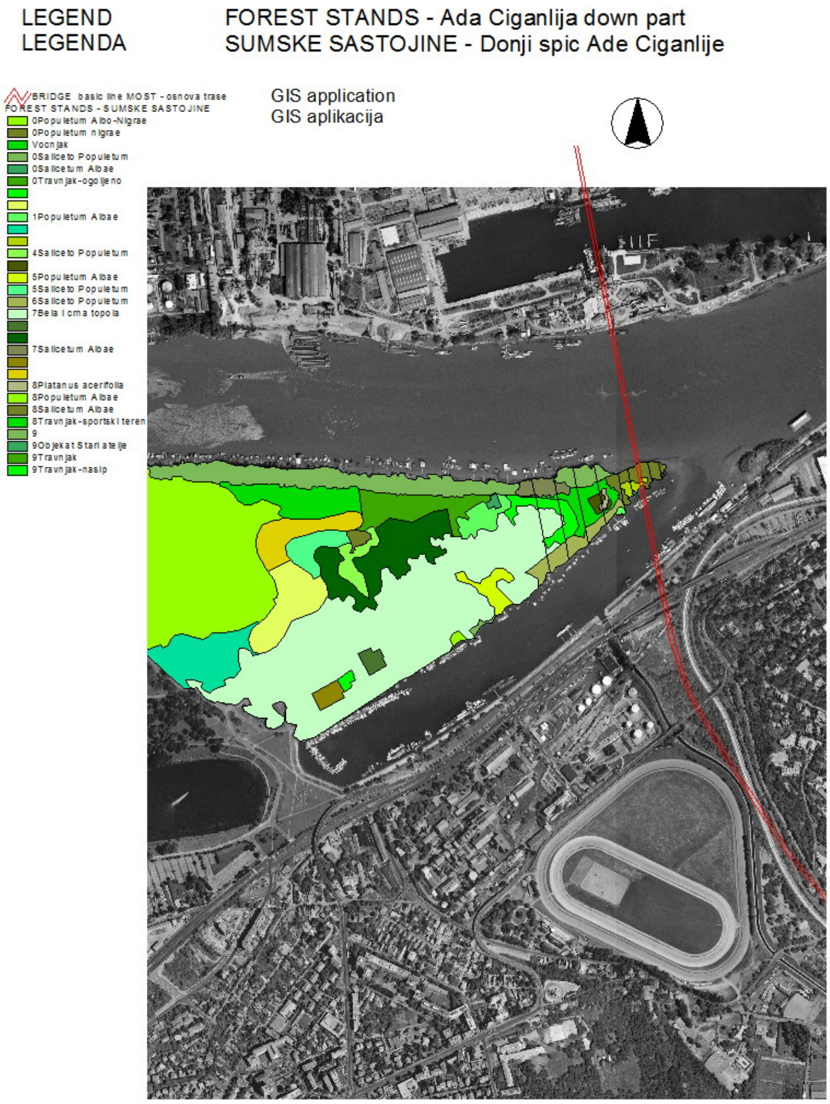

Figure 2. *Forest stands Ada Ciganlija Lower part*

The following tasks have been undertaken to meet the study objectives

- Generate thematic maps of various natural resources
- Integrate the thematic maps
- Define the plan of implementation

The use of satellite data in recent years has gained much importance for natural resource mapping. This study is carried out by combining the features of satellite imagery, topographic sheets and secondary maps data to produce the necessary information layers of natural resources

The input data from all of the above diverse sources are translated into the thematic maps by the methods of:

- interpretation,
- classification,
- manipulation,
- integration,
- editing and
- analysis

The data translation into thematic maps employed the GIS software Arc/Info and Arc View and the remote sensing image. The multi layer thematic maps generated necessary information to provide detail insight to suggest the necessary improvement of the command and catchment area. Logical expressions are used to select the treatment areas in the command and the catchment area. Applications, analyses and model are worked out, supported by GIS tool ArcInfo 7.2. and ArcView 3.2a.

Parallel spatial analyse – methodology of impact and atractive analyses , methods and GIS are the main tool for establishing the spatial relation and possible negative impacts on vegetation coverage.

3. RESULTS

Some dominant forest stands of the Ada Ciganlija lower part area, as it was noticed in (Jovanović, 1984), are: community of Salicetum triandrae Malc. Which have been occupied in small belts near River Sava banks making little stands of the lower part of island (Fig. 3).

Such vegetation communities are caracteristis for lower part of Ada Ciganlija as rarity. Ground vegetation from genus Polygonum, Polygonum lapatipholium, P. Mite and rest, willow Salicetum triandrae Malc, growing as a shurb few meters high.

Forest of white willow – Salicetum albae s.l. was in quite poor condition situated near Almond Willow stand (Figure 2).

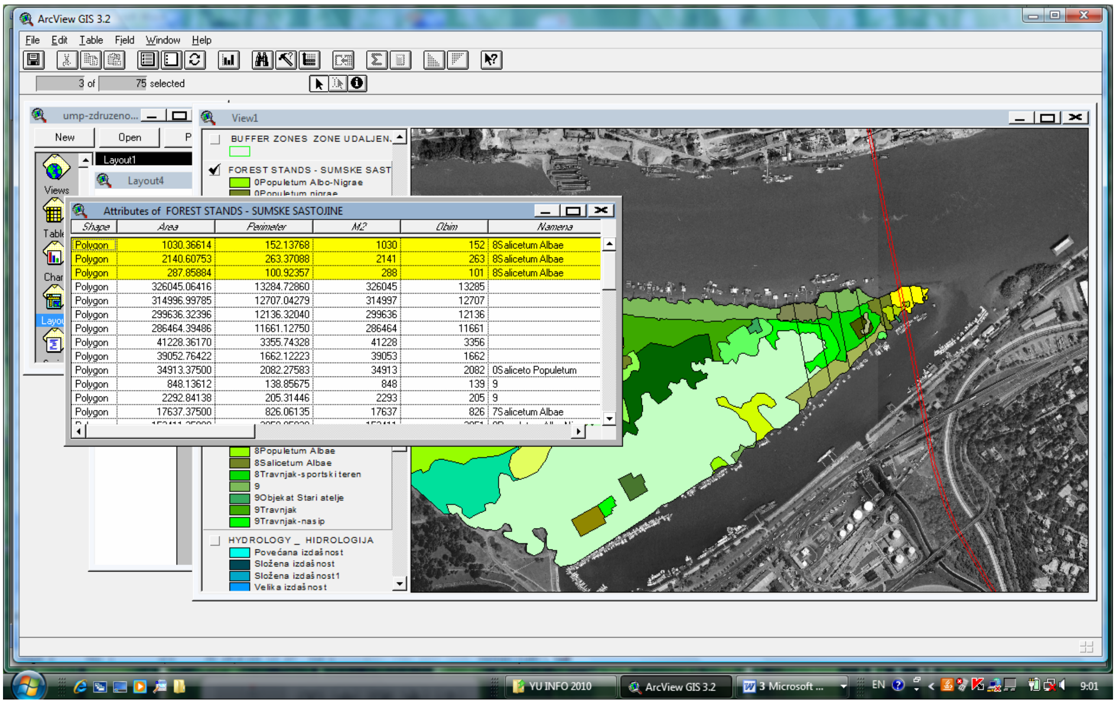

Figure 3. *Stand selection (yellow poligon) – Stand clear cutting of the lower part of Ada Ciganlija*

Figure 4. *Ada Ciganlija lower part without Willow stand*
Preparing the place for bridge construction (Photo R.Nevenic, November 2008.)

In zone of 50m distance from the bridge corridor vegetation is cuted off in total amount of 3.459 m^2 (Table 1) - yellow poligon (Figure 3), because of future bridge fundaments construction (Figure 4), and potential impact on vegetation is 150-200m.

Table 1. *Species of the vegatation coverage - total amount*

Forest stands	Stand surface
1. Salicetum albae	3.459 m^2 (0,34 ha)

Imacts on vegetation coverage is graphicaly presented by GIS applications and Distance model. By selection of particular forest species in a frame of the Distance model it is possible to recognized deliverable and surface of the vegetation coverage for each dendro species. Buffer zones shows in square metres number of trees which are cutted off or what are could be in danger. Possibility of GIS applications, apporaches in this model give us definite quantified datas, values in zone of the 50-200m of the graphical expression which is able to to verify questions.

The number of impacts important for forest ecosystem could be, such as:

- low insolation because the shadow of the large bridge dimensions, the last result will be in the future forest defoliation as well the forest and groun flora.
- Huge temperature radiation from the bridge construction;
- Local air circulation, changing the direction during the wind period called “Kosava”;

Intensive traffic, huge numbers of vehicles on the road/bridge – gasoline pollutions, heavy metals pollution etc.

- chemical pollutions caused by anti-ice on road chemicals;
- industrial salts on road in winters time;
- polutions cas
- destroying of the forest coverage in range of 50 m. etc.

Air, water and soil pollution impacts made by trafic will be directly linked to the nature and magnitude of the pollutants dispersed (based on the nature of chemicals/gases released and their prior treatment, the source and the distance). The overall impact of the pollution is linked to the vegetation coverage and after to the recreational and tourism potential of the area, and to the health conditions of the visitors. There would be an expected change in all these aspects over time, and the long-term biological, economic and ecological scenario could be quite different from the short-term ones.

We will then deal with the problems posed by the planning proces itself, the ways in which planning is based on goals and objectives which are optrimized (at least in part) through designs, and types of information required to serve and advance such processes. If curent GIS fall short of the requirements of urban system models, they barely consider the much wider set of requirements posed by the planning process (Harris and Batty 2001).

A GIS software application for environmental risk assessment of such properties/ portfolio could serve as a powerful risk management tool for the future Ada Ciganlija life. The framework of such an application would comprise of three main parts:

1. Exposure: Spatial location of the future forestation or re-construction Ada urban forest/ area.
2. Hazard: Location of sources causing pollution/contamination risk, nature of pollutant/contaminant and probability of any leakage/accident, because of natural or man-made factors, “footprint” or the thematic concentration map for such scenarios.
3. Vulnerability of the urban forest/area: This could be specified in terms of percentage damage or cleaning/reconstruction cost, for different pollution/contamination concentration ranges.

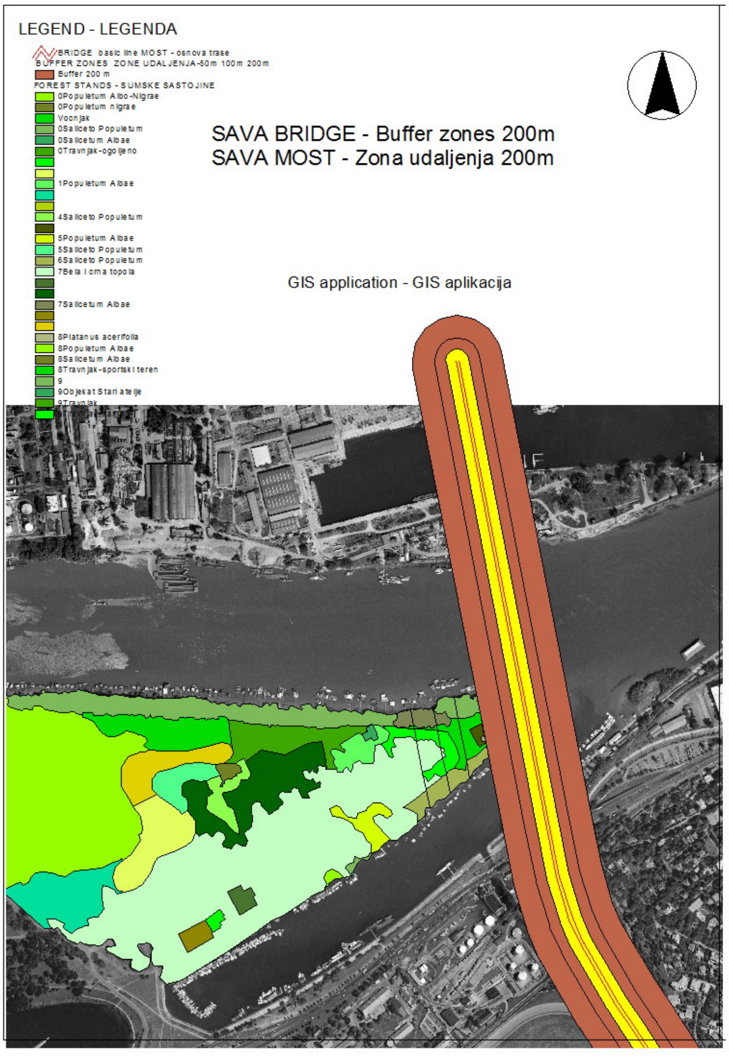

Figure 4. *Distance model*

Distance Model - Spatial articulation under established condition and criteria's could be simulated with results to establish impact on vegetation (Figure 4). The main tool for that task is the distance model with numbers of dates and questions possibilities. For example if we what to know what is the vegetation coverage condition according the habitat conditions (ground surface, hydrological regime, vegetation community of the ecosystem, buffer zones from the source of negative impact, etc.) establishing the criteria's and themes selection, characteristics, it is possible to get information by quantified dates and graphical expressions as it is GIS tool. Building the model in operational working is the task which needs all spatial elements and dates in selected zone. It is given by graphical application, tables with relation between.

Figure 6. *New Sava Bridge in construction (Photo R.Nevenic, 21. January 2010.)*

4. CONCLUSION

Numbers of GIS applications, simulations and GIS spatial-ecological analyses are necessary to be done and determinate ways of air circuit orientation, choice of the future vegetation species, which will have multi-designed function. Also, visual esthetic exposure of the large object (Figure 6) should be lighten with the greenery, deciduous species, conifers and similar vegetation in the future.

Ada Ciganlija climate conditions are different than macroclimate conditions of Belgrade region. Winter temperatures are different up to couple degrees. On the Ada area is much cooler because of the air circulation inversion which is one the important conditions for future actions in this area, traffic, highway maintanance activities. Frost feature is characteristic for such an island surrounding. Each continuity break of these temperature conditions can lead to disturbance

Such a scenario simulation and analysis application could help in having in future presentation of the possible situations, and planning suitable actions and alternatives, both in term of the specific locations (spatial) and the time factor (temporal) associated with such actions. The results obtained from this type of approach can be used for preparing effective policy recommendations and guidelines for maintaining the long-term environmental sustainability of a specific recreation area, while keeping the vegetation and environment sustainability and development needs in mind.

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THE MEASURES SUGGESTED FOR MITIGATION OF NEGATIVE IMPACT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS

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Abstract: *The environmental pollution causes many ecological problems, climate changes and global warming, with adverse effect on forest ecosystems in the whole world, as well in Serbia. Forest plants tend to release carbon instead of natural process of absorbing it because of global warming. Thus forests instead of being lungs of the Earth become one of the sources of pollution. Numerous studies about global warming and potential changes in temperature and humidity, point to wide spectrum of effects both on the forests ecosystems on the whole and on the single tree. Even though climate and other environmental conditions, especially negative ones have the most direct influence on the forest vegetation and its structure the forest itself can also modify these conditions to a great extend. To mitigate negative effects and to exceed expected consequences the adaptive measures should be taken in to account in the forest management. And these measures will help forests to acclimatize to new environmental conditions. If new regulations and other polices regarding forest adaptation would be provided and acknowledged one will have the actual indication for taking different actions in state and private forests, all in aim of sustainable forest management even under changed climate conditions. The paper presents negative effect of climate change, consequences and disturbances in forest ecosystems and the modified framework of adaptable forest management. The potential strategic and operational methods for forest ecosystems adaptation to negative climate changes are also suggested.*

Key words: forest ecosystems, climate changes, strategic measures, adaptable forest management

PREDLOG MERA ZA UBLAŽAVANJE NEGATIVNOG UTICAJA KLIMATSKIH PROMENA NA ŠUMSKE EKOSISTEME

Izvod: *Zagađivanje životne sredine dovodi do brojnih ekoloških problema, klimatskih promena i globalnog zagrevanja, koji negativno utiču na šumske ekosisteme u celom svetu, pa i u Srbiji. Globalno zagrevanje je dovelo do toga da biljke u šumama počinju da otpuštaju ugljen-dioksid u atmosferu, umesto da ga apsorbuju. Tako šume, umesto pluća planete, postaju zagađivači. Brojne studije o globalnom zagrevanju i potencijalnim promenama temperature i vlažnosti, ukazuju na vrlo širok spektar efekata kako na šumske ekosisteme u celini, tako i na pojedinačna stabla. Iako klimatski i drugi ekološki uslovi, a pogotovo oni nepovoljni, najneposrednije deluje na šumsku vegetaciju i njen sastav i sama šuma može u velikoj meri da modifikuje te uslove. Da bi se ublažili negativni uticaji i prevazišle očekivane posledice, pri gazdovanju šumama moraju se uzeti u obzir mere koje će dovesti do adaptacije šuma na novonastale klimatske uslove. Ukoliko se donesu i usvoje novi pravilnici i drugi pravni instrumenti u vezi sa adaptacijom šuma, dobiće se pravi putokazi za preduzimanje različitih akcija u okviru državnih i privatnih šuma, a sve u cilju održivog gazdovanja šumama i pod izmenjenim klimatskim uslovima. U radu su detaljno prikazani negativni uticaji klimatskih promena, posledice i poremećaji nastali unutar šumskim ekosistemima. Prikazan je modifikovan okvir adapbtibilnog gazdovanja šumama i predložene su potencijalne strateške i operacione metode adaptacije šumske ekosisteme na negativne uticaje klimatskih promena.*

Ključne reči: šumski ekosistemi, klimatske promene, strateške mere, adaptibilno gazdovanje šumama.

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1. INTRODUCTION

A numerous studies concerning global warming and potential temperature and humidity change indicate a very broad spectrum impact and influence on both forest ecosystems as whole and individual trees (Smith, Tirpak, 1989; Andrasko, 1990; Botkin *et al*., 1992).

It has been foreseen that the global temperature increase from 1.1°C to 6.4°C and humidity increase from 7.1% to 15.8% in 21st century will lead to serious and rapid changes in forest ecosystems. It has been indicated that the impact of global warming could be that strong in certain regions that it would cause a change in forest productivity, in structure of plant and animal communities in forests and, as a consequence, the existence of forest cover would be no longer possible. Such response to climate conditions change would result in numerous implications and negative impact upon preserving biodiversity and water integrity, protection of natural areas and soil against erosion, commercial forestry, wood industry, recreation and other.

Despite the fact that climate and other ecological conditions, those unfavourable in particular, affect forest vegetation and its structure in the most direct manner, the forest itself is capable of modifying those conditions to a large extent. Forest ecosystems are an irreplaceable means of resolving environmental issues, not only in regional, but in broader framework, since their generally beneficial functions produce global effect and have a significant biosphere importance (Brašanac-Bosanac, Ćirković-Mitrović, 2009).

2. NEGATIVE IMPACT OF CLIMATE CHANGES ON FOREST ECOSYSTEM

Environmental pollution leads to numerous ecological problems, climate changes and global warming, creating negative impact on forest ecosystems. In order to mitigate the negative impact of climate change on forest ecosystem and overcome implications that have arisen, forest management must consider adopting measures leading to forest adaptation to newly created climatic changes.

Innes et al. (2009) identify global warming negative impact groups which affect forests.

Table 1. *Global warming negative impact and disturbances in forest ecosystems (Innes et al., 2009)*

Area of negative impact	Implications / disturbances
Forest ecosystems	Forest conversion into herbaceous energy plantations Rapid deforestation and forest degradation Increased use of forest trees as a source of energy
Forest ecosystems biodiversity	Change in distribution of plant and animal communities Biodiversity loss Occupation of habitats by allochthonous species Change in pollination system Change in plant dispersion and regeneration
Forest ecosystem productivity	Change in forest growth and ecosystem biomass Change in relation between species / habitat Change in ecosystem nitrogen cycle
Forest ecosystems health condition	Increased mortality due to climatic stress Reduced forest ecosystem vitality and health due to cumulative impact of different stresses Health deterioration of local population
Land and water	Changes in seasonality and intensity of humidity Changes in flood flow regime Increased possibility of extreme draughts occurrence Increased terrain instability and soil erosion due to increased humidity

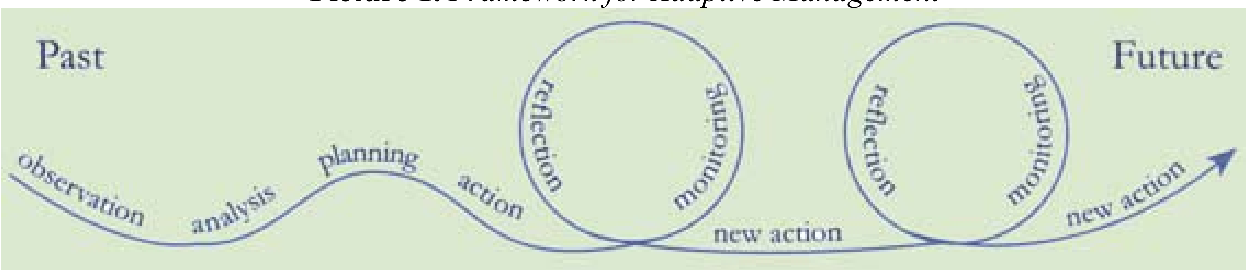
	Early snow melting leading to change of period of maximum flow and amount of water in streams
Carbon cycle	Changes in forest CO_2 reservoirs and increased emission of CO_2 from forest ecosystems due to change in forest growth and productivity
Direct forest benefits for people	Change in woodiness degree Socio-economic changes Changes in specific forest products availability (timber, wood fuel, medicinal plants, fungi, etc)
Indirect forest benefits for people	Change in frequency of conflicts between people and nature Income changes for forest owners and local population Socio-economic changes Changes of cultural, religious and spiritual values

In the event of adoption of new regulations and other legal acts related to forest adaptation, a proper course for taking different actions in state and privately owned forests will be assumed, with the aim to attaining sustainable forest management even under altered climate conditions, occurring as a result of global warming.

3. ADAPTIVE FOREST MANAGEMENT

Roberts *et al.* (2009) provide survey of current forest management trends which are promoting forest and forestry adaptation to new climate changes. The proposed management measures are mainly oriented to creation of stable, resistant to negative climate changes, forests. The management model which aims at preserving forests in their most natural form, avoiding mono-cultures and creating mixed forests, both in the structure of species and age, is supported. Furthermore, it aims at maintaining natural or nature appropriate regeneration, as methods of maintaining genetic diversity, and consequently, forest ecosystems sensitivity reduction. For the purpose of preventing extreme disturbances, methods of improving fire location and extinguishing, as well as pest and disease control, are proposed. Primarily, they concern establishing quarantine and additional sanitary measures, which proved highly effective. Establishing of migration corridors between forest reservations was carried out in practice and, in that manner, an autonomous species colonisation and migration were enabled, as a response to climate changes.

Picture 1. *Framework for Adaptive Management*



Source: Colfer 2005a. by Innes *et al*. (2009) p.135

It is certain that implementation of number of measures aiming at adapting forests to climatic changes conveys a degree of uncertainty. Essentially, adaptive forest management can be understood as a systematic process aiming at constant improving of management policy and practice itself by monitoring, and later, learning by means of analyses of operative programmes results (Innes *et al*., 2009).

4. POTENTIAL STRATEGIC AND OPERATIONAL METHODS OF FOREST ECOSYSTEMS ADAPTATION

There is a large number of potential methods, related to resolving issues that have arisen in forestry owing to global climate change and forest adaptation to new environmental conditions (Ogden, Innes, 2007; Aragao *et al.*, 2008, Barlow, Peres, 2008; Betts *et al.*, 2008; Biringer, 2003; Carey, 2003; Drever *et al.* 2006; Schroeder, 2007; Koski V., Rousi, 2005; Gitay, 2001; Spittlehouse, Stewart, 2003; Innes *et al*., 2009; IPCC, 2000). A survey of potential strategic and operational methods of adaptation, which can be implemented in sustainable forest management, is presented in further text.

For the purpose of preventing deforestation and forest degradation, it is necessary to:

- ✓ strictly comply with legal provisions concerning prevention of unlimited and unrestrained wood felling;
- ✓ intensify work of forest services (foresters and inspectors), where illegal wood felling is evident;
- ✓ provide funds for ensuring economic flexibility for land owners, should they decide to plant forests on their land.

For the purpose of preventing increased use of forest trees as fuel:

- ✓ substitute the use of wood fuel with more energy efficient fuels (e.g. wood coal);
- ✓ substitute wood fuel and wood coal with renewable sources of energy.

For the purpose of preventing negative changes in plant and animal community distribution:

- ✓ minimise habitat fragmentation and maintain connectivity ;
- ✓ reduce deforested areas to the level above bordering values (30-40%);
- ✓ protect high forests;
- ✓ protect climate refugia by different measures;
- ✓ identify and protect functional groups and major species;
- ✓ strategically increase the size and number of protected areas, particularly in exceptionally valuable habitats;
- ✓ provide buffer zones for the purpose of adaptation of forest reservation borders;
- ✓ protect most endangered ex-situ species;
- ✓ create artificial forest reservations or arboreta for the purpose of rare species preservation;
- ✓ improve regional co-operation concerning species management and protection;
- ✓ support changes in distribution of endangered and sensitive species by means of their introduction to new areas;
- ✓ in artificially planted woods and mixed cultures, encourage natural genetic diversity, imitate the structure of neighbouring forests and avoid direct substitute of natural ecosystem;
- ✓ maintain seed sources (seed banks and seed facilities);
- ✓ allow forest regeneration through natural succession after large disturbances wherever possible.

For the purpose of preventing habitat invasion by allochthonous species or autochthonous species not indigenous in a given habitat, control of invasive species ought to be conducted.

For the purpose of preventing increased frequency and intensity of pest and disease outbreak:

- ✓ adapt the schedule of planned wood felling in most sensitive stands so as to correlate with harmful insects outbreaks;

- ✓ plant and sow genotypes resistant to draught and other climate extremes, insects and diseases;
- ✓ reduce losses due to disease by means of sanitary wood felling;
- ✓ use standard forest techniques for improving forest productivity and stand resistance;
- ✓ increase genetic diversity of trees used in setting up plantations;

For the purpose of preventing mortality due to climate stress, avoid planting new forests on locations prone to natural disturbances (for instance floods).

For the purpose of preventing poor health condition and vitality of forest ecosystem, which are the results of cumulative effect of different stress factors:

- ✓ reduce stress factors not linked to climate conditions, in particular air pollution, in order to increase ecosystem ability to respond to climate change;
- ✓ re-cultivate degraded area in order to preserve genetic diversity and improve ecosystem health;
- ✓ carry out monitoring of all forests by means of establishing and improving national, regional and operational network for monitoring forest health condition, and subsequently, diagnostic – forecast services, as well as services for invasive species distribution monitoring;

For the purpose of preventing changes in forest distribution frequency and intensity:

- ✓ help tree regeneration;
- ✓ maintain seed banks;
- ✓ actively implement control measures against pests and diseases;
- ✓ improve plantation stability by means of increasing species and structure diversity;
- ✓ increase use of commercial thinning in draught areas in order to increase tolerance of remaining trees and to introduce species tolerant of draught, where possible;
- ✓ include risk management in management policy and forest plans
- ✓ increase people's awareness in regard to potential impact of climate changes on fire regime and promote proactive actions in regard to fuel management and community protection.

For the purpose of preventing negative changes affecting forest growth:

- ✓ include climate parameters in forest growth and production models;
- ✓ apply thinning or selective removal of suppressed, damaged trees of poor quality;
- ✓ mark more suitable genotypes;
- ✓ adapt the time of annual wood felling in such a way that forest processes remain in a state of most possible balance.

For the purpose of preventing increased loss of nitrogen, nitrogen fertilisers ought to be used, and planting of nitrogen fixators in the ground layer of vegetation ought to be promoted.

For the purpose of preventing habitat invasion by allochthonous species or autochthonous species not indigenous in a given habitat, those species ought to be constantly controlled, bearing in mind that they enter stronger competition with exploited species in altered climate conditions.

For the purpose of preventing increased soil erosion:

- ✓ maintain roads so as to significantly reduce washing away of sediments, resulted from increased humidity and snow melting;
- ✓ reduce land disturbances by means of application methods of wood felling with the least possible environment impact;
- ✓ limit wood felling to those time periods when it is not necessary to build roads for hauling wood mass and when the least land disturbance is expected;
- ✓ reduce the density of permanent road network and reconstruct main forest roads, so as to increase productive forest area to a maximum degree.

For the purpose of preventing increased land instability, avoid road building on soil prone to rockslide, avalanches and landslide.

For the purpose of preventing negative changes concerning CO_2 storage forest reservoirs and increased CO_2 emission from forest ecosystems:

- ✓ increase forest area by means of afforestation and re-cultivation of degraded areas;
- ✓ include forest ecosystems CO_2 emission and forest ecosystems CO_2 binding in all national and global calculations of nitrogen supply and change in its supply;
- ✓ reduce forest degradation and avoid deforestation;
- ✓ combine existing multifunctional forest areas and reservations with afforestation, that is, planting of short rotation energy plantations;
- ✓ modify the practice of thinning (its time and intensity) and rotation period so as to enhance forest growth increase and transformation of CO_2;
- ✓ reduce the impact of natural disturbances upon CO_2 supply by means of fire, pest and disease prevention;
- ✓ reduce soil disturbances by means of application of wood felling methods with the least possible environmental impact;
- ✓ increase use of forest for generating biomass energy;
- ✓ practise forest management with the least possible environment impact and prevent transformation of forests into plantations.

5. CONCLUSION

Forest ecosystems are the largest reservoirs for storage of atmospheric $CO_{2.}$ Carbon dioxide is extracted from atmosphere thanks to photosynthesis process, and then it is incorporated into wood biomass. Globally, forest ecosystems can store from 20 to 100 times larger amounts of CO_2 per area unit in comparison with agricultural areas and, consequently, they play far more important role in reduction of CO_2, which is one of the most important greenhouse gases. However, the problem arises when forest ecosystems, due to a disturbance in forest itself (caused either by anthropogenic activities, for instance wood felling or by a natural cycle of other type – old trees dying out, herbivore feeding, pest or disease outbreak and other) begin to release stored CO_2 back to the atmosphere. Forests themselves will never be able to stabilise atmospheric concentrations of greenhouse gases or to balance the total CO_2 emission in different countries. Rule books concerning forest and forestry adaptation to new climate conditions present a part of national forestry strategies or rural development programmes and they are involved in finding ways of increasing forest flexibility in relation to climate changes by means of increasing forest areas, sustainable management and protection.

Economic instruments, such as donations, aid instruments and compensations are used for promotion of afforestation, changing the structure of plant and animal communities and extreme disturbance recovery.

Measures for mitigation of negative impact of global warming on forest should be:

- ecologically sustainable over time,
- economically viable and justifiable,
- have low starting costs,
- socially integrated,
- based on local needs and tradition,
- technologically simple and
- adaptable to volatile economic, political, social, ecological and climate conditions.

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BIOLOGICAL SYSTEMS FOR WASTEWATER TREATMENT AND RAINWATER HARVESTING IN THE VILLAGE ZAGORA, MONTENEGRO

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Abstract: *The paper presents research results related to the construction of the biological system for wastewater treatment and the design of the integrated system for the rainwater harvesting and purification in touristic village Zagora. The village does not have conventional water supply and sewerage systems. The water is supplied by water desalinization system. Seventeen houses and one reception facility will be built according to the plan. Houses vary in size and they can accommodate one hundred visitors. In regard to climatic conditions and type of housing project the intent is to construct an integrated biological system for wastewater collection and treatment. The system comprises pretreatment compartment, constructed wetland and restorer. The technical water supplied at the inlet returns back to the reception and all houses. The composting toilets are installed in all houses and reception for the purpose of saving water and unburdening biological system for wastewater treatment by microorganisms and aquatic plants. The restoration of old water reservoirs, called bistjerne and ubla, is planned in the aim of rainwater harvesting and treatment. The construction of the new system for rainwater harvesting from roofs, all kinds of eaves and ground is suggested for the purpose of gathering more rainwater. In this way sustainable management of present water resources will be enabled in village Zagora.*

Key words: waste water, constructed wetland, restorer, rainwater harvesting, Zagora

BIOLOŠKI SISTEMI ZA PREČIŠĆAVANJE OTPADNIH VODA I SAKUPLJANJE ATMOSFERSKIH VODA U SELU ZAGORA U CRNOJ GORI

Apstrakt: *U ovom radu su prikazani rezultati istraživanja, koji se odnose na konstrukciju biološkog sistema za prečišćavanje otpadnih voda kao i formiranje integralnog sistema za sakupljanje i prečišćavanje atmosferskih voda u turističkom selu Zagora. Selo nema vodovodni i kanalizacioni sistem. Snabdevanje vodom je obezbeđeno zahvaljujući izgradnji sistema za desalinizaciju vode. Planirana je izgradnja 17 kuća i jednog objekta recepcije. Kuće su različite veličine i u njima ima mesta za ukupno 100 ljudi. S obzirom na karakter klime i naselja predložena je izgradnja integralnog sistema za sakupljanje i prečišćavanje otpadnih voda. Sistem se sastoji iz dela za predtretman, konstruisanog akvatičnog ekosistema i restauratora. Na izlivu ovog sistema dobija se tehnička voda, koja se vraća u kuće i objekat recepcije. Zbog uštede vode i rasterećenja sistema za prečišćavanje otpadnih voda pomoću mikroorganizama i biljaka, u toalete kuća i u objektu recepcije ugrađuju se kompostni toaleti. U cilju sakupljanja i prečišćavanja atmosferskih voda predloženo je obnavljanje svih postojećih „bistjerni“ i ubla. Kako bi se prikupilo što više vode predložena je i izgradnja novih sistema za sakupljanje kišnice sa krovova, nadstrešnica i sa površine zemlje. Na ovaj način omogućiće se održivo upravljanje postojećim vodnim resursima u selu Zagora.*

Ključne reči: otpadne vode, konstruisani akvatični ekosistemi, restauratori, sakupljanje kišnice, Zagora

1. INTRODUCTION

Zagora is a maritime village, located at the altitude of 20-232 metres. It has no live springs, but there are wells, used for water collection from plateaus and house roofs. Therefore,

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since oldest times people have resorted to the only possible solution to a problem of harvesting atmospheric waters, which are abundant in winter months, – building of water accumulation cisterns. Apart from cisterns, a type of well – large round ground holes, walled with stones, were built in the village. They were used for rainwater harvesting from the ground surface. The village has no water supply system nor sewer system.

The further development strategy envisages several possibilities for its revitalisation. It can be transformed into a scientific, agricultural, tourist or sport village.

For the purpose of transforming Zagora into a tourist village, building of 17 houses and a reception building has been planned. The houses are of different size (from 2 to 8 beds) and they provide accommodation for 100 persons in total. Approximately 10 persons will be employed in the reception building.

The water supply has been provided thanks to the construction of water desalination system.

Having in mind the type of climate and settlement, a construction of integral system for wastewater collection and treatment has been proposed. The system consists of a pre-treatment part, constructed aquatic ecosystem and restorers.

For the purpose of water saving and wastewater system relief, compost toilets are installed in house and reception toilets. The remaining wastewater is conveyed into a constructed aquatic ecosystem and restorers, through pre-treatment tanks.

Water for non-potable uses is obtained in the system outflow, from where it flows back into the houses and reception building. A possibility of water going back into a constructed aquatic ecosystem and restorers is envisaged, should the need arise.

2. A SOLUTION PROPOSAL FOR WASTEWATER COLLECTION AND TREATMENT IN THE VILLAGE OF ZAGORA IN MONTENEGRO

An amount of water used by one person per day is adopted as a starting parameter for determining the size of a pre-treatment tank and constructed aquatic ecosystem. According to the data by PUC Belgrade Water Supply and Sewerage (2008), 200 l is a fully sufficient daily amount of water for one person. Having in mind that it is assumed that 110 persons per day will be accommodated in the village, a daily water consumption amounts to 22,000 l (22m^3 / per day). Should the village increase in time, a problem of generating larger amounts of wastewater than originally planned, will be resolved by adding new pools within the framework of existing constructed aquatic ecosystem.

A treatment of wastewater will be carried out in the constructed aquatic ecosystem and restorers, but it will not include toilet wastewater ('black' wastewater).

This type of wastewater presents the largest source of pathogenic microorganisms and, therefore, it has been decided that it will be treated separately. It should be mentioned that a household wastewater filtration facility, using aquatic plants, successfully remove pathogenic microorganisms, but the above-mentioned concept of treatment organisation is adopted, since it enables reducing water consumption. 1/3rd of the total water consumed or 20-40 l per person per day is used for toilet usage.

Although kitchen wastewater is also considered 'black' wastewater, the project envisages that it flows directly into the constructed aquatic ecosystem.

2.1. Compost (biological) toilet

A traditional household toilet is substituted with a compost toilet. It is a type of toilet which uses a very small amount of water for its functioning or no water at all. They are ideal for houses which have no connection to a central sewer system. Combined with constructed aquatic ecosystem, they can fully substitute conventional septic tanks, used for the treatment of ’black’ wastewater.

The basic task of the compost toilet is to destroy organisms which can cause different human diseases. Apart from that, a transformation, by means of bacterium, actinomycetes and fungi of nitrogen and phosphorus from human excreta, toilet paper or food remains, into fully oxidised and stable forms of these elements, which can be absorbed by plants, is carried out in these toilets. The final product is humus, which can be used as a fertiliser in gardens or to improve the quality of agricultural soil.

The toilet should be constructed in such a manner that it can separate solid matters from liquid and to have stable matter as final product, – humus, which will contain less than 200 mpn[1] coliform bacterium of faecal origin in 1 gram (Oikos, 2008).

Different types of these toilets can be found on the world market. The differences are usually reflected in the amount of water they use or do not use at all for its functioning, placement of a compost tank and a design of a toilet bowl.

The project envisages that the liquid and sludge from compost toilet, which are now considered ’grey’ water, are sent to pre-treatment system.

Humus obtained can be used as fertiliser for plants. It is suggested that this humus should be mixed with different types of organic waste (food remains, removed parts of plants, etc.) and placed in compost piles. For the purpose of more rapid quality humus obtaining, microorganisms, which are subsequently added to the compost piles, ought to be included in the process of organic matter decomposition. Composting area should be located far from the living area.

2.2. Pre-treatment of wastewater

Pre-treatment of wastewater is carried out in three chamber tanks. A standard mechanical wastewater treatment is conducted in the first chamber, while introduction of aeration to the second chamber and microorganisms in the third chamber reduces the concentration of pollution matter to minimum prior to entering aquatic plant pools.

Such an intensive wastewater pre-treatment is selected primarily because of the tourist character of the village and the intention to occupy least possible land area for constructed aquatic ecosystem, but also because of the climate conditions of the environment which inevitably lead to exceptionally high plant evapotranspiration and evaporation of water.

Provided that sufficient area is available, a pre-treatment tank will be installed in every house, while in case it is not, an area will be designed for placing a tank which will receive wastewater from a group of houses.

2.3. Constructed aquatic ecosystem

A construction of an aquatic plant wastewater treatment facility generally involves simple groundwork, such as terrain clearing, earth digging, leveling and other. Naturally, in the course of its construction, some specificalities appear, related to ensuring regular water flow, its even distribution, maintaining a desired water level, filling up pools with substratum and planting plants.

A construction of three surface water flow pools is planned. A pool tank will be formed by excavating holes of required size, tamping earth, laying down a perlite buffer layer and pvc foil.

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[1] mpn – *most probable number*

The pool substratum consists of 5 cm of sand, 50 cm of gravel and 10 cm of fertile soil. In that manner, a 0.65 m layer is obtained, which is quite sufficient for development of aquatic plant root system.

Aquatic plants are obtained from nature and with the consent of authorized organs. In this manner, acclimatized plants will be provided and, more importantly, they will already have settled microorganism colonies around their root system. In case that planting is carried out in early spring, the whole plants will be planted, while if the planting period is autumn, a rhisome will be used.

Plants planted in the first pool are *Phragmites communis, Typha latifolia, Schoenoplectus lacustris, Lythrum salicaria, Carex pendula, Butomus umbellatus* and *Sagittaria sagittifolia.* The processes of flocculation and sedimentation dominate inside this pool, whose lower parts have characteristic of anaerobic environment. That means that mostly sedimentation of suspended matter and removal of pathogenic microorganisms take place in it, while the reduction of BPK, nitrogen and phosphor is somewhat less intensive.

Submersible plants *Potamogeton perfoliatus*, *Potamogeton natans* i *Elodea canadensis* are planted in the second pool. This pool has a large area of free water and it presents the aerobic environment, inside which BPK reduction and nutritious matters reduction (nutrification) are carried out. The removal of suspended matters and pathogens is continued here.

The characteristics of the third pool are the same as those of the first one. These pools differ only in structure of vegetation. Plants *Iris pseudoacorus, Caltha palustris, Lemna minor, Alisma plantago – aquatica* i *Menyanthes trifoliata* are planted in the third pool. The final water treatment is carried out in this pool. By further sedimentation, denitrification and other processes, the final removal of suspended matters, nitrogen, phosphor, pathogens and other pollutants is carried out.

Cleaned water is transported through outer pipe to other pipes, which conveys water to a restorer.

2.4. Restorers

Restorers present floating ecosystems, which can carry out wastewater treatment, help recovery of old and over-laden lagoons, suppress algae breeding and help maintaining vitality of different aquatic ecosystems (Todd, 1996). These floating islands are placed into new and existing lagoons and lakes in order to provide simple, powerful and aesthetically attractive method of wastewater treatment or cleaning up of polluted water areas.

Cascade canals, which follow the central pedestrian path, are used for installing restorers. Floral decorative flowers, such as *Canna indica* L., *Iris pseudoacorus* L., *Butomus umbellatus* L., *Caltha palustris* L. and other are planted in substratum holders.

After leaving the restorer, water is conveyed to houses and reception.

Moreover, the construction of proposed wastewater treatment system in village of Zagora allows return of cleaned water into pools and restorers of constructed aquatic ecosystem.

3. HARVESTING AND TREATMENT OF ATMOSPHERIC WATER

In the broadest sense, rainwater harvesting presents a technology by which atmospheric precipitation is collected from roofs or ground surface and stored, by means of simple techniques, which involve use of different barrels, tanks or built tanks. It is not a new technology and it has already been in use for 4,000 years. Harvested rainwater presents an important source of water in many regions with high amounts of precipitation, which do not have a conventional, centralised water supply system or lack surface or underground water of sufficient quality.

The importance of atmospheric precipitation harvesting has been realised in a village of Zagora since oldest times and, therefore, „*bistjerne*" (cisterns) for accumulation of rain from roofs and „*ubla"*(wells) – large round ground holes, walled with stones, for the purpose of collecting ground water, can be found in this area. The collected water, not being sufficiently clean, was mainly used by villagers for watering cattle and field irrigation.

3.1. Basic components of a system for atmospheric water harvesting

Basic components of a system for atmospheric water harvesting are: an area for rain collection (eaves), conveying system (gutters) and a rainwater storage tank.

The effectiveness of rainwater collection and the quality of collected water directly depend on the type of material used for construction of collection area. It must be smooth, non-toxic and must not contain matters (colours, spreads, etc.) which could have any sort of negative impact on water quality.

The conveying system is used for transport of collected water to the reservoirs, that is, tanks. Plastic (or other inert material) pipes are generally used, having in mind that low pH value of rainwater can cause corrosion and metal mobilisation in pipes.

Storage tanks can be placed above or under ground. They can be built as a part of an existing structure or as an independent unit located at a certain distance from the building.

3.2. A solution proposal for harvesting and treatment of atmospheric waters in village of Zagora in Montenegro

A reconstruction of all existing „bistjerna" (water tanks) and *„ubla"* (wells) is proposed in order to restore their original appearance, but also to remove all cracks and other tank damage, which could occur in the course of time.

In order to collect as much water as possible, construction of new systems for collection of rainwater from roofs, eves and ground surface is also proposed.

The reservoirs, for harvesting atmospheric precipitation from ground surface, are laid down under ground on plateaus and lowest points of the terrain.

Harvested water can be used for watering green areas. In case that extracted water is treated by aeration, microorganisms and UV reflection are added, and non-palpable water, that can be used in households, is obtained. Depending on the results of pathogenic microorganisms monitoring, a treatment system can be built separately or harvested water can access constructed aquatic ecosystem directly.

4. CONCLUSION

By the construction of biological system for collection and treatment of wastewater and system for harvesting and purification of atmospheric water a big step was made in preserving water resources in the village of Zagora.

Such systems have great significance in rural areas and settlements which have no conventional water supply and sewerage systems .

In addition to improving the sanitary and hygienic conditions in the settlement, they greatly contribute to and improve the aesthetic value of the village.

Through further improvement this alternative technology could take the leading place in wastewater treatment and recovery of different water surfaces.

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SOIL EROSION IN THE DRAINAGE BASIN OF THE RIVER RASINA UPSTREAM OF THE RESERVOIR “ĆELIJE“

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Abstract: *The dam and the reservoir “Ćelije“ is located on the river Rasina about 33 km from its confluence in the river Zapadna Morava. The river Rasina drains the slopes of the mountains Jastrebac, Kopaonik and Goč, which attain the altitudes of up to 1500 m i.e. 1900 m. The lowest elevation of the Rasina at the confluence to the Zapadna Morava is about 200 m, and the elevation of the Rasina bed in the profile of the dam “Ćelije“ is about 239 m. The drainage basin is elongated, curved, with a developed drainage pattern, The drainage basin area to the dam profile amounts to 609.15 km^2.*

The reservoir "Ćelije" is a strategic part of the Rasinsko-Pomoravski regional water-supply system which includes the downstream part of the Zapadna Morava and the upstream part of the Velika Morava. It is planned that the sub-system “Ćelije“ should be the regional system which provides full supply of water to the municipalities: Kruševac, Aleksndrovac, Varvarin, Ćićevac, Trstenik and Vrnjačka Banja and partial supply to the municipalities: Ražanj, Paraćin, Ćuprija, Jagodina and Despotovac.

Taking into account the increasing demands of clean water, it is important to protect the reservoir “Ćelije“ against erosion in the catchment and the resulting damage.

This paper presents the results of the study of the catchment natural characteristics significant for the development of soil erosion process and the present state of erosion in the drainage basin upstream of the reservoir “Ćelije“, as the indicator of its erosion and sediment risks. The research was carried out over 2008 and 2009.

Key words: erosion, reservoir, risk, state.

1. INTRODUCTION

Soil erosion control and torrent control are some of the most significant factors of the development of water management. Many excellent water management solutions in the past were compromised because soil erosion and sediment yield as the product of erosion were not taken into account. Reservoirs are the most susceptible water engineering structures to the effects of erosion processes in the drainage basin and the silting up risk. Due to erosion, many reservoirs in Serbia were very soon silted up with sediment and practically turned into reservoirs for sediment. A typical example of silted up reservoirs is the reservoir “Zvornik“ on the Drina, the reservoirs on the Zapadna Morava, etc.

The impact of sediment yield on reservoirs is detrimental for multiple reasons:

- silting up of reservoirs with sediment and thus the reduction of storage space for water,
- mechanical contamination of water, and
- chemical contamination of water.

Water contamination caused by erosion sediment, is often so severe that such water is unusable not only for water supply but also for irrigation and industrial use.

2. STUDY AREA AND METHOD

2.1. Study area

The dam and reservoir “Ćelije“ is located on the river Rasina, about 33 km from the confluence in the river Zapadna Morava. The river Rasina drains the slopes of the mountains

Jastrebac and Kopaonik which attain the altitude of 1500 m, i.e. 1900 m. The lowest elevation of the Rasina, at the confluence in Zapadna Morava is about 200 m, and in the profile of the dam Ćelije, the elevation of Rasina is about 239 m. The catchment is elongated, bended, with a developed hydrographic network. The area of the drainage basin to the dam profile is 609.15 km^2. In the drainage basin, there are several rain gage stations and one weather station, Kruševac, functional for many years. Average rainfall in the drainage basin to the dam "Ćelije" is about 745 mm.

The reservoir "Ćelije" is a strategic part of the Rasinsko-Pomoravski regional water supply system, which includes the downstream part of the Zapadna Morava course and the upstream part of the Velika Morava.

The river Rasina drainage basin has a dual character, the upper part of the drainage basin is characterised by a mountainous and hilly relief, while the lower part of the drainage basin is mainly lowland. The catchment area consists of various types of relief, so the terrain of the drainage basin can be divided into the Kopaonik block, the flysch belt, Moravski Graben and the area of Jastrebac.

The subject of research is the study of natural characteristics of the river Rasina drainage basin, upstream of the reservoir "Ćelije" (Table 1), significant for the genesis of erosion processes and sediment transport, erosion status in the catchment and sediment yield and transport (sediment inflow in the reservoir "Ćelije").

Table 1. *The parameters of the watershed*

Parameters	Symbol	Units	Values
Watershed area	A	km^2	609,15
Watershed length	L	km	69,49
Watershed perimeter	O	km	184,47
Watershed mean altitude	Nsr	m	695
Watershed mean altitude difference	D	m	447
Watershed mean slope	Isr	%	34,65
Stream bed slope	It	%	1,62
Local erosion basis	H	m	1688

2.2. Method

The applied methods are standard methods for the study of drainage basin natural characteristics using GIS technology (Kostadinov 2008).

The erosion status, sediment yield and transport are defined by the method of erosion potential by S. Gavrilović (Gavrilović 1972) using satellite images and the detailed reconnaissance of the terrain, using GIS technology.

3. RESULTS

3.1. Parent rock characteristics

The geological structure of the study area consists mostly of the following bedrocks: Palaeozoic rock complex (schists); Mesozoic rock complex (flysch); Palaeogene rock complex; Neogenic rock complex, and the Quaternary deposits.

According to the basic geological map of Kruševac, the oldest (Palaeozoic) rocks in this area are schists of a high degree of metamorphism, which are the building blocks of the western and eastern parts of Veliki and Mali Jastrebac (Serbian-Macedonian mass), and smaller masses occur among the rocks of the Kopaonik block. This rock complex consists of gneisses, micaschists, amphibolites, amphibolitic and other schists. The series mica-quartz-plagioclase schists occurs in the eastern and western sides of the central and northern parts of the lake Ćelije. In the central-narrowed part of the lake, there is a fault zone in which the schists in this series are mostly catalysed and limonitised.

The Mesozoic rock complex consists of the Jurassic and Cretaceous formations, flysch formations represented by limestones, sandstones, conglomerates, marls and argillites. These rocks occur in the greatest part of the Rasina drainage basin territory. Senonian flysch (Upper Cretaceous) is found in the south-western part of the lake and lies discordantly across the highly metamorphosed schists. In addition to this formation, the diabase-chert formation is also developed, as well as the diabase-spilite-Albian formation, primarily in the headwater parts. There are also some smaller parts of serpentine peridotites and gabbros, which are mostly found in the Kopaonik block.

The Palaeogenic rock complex is represented by granodiorites, granites, quartz diorites and diorites. These rocks are the building blocks of the western and south-western slopes of the mountain Goč.

The Neogenic rock complex ranges within the complex tectonic depression of the Moravski Graben. The Neogenic deposits in the area of the reservoir "Ćelije" (south-western bank) consist of the Helvetian deposits composed of conglomerates, sandstones and more rarely of sandy marls. A small part of the Pannonian-Pontian sediments, represented by the facies of clays, sands and gravels, range on the northern edges of the lake.

3.2. Soil characteristics of the Rasina drainage basin

The Rasina valley is filled with the alluvial material consisting of impermeable clayey material (75 %), significant for the formation of reservoir channel and especially the reservoir bed.

The soil of the right riparian part of the lake is developed on schists and consists of humus siliceous eutric soils, i.e. eutric brownised podzols of loamy structure, which are skeletised to a high degree (up to 50 %) thanks to anthropogenic erosion. Above the right bank, in Zlatarski Basin and in a great part of Vasićki Basin, the soil is reduced by degradation to shallow, reddish-brown, skeletoid siliceous soils, rich in iron, without a developed clay component.

The soil on the left side of the lake is developed on the clastites and, for the most part, it is brown soil considerably skeletised by devastation (20-50 %) on the steep exposures. On the less drained parent rock, the soil turns into eutric brown soil.

The soil in the lake surroundings is to a great degree devastated by inadequate forest cutting and by low-quality tillage, so the soil around the lake is classified as low as the IV site class, with the prevailing VII site class.[7][Plamenac 2007].

3.3. Climate characteristics of the Rasina drainage basin

The drainage basin area is characterised by temperate continental climate, in the lowland part, and by continental climate in the upland and mountainous part, with heterogeneous altitudes.

The lowland part of the terrain (the narrow zone of the reservoir) is represented by the weather station "Kruševac" (altitude 166 m). Mean air temperature is 11°C, the coldest month is January (-0.6°C), and the warmest is July (21.2°C). The upland part of the terrain (weather station "Brus", 440 m) is under the effect of continental climate and its mean air temperature is 10.6°C, the coldest month is January (-0.8°C), and the warmest month is July (20.9°C).

Table 2. *Mean annual precipitation in Rasina River watershed*

Gage station	Hgod
Vrnjačka banje	779
Goč	991
Pleš	798
Veluće	766
Aleksandrovac	580
Milentija	704
Kriva Reka selo	898
Brus	678
Kupci	720

3.4. Land use in the drainage basin upstream of the reservoir "Ćelije"

The maps of vegetation cover in the drainage basin are constructed based on the satellite images and field reconnaissance data. The Table of land use in the drainage basin is also made based on the above data.

Table 3. *Land Use in the watershed*

Culture	km	%
Forests	309,59	50,82
Bare land	3,6	0,59
Degraded forests	34,74	5,7
Meadows and pastures	137,08	22,5
Arable land	72,82	11,96
Orchards	18,15	2,98
Water reservoir	4,5	0,75
Settlements	28,67	4,7
Total	609,15	100

Forests occupy about 51% of the catchments area, but a great portion of the area under forests is degraded, especially on the steep slopes of southern aspect.

3.5. Soil erosion and sediment transport

Erosion map of the drainage basin was constructed based on satellite images and field reconnaissance data, using the method of erosion potential designed by S. Gavrilović (Gavrilović 1972). The Table presents the distribution of erosion intensity in the drainage basin. Mean value of the erosion coefficient Z = 039.

According to the data collected at the dam – reservoir "Ćelije" in the period 1979 – 1988, i.e. from the hydro-system establishment to the topographic surveying of the reservoir in 1988, total siltation of the storage space amounted to 1,416,000 m^3, i.e. on average about 155,000 m^3/yr. Of the above amount, 616,000 m^3 was deposited in the unavailable storage volume, and 799,940 m^3 was deposited in the live storage capacity. The period 1979/1988 is similar to the multiannual average inflow in the reservoir Ćelije, so, based on the above data, approximately the same dynamics of the loss of reservoir volume can also be expected in the period after 1988.

Tabela 4. *Distribution of soil erosion intensity in the watershed, according Gavrilović's classification*

Soil erosion intesity	**Kategory**	**Area km^2**	**%**	**Z**
Excessive erosion	I	-	-	1,25
Intensive erosion	II	16,29	2,67	0,85
Medium erosion	III	199,85	32,81	0,55
Low erosion	IV	360,48	59,18	0,3
Very low erosion	V	27,94	4,59	0,1
Water reservoir area		4,59	0,75	
Coefficient of erosion for the watershed area				
Total		**609,15**		
Ggod = 162 165,00 m^{3}god^{-1}	**Ggod/sp = 265, 0 m^{3}god^{-1}km^{-2}**			

According to the main project, after fifty years of the reservoit exploitation, total silting of the reservoir would amount to about 20×106 m^3, i.e. 400,000 m$^{3/}$yr.

Based on the wider regional assessments and calculations using the method of erosion potential designed by S. Gavrilović, and based on the erosion map, average annual soil loss from the river Rasina drainage basin amounts to 265 m^3/km^2/yr, i.e. average annual discharge of sediment to the dam "Ćelije" is about 162,000 m^3/yr.

4. CONCLUSION

The upper part of the watershed upstream from the „Ćelije" dam is situated on the slopes of three mountains Jastrebac, Goč and Kopaonik, and features intensive water erosion processes.

For all the watershed it can conclude that soil erosion and sediment transport are on the border between low and mediom erosion. In short period of measurement and calculation usin Method of erosion potential by S.Gavrilovich shows that average annual sediment transport is about 162.000 m^{3}year^{-1}km^{-2}.

In addition to the generally known damages caused by erosion and torrents (soil loss, loss of soil fertility, water loss, torrential floods and land degradation), more significant damage will be caused to the „Celije" reservoir includin a loss of the storage capacity due to siltation by eroded sediments, and increased contamination of water by sediment and chemical pollutants (contaminants and nutrients).

For this reason, it is necessary to undertake the required erosion control works in order to reduce the intensity of erosion in the watershed, and in this way also the sedimentation of the water „Celije" reservoir.

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ANALYSIS OF LAND USE EFFECT ON THE STATE OF EROSION IN THE TRGOVIŠKA REKA DRAINAGE BASIN

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Abstract: *The changes of the state of erosion processes and sediment yield in the Trgoviška Reka catchment occurring after erosion control works performed in the catchment are analysed. The state of erosion processes and the calculated sediment yield (2009) were compared to the corresponding magnitudes from the period before the erosion control works.*

The main objective of this paper is to determine the causes of the observed changes in the intensity of erosion processes and sediment yield in the study area. The study area is defined by the boundary of the Trgoviška Reka drainage basin area.

The study results show that the intensity of erosion processes in the study area over 2009 was decreased compared to the state in the catchment before the erosion control works. This was manifested also by the estimated state of erosion processes (mean value of erosion coefficient in the study area), and also by the calculated sediment yield, as the consequence of erosion processes, i.e. as the final result of the effects of numerous erosion factors. Although the state of erosion processes in an area is the consequence of the conditions prevailing in the observed area, i.e. the effect of numerous factors, it was concluded that the changes in the state of erosion processes in the study area were almost exclusively resulting from the change in a small number of erosion factors, mainly covered by the term ″land use″. The establishment of forest plantations resulted in the positive changes in the intensities of erosion processes and in the decrease in sediment yield.

Key words: land use, erosion control works, erosion processes, sediment yield

ANALIZA UTICAJA NAČINA KORIŠĆENJA ZEMLJIŠTA NA STANJE EROZIJE U SLIVU TRGOVIŠKE REKE

Izvod: *U ovom radu analizirane su promene stanja erozionih procesa i produkcije nanosa u slivu Trgoviške reke nastale nakon izvođenja antierozionih radova u slivu. Stanje erozionih procesa i proračunata produkcija nanosa (2009. god.) upoređeni su sa odgovarajućim veličinama iz perioda pre izvođenja radova.*

Osnovni cilj ovoga rada je da utvrdi uzroke evidentiranih promena u intenzitetu erozionih procesa i produkciji nanosa na istraživanom području. Područje na kome su sprovedena istraživanja definisano je granicom slivnog područja Trgoviške reke.

Rezultati sprovedenih istraživanja pokazali su da je jačina erozionih procesa, na posmatranom području, 2009. godine umanjena u odnosu na stanje u slivu pre izvođenja radova. Ovo se manifestovalo i kroz ocenjeno stanje erozionih procesa (srednji koeficijent erozije za posmatrano područje), a i kroz proračunatu produkciju nanosa kao posledicu erozionih procesa, odnosno kao završni čin dejstva brojnih faktora erozije. Iako je stanje erozionih procesa na nekom području posledica uslova koji vladaju na tom području, odnosno dejstva mnogobrojnih faktora, zaključeno je da su promene u stanju erozionih procesa na posmatranom području vezane skoro isključivo za promenu malog broja erozionih faktora, uglavnom obuhvaćenih pojmom ″način korišćenja zemljišta″. Podizanje šumskih kultura rezultiralo je pozitivnim promenama u intenzitetima erozionih procesa i smanjenom produkcijom nanosa.

Ključne reči: način korišćenja zemljišta, antierozioni radovi, erozioni procesi, produkcija nanosa

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1. INTRODUCTION

Soil erosion is a natural process which cannot be discontinued completely, but it can be controlled by erosion control measures and works, i.e. its harmful effects can be mitigated. The system of erosion control measures and works includes a complex of protection measures and methods directed towards the control of erosion processes and the defence against torrential floods. Erosion control measures (economic, administrative, educational, etc.) involve the actions which affect the land use and soil and water management and conservation. Erosion control works (engineering, biological, bioengineering and agro engineering) include the works which directly improve the material structure of torrential drainage basins or erosion areas.

Biological and bioengineering erosion control works solve the erosion problems on the drainage basin slopes. The degree of efficiency of the control works in the control of erosion processes in catchments greatly depends on the crop species, method of new plantation establishment and the selection of species for afforestation. The effect of biological works is expressed by the decrease in erosion intensity, i.e. decrease in sediment yield in the area where the works are performed (Kostadinov et al. 2008).

The damage caused by the Trgoviška Reka were reflected in agriculture, water management and forestry. In the hilly parts of the drainage basin, agriculture suffered the damage caused by washing and removal of the surface layer of the fertile soil and, in the lower parts, by covering the fertile soil with sediment. The soil in the upper parts of the drainage basin became degraded and, in the lower parts, the soil became sterile. The settlements, because of the frequent flood waves, retreated upwards from the valleys, and the wide floodplain at the confluence in the Trgoviški Timok spread wider and covered the new areas. Flood water endangered the main road Knjaževac – Pirot, as well as many local roads.

As the Trgoviška Reka was characterised by significant torrential properties, it was necessary to undertake the regulation of this torrential drainage basin. For this reason, in 1956 the project of erosion control works in the drainage basin was designed (Popović, D.: Main project of the Trgoviška Reka torrent management, Bureau for forestry projects Belgrade), and the greatest part of the works foreseen by this project were performed over the period from 1956 to 1966.

This paper analyses the changes in the state of erosion processes and sediment yield in the Trgoviška Reka drainage basin occurring after erosion control measures in the drainage basin, primarily biological works. The present state of erosion processes and the calculated sediment yield (2009) were compared to the corresponding values of the period before the control works. The main objective of this paper was to determine the causes of the observed changes in the intensity of erosion processes and sediment yield in the study area.

2. STUDY AREA AND METHOD

The study area presented in this paper is defined basically by the boundary of the Trgoviška Reka drainage basin. Trgoviška Reka is the first large right tributary of the river Trgoviški Timok, looking upstream from the confluence with the Svrljiški Timok. It is located in the region of the settlements Trgovište, Štitarac, Vidovac, Lokve and Staro Channel. The main stream consists of two component stems: right Lokvanjska Reka and left Vidovačka Reka. The right stem flows through the village Lokve, and the left stem flows through Vidovac.

Total area of the Trgoviška Reka drainage basin is 22.77 km^2. The river length is 9.5 km, and relative channel slope is 7.5%. The direction of flow is east-west. The drainage basin terrain features are for the most part hilly, with elevations along the boundary as high as 1000 m. Average slope gradient in the drainage basin is 35-40 %. The confluence of the Trgoviška Reka in the Trgoviški Timok is near the settlement Trgovište at the altitude of 230 m.

The investigations presented in this paper included the following phases:

1. Collection and analysis of the existing documents and data on the state of erosion before the beginning of erosion control works in the Trgoviška Reka drainage basin
2. Study of natural characteristics of the Trgoviška Reka catchment
3. Collection of data on the type and scope of implemented works
4. Assessment of state and erosion intensity before the beginning of works
5. Assessment of state and erosion intensity in 2009
6. Calculation of sediment yield before the beginning of works and in 2009.

Natural characteristics of the drainage basin were studied based on the digital cartographic material and field investigations.

Digital geological map of the drainage basin was made based on OGK scale 1:100,000.

The soil map is also digital, and it is based on the soil map of Serbia, scale 1:50,000 and based on field and laboratory researches of the soil from opened soil profiles in the drainage basin.

The land use map representing the state before the control works was constructed based on the collected technical documents. The state in 2009 was based on the topographic maps scale 1:25,000, satellite imagery, and direct field reconnaissance.

The analysis of climate data was based on the data collected by the Hydrometeorological Service of Serbia at the weather station Knjaževac and raingage station Radičevac.

The state of erosion in the drainage basin before the beginning of control works was taken from the existing documents. The intensity and distribution of erosion processes in the drainage basin in 2009 were defined based on the digital erosion map. Erosion map was constructed by Gavrilović's method using the satellite imagery and the reconnaissance of the drainage basin.

Sediment yield and sediment transport over the period before the beginning of control works and in 2009 were calculated by Gavrilović's method.

3. RESULTS

The main drainage basin parameters which influence the development of erosion processes and sediment yield are presented in the Table.

Table 1. *The main drainage basin parameters*

Parameter	Mark	Trgoviška Reka
Drainage basin area	F (km^2)	22.77
Drainage basin perimeter	O (km)	25.19
Drainage basin length	L (km)	9.5
Gavrilović's coefficient of drainage basin shape	A	0.517
Module of catchment divide development	E	1.478
Morphological coefficient	n	0.252
Density of hydrographic network	G (km km^{-2})	1.437
Coefficient of drainage basin asymmetry	a	0.621
Coefficient of sinuosity	K	1.073
Drainage basin mean altitude	N_{sr} (m)	559.22
Mean altitudinal difference	D (m)	329.22
Mean slope of the drainage basin	I_{sr}	27.12%
Relative bed slope	I_t	7.5%
Equilibrium bed slope	I_{urt}	5.0%
Drainage basin potential during torrential water	P_{sl}(m km s^{-1})	383.51
Coefficient of erosion energy after Silvestrov	E_r(m $km^{-1/2}$)	111.861
Geomorphologic coefficient	M (m $km^{-2/3}$)	160.692

The value of Gavrilović's coefficient of drainage basin shape, the module of catchment divide development, morphological coefficient, and coefficient of sinuosity indicate that the conditions for sudden and simultaneous inflow of water from the entire basin area are low.

Parent rock in the lower part of the drainage basin consist of limestones, in the central part - conglomerates and sandstones, and gabbros in the upper part.

The soil map scale 1 : 50 000 presents the data on the distribution of individual soil types in the Trgoviška Reka drainage basin. The most represented soil type is eutric cambisol, and in the lower parts of the drainage basin there are also cambisols, lithosols, verisols and rendzinas.

Mean air temperature over a multiannual period at the weather station Knjaževac was 10.2^0C. The coldest month was January with mean monthly air temperature -1.2°C, and the warmest month was July, with mean monthly air temperature 20.5°C. Mean annual precipitation for the study catchment which was H_{sr} = 722.43 mm, was calculated based on the value of mean annual precipitation at two raingage stations (Knjaževac and Radičevac) and the constructed map of raingage station coverage.

The drainage pattern in this catchment is very well developed. Basically, it consists of Trgoviška Reka and its two component stems: right - Lokvanjska Reka and left – Vidovačka Reka.

The spring of the right stem Lokvanjska Reka is at the elevation of 800 m. It meets Vidovačka Reka at the elevation of 318 m downstream of the village Vidovac. It is composed of several short streams in the alluvial fan and it receives from the right side 19 tributaries with the total length of 9.0 km, of which the longest is Jasenov Vrt. The left side is, from the hydrographic aspect, less developed than the right side. On the left side, it receives 5 tributaries, total length 3.5 km. Its catchment is hilly with steep slope gradients 30-50 %, area 9.2 km^2. Channel length is 5 km, and mean streambed slope is 9.6 %.

Vidovačka Reka consists of two arms: the right one – Garnovica, and the left one - Crna Reka. Downstream from the convergence to Lokvanjska Reka, it receives only two tributaries: Rajevića Potok on the right and Mačak on the left. Its spring is at the elevation of 740 m. The catchment is hilly with steep slope gradients 30-40 %, area 8.41 km^2. Channel length is 5 km, and mean streambed slope is 8.1 %.

The main stem of the Trgoviška Reka receives five tributaries on the right side: Duboki Potok, Đuričin Potok, Ciganski Potok and two nameless streams. On the left, there are six tributaries of which only Jašin Kladenac is somewhat larger.

The data on the crop structure, i.e. land use in this drainage basin were taken from the available documents, cartographic data and field investigations. The state and the structure of land use before the control work implementation was based on the existing technical documentation (Popović,1956).

Table 2. *Land use structure in 1956 and 2009*

Year	Forest	Pastures and meadows	Orchards and vineyards	Ploughland	Bareland	Total
	%	%	%	%	%	%
1956	22.13	21.78	2.0	16.89	37.20	100.0
2009	53.87	39.48	1.63	3.66	1.36	100.0

The existing state of land use indicates that the plant cover consists mainly of forests of oak, beech, black locust and Austrian pine plantations (53.87 %) and pastures and meadows (39.48 %). A much lower percentage is occupied by ploughland, vineyards and orchards. Only 1.36 % of the land of the total Trgoviška Reka drainage basin area is without any plant cover (bareland).

During the project drawing period, 37.20 % of the area was without any plant cover (bareland), and 16.89 % of the area was under ploughland. Forests occupied 22.13 %, and pastures and meadows 21.78 % of the drainage basin area. From the above data, it can be seen that the areas without vegetation cover (bareland), and the areas which were without plant cover during one season (ploughland) occupied more than a half of the drainage basin area (54.09 %).

Erosion map for 2009 was constructed based on satellite imagery and field reconnaissance data over 2008 and 2009. Erosion coefficient for the entire catchment was Z = 0.53 which means that the dominant erosion processes in the drainage basin can be classified in the category of medium erosion.

Table 3. *State of erosion and sediment yield in Trgoviška Reka catchment in 1956 and 2009*

Year	Erosion category					Total	Z_{sr}	W_{year}
	Excessive	Strong	Medium	Weak	Very weak			
	%	%	%	%	%	%		m^3year^{-1}
1956	78.6	4.6	16.9	0.0	0.0	100.00	1.11	63926.74
2009	1.4	6.9	75.1	15.9	0.7	100.00	0.53	21091.67

Before the implementation of control works in the Trgoviška Reka drainage basin, i.e. in its component stems, the prevailing erosion was classified as excessive. Mean coefficient of erosion for the entire catchment amounted to Z = 1.11 (according to Gavrilović's classification). In the area of Lokvanjska Reka, processes of sheet erosion attacked ploughland on steep slopes and degraded pastures and forests. The most intensive erosion processes occurred on bareland Čojnica which was also the main source of sediment.

The works on the reclamation of erosion process in Trgoviška Reka were implemented in its components Lokvanjska Reka and Vidovačka Reka showing the severest erosion processes. The works were implemented over the period from 1956 to 1966.

The greatest part of the works was performed in the Lokvanjska Reka drainage basin. 139.3 hectares were afforested of which 53.5 hectares on bench terraces and 85.8 hectares in pits. The reclamation of pastures and grassing was performed on 33.3 hectares. The afforestation was mostly performed with Austrian pine in the complex Čojnica mainly, and black locust was planted in the gullies. Afforestation with Austrian pine was performed on altogether 120.0 hectares, black locust on 16.0 hectares, and ash, birch and red oak were planted on 3.3 ha, in the aim of establishing an experiment.

Vidovačka Reka had predominantly the character of gully washer, so in this catchment the works were mainly performed in the channel, and the afforestation of Austrian pine was performed on the plot of 5.0 ha on bench terraces.

The constructed digital erosion maps, i.e. the analysis of the state of erosion processes in the drainage basin and the data on the percentages of erosion processes of different destruction categories, made possible the calculation of sediment yield in the study catchment. Total quantity of sediment which was yielded in the drainage basin was calculated by Gavrilović's method in both study periods.

The changes in land use structure were mainly the results of the works performed in the drainage basin over the period 1956 - 1966. In addition to erosion control works, the contributing factor were also the demographic changes in the catchment. Thanks to depopulation and the negative migration of the population, the abandoned ploughlands, orchards and vineyards, which were not maintained, were invaded by forest and grass cover resulting from the development of spontaneous vegetation. The above factors contributed to the change in land use, in favour of grass and forest areas.

After the implementation of large-scale erosion control works in the drainage basin, the research showed a significant decrease in the value of all indicators of erosion intensity. Erosion coefficient for the entire catchment was Z = 0.53 (medium erosion), which was significantly less than erosion intensity before the works were implemented when excessive erosion prevailed in the drainage basin with mean coefficient of erosion Z = 1.11. Calculation of sediment yield over the period brfore erosion control works in the drainage basin and the state in 2009 show that sediment yield over the period after the control works decreased to one third of the original value, which proves that the implemented erosion control works in the drainage basin contributed to a substantial reduction in erosion intensity, sediment yield and sediment transport in the Trgoviška Reka drainage basin.

4. CONCLUSIONS

The study results show that the erosion intensity in the investigated area in 2009 was reduced compared to the state in 1956. This was manifested by the assessed state of erosion processes (mean erosion coefficient in the study area), and also by the calculated sediment yield, as the consequence of erosion processes, i.e. as the final act of numerous erosion factors.

The state of erosion processes in an area is the consequence of the conditions prevailing in the area, i.e. the action of numerous factors. As most of these factors cannot be influenced by human activities, at least not to a significant degree, the changes in the state of erosion processes in the study area were almost exclusively related to the change of a few erosion factors, mainly included under the term ″land use″.

The changes in land use structure are the result of erosion control works implemented in the drainage basin over the period 1956 - 1966.

The works implemented in the Trgoviška Reka drainage basin had a significant impact on the reduction in erosion intensity in the drainage basin.

Land use is shown to be the principal modifier of erosion intensity, i.e. the modifications in land use caused by the scale of erosion control works in the drainage basin, resulted in the changes in the intensities of erosion processes.

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ANALYSIS OF LAND USE EFFECT ON THE STATE OF EROSION IN THE TRGOVIŠKA REKA DRAINAGE BASIN

Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Zoran MILETIĆ, Mihailo RATKNIĆ

Summary

Biological and bioengineering erosion control works solve the erosion problems on the drainage basin slopes. The degree of efficiency of the control works in the control of erosion processes in catchments greatly

depends on the crop species, method of new plantation establishment and the selection of species for afforestation. The effect of biological works is expressed by the decrease in erosion intensity, i.e. decrease in sediment yield in the area where the works are performed.

This paper analyses the changes in the state of erosion processes and sediment yield in the Trgoviška Reka drainage basin occurring after erosion control measures in the drainage basin, primarily biological works. The present state of erosion processes and the calculated sediment yield (2009) were compared to the corresponding values of the period before the control works.

The study area presented in this paper is defined basically by the boundary of the Trgoviška Reka drainage basin. Total area of the Trgoviška Reka drainage basin is 22.77 km^2. The river length is 9.5 km, and relative channel slope is 7.5%. The drainage basin terrain features are for the most part hilly, with elevations along the boundary as high as 1000 m. Average slope gradient in the drainage basin is 35-40 %. The confluence of the Trgoviška Reka in the Trgoviški Timok is near the settlement Trgovište at the altitude of 230 m.

The existing state of land use indicates that the plant cover consists mainly of forests of oak, beech, black locust and Austrian pine plantations (53.87 %) and pastures and meadows (39.48 %). A much lower percentage is occupied by ploughland, vineyards and orchards. Only 1.36 % of the land of the total Trgoviška Reka drainage basin area is without any plant cover (bareland).

During the project drawing period, 37.20 % of the area was without any plant cover (bareland), and 16.89 % of the area was under ploughland. Forests occupied 22.13 %, and pastures and meadows 21.78 % of the drainage basin area. From the above data, it can be seen that the areas without vegetation cover (bareland), and the areas which were without plant cover during one season (ploughland) occupied more than a half of the drainage basin area (54.09 %).

The changes in land use structure were mainly the results of the works performed in the drainage basin over the period 1956 - 1966. After the implementation of large-scale erosion control works in the drainage basin, the research showed a significant decrease in the value of all indicators of erosion intensity. Erosion coefficient for the entire catchment was $Z = 0.53$ (medium erosion), which was significantly less than erosion intensity before the works were implemented when excessive erosion prevailed in the drainage basin with mean coefficient of erosion $Z = 1.11$. Calculation of sediment yield over the period brfore erosion control works in the drainage basin and the state in 2009 show that sediment yield over the period after the control works decreased to one third of the original value, which proves that the implemented erosion control works in the drainage basin contributed to a substantial reduction in erosion intensity, sediment yield and sediment transport in the Trgoviška Reka drainage basin.

Land use is shown to be the principal modifier of erosion intensity, i.e. the modifications in land use caused by the scale of erosion control works in the drainage basin, resulted in the changes in the intensities of erosion processes.

THE CREATION OF THE EROSION MAP BY THE USE OF THE SATELLITE PHOTOS OF HIGH RESOLUTION FOR KRPEJSKI POTOK DRAINAGE AREA

Sonja BRAUNOVIĆ, Mihailo RATKNIĆ[1]

Abstract: *Krpejski potok drainage basin is a part of the Južna Morava drainage basin, and in the recent past was the strong erosion area, which endangered the international communication lines and inhabited places in the Grdelicka Gorge. This paper presents the results of the intensity of erosion in 1953, 1970 and 2009. The intensity of the erosion process in 2009 was determined by the use of the satellite photos of the high resolutions. By the comparative analysis of the obtained results the positive effect of the erosion control activities performed in the basin, as well as the influence of the socio-demographic factors were determined.*

Key words: erosion map, intensity of erosion, satellite photo, Krpejski drainage basin

IZRADA KARTE EROZIJE KORIŠĆENJEM SATELITSKIH SNIMAKA VISOKE REZOLUCIJE ZA SLIV KRPEJSKOG POTOKA

Izvod: *Sliv Krpejskog potoka pripada neposrednom slivu Južne Morave i u skorijoj prošlosti predstavljao je jako eroziono područje koje je ugrožavalo međunarodne komunikacije i naselja u Grdeličkoj klisuri. U radu će biti prikazani rezultati intenziteta erozije 1953, 1970 i 2009. godine. Intenzitet erozionih procesa za 2009. godinu utvrđen je korišćenjem satelitskih snimaka visoke rezolucije za područje Grdeličke klisure. Komparativnom analizom dobijenih rezultata potvrđen je pozitivan efekat izvedenih antierozionih radova u slivu, kao i uticaj sociodemografskog faktora.*

Ključne reči: karta erozije, intenzitet erozije, satelitski snimak, sliv Krpejski

1. INTRODUCTION

Grdelicka Gorge and Vranjska Basin are located in Southeastern Serbia and is known as the erosion focus. The main river in the region is the Juzna Morava, which typically has torrential tributaries. The greatest number of torrent tributaries flow into the Juzna Morava in the sector of the Grdelicka Gorge (143) and Vranjska Basin (more than 80). Two very important communication lines cross the Juzna Morava valley in this area and connect Europe with Greece and the Mediterranean, namely the Belgrade – Skopje - Athens (Greece) road and railway line. Krpejski potok is one of the right torrential tributaries of the Juzna Morava River in Grdelicka Gorge. The best illustration of the damages and needs for the arrangement of this drainage basin area are the quotes from the daily paper from 1960s:

"In Grdelicka Gorge the whole hills are in movement. The retaining walls tear down under the pressure of the earthen mass, which slide in the direction to the highway. In the middle of summer the great and dangerous landslide between Grdelica and Predejane, in the vicinity of Krpejski potok activated again. In the direction to the highway the whole hill, with several dozens m^3 of soil and stone slides, owning to which the frequent distruption of traffic occurs, which lasts for 6, 12, and even more hours... Needless to say, the danger to human lives and damages in agriculture is great..." ("Borba", July 20th, 1966).

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“ In Grdelicka Gorge the new quantity of stone and soil fell to the highway, at the 307th km of the Belgrade-Skopje highway, between Grdelica and Predejane. The traffic is distrupted. The 16,000 m^3 of soil and stone is in the movement“ (“Borba“, July 22th, 1966).

2. METHOD

The project documentation was collected and analyzed, the data on the way in which soil is used, and on the intensity of the erosion processes for the period before the erosion control works and measures were conducted, as well as the data on the way in which soil is used and on the intensity of the erosion processes for the period after the erosion control works and measures were conducted (in 1970 and 2009). The condition of erosion in the drainage basin, its spread and intensity were determined based on the detailed erosion maps for all three observed periods in by using Gavrilovic method (1972). The erosion maps created in 1953 and 1970 were brougth into harmony in order to make comparison between them. The classification of erosion processes per intensity was conducted based on Gavrilovic method. By using this classification, the erosion areas were divided into 5 categories of intensity (I – excessive; II – intensive; III – medium; IV – weak and V – very weak erosion), whereas for the determination of the intensity of erosion the coefficient of erosion Z is used. It ranges from 0.01 to 1.50. By the field researches conducted in 2009, by the use of the satellite photo of the area, the condition of erosion and the way in which the soil is used in the drainage basin area were determined. This methodological approach is aimed at the comparison of results from 1953, 1970, and 2009.

3. RESEARCH OBJECT

Krpejski potok is the right tributary of the Juzna Morava and it flows into this river 1km downstream from Predejane town, and in the administrative sense it belongs to Leskovac municipality. It was named after Krpejci village, to the district of which the drainage basin of this brook belongs. The drainage basin area of Krpejski potok is 2.6 km^2. The drainage basin is of egg-elongated shape, with the maximum lenght 2.8 km, with the maximum width 1.5 km, and it spreads into the direction east-west. In the regard of topography, it belongs to the extremely hilly terrain. The highest point in the drainage basin is located at 911 m, whereas the mouth is located at 274 m, so the altidinal difference is 637 m, and the mean slope of the drainage basin is 22.75 %.

4. RESULTS

4.1 Orographic-hydrographic characteristics of the drainage basin

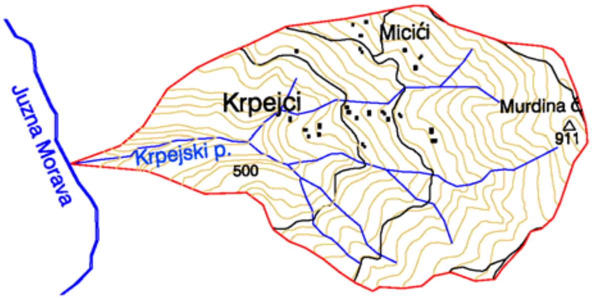
In the lower and middle part of the drainage basin the slopes are considerably steeper than in the upper part of the drainage basin. The right bank of the main course and right branch (south exposure) are intercepted and it has more tributaries than the left bank which is more compact (north exposure). The stream bed slope in the main course up to the confluence of the branches ranges from 2.14 to 61.43%. The influence of the relief and configuration of the terrain on the development of the erosion processes is presented by the determination of the most important orographic paremeters (Table 1).

Table 1. *Orographic-hydrographic parameters of the Krpejski potok drainage basin*

Parameter	Symbol	Value
Orographic characteristics of the drainage basin		
Drainage basin area	F (km^2)	2.60
Drainage basin perimeter	O (km)	6.80
Drainage basin lenght	L (km)	2.80
Highest point in the drainage basin	K_v	910.00
Altitude of the source (confluence)	K_{izv}	402.50
Altitude of the mouth	K_u	274.10
Mean altitude of the drainage basin	N_{sr}	644.26
Mean altitudinal difference	D	370.16
Mean slope of the drainage basin	I_{sr}	34.42
Flood potential during the torrential rains	P_{sl}	137.41
Local erosion base	B_e	635.90
Coefficient of the erosion energy of relief	E_r	158.46
Coefficient of massiveness	tg	0.24
Geomorphological erosion coefficient	M	0.73
Hydrographic characteristics of the drainage basin		
Module of the watershed development	E	0.73
Morphological coefficient	n	0.33
Coefficent of the drainage basin form	A	0.47
Main course lenght	L_{gl} (km)	1.06
Total lenght of all tributaries	L_{pr} (km)	10.89
Density of the hydrographic network	G (km/ km^2)	4.59
Mean slope of the drainage basin	I_t (%)	12.11

4.2 Hydrographic characteristics of the drainage basin

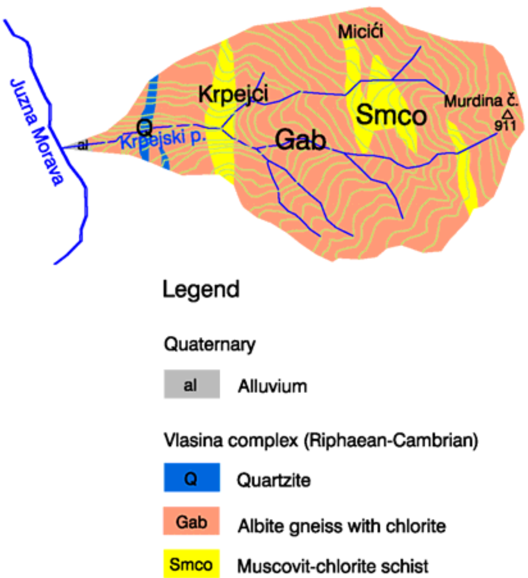
Krpejski potok drainage basin has a well-developed hydrographic network. The main course is divided into two main parts and both of them have several tributaries. The lenght of the main course up to the confluence of the branches is 1.06 km. It is characterized by the wide bed and great quantity of the sediment of the different particle size. The main course have two tributaries at the right side and one gully at both sides, and left branch resembles the extension of the main course and is somewhat longer than the right branch. In regard to the hydrography it is very developed: from the right side it receives three, and from the left side six tributaries. The right branch, by the direction almost parallel with the left, is hydrographically somewhat more developed than the left branch: from the right side it receives seven tributaries, and from the left side only one. The drainage basin is connected to the Juzna Morava by the flood plain, which is formed by the deposition of the extremely high quantity of sediment originates from the multi-annual destruction and soil run off under the influence of the strong erosion in the bed and basin area.

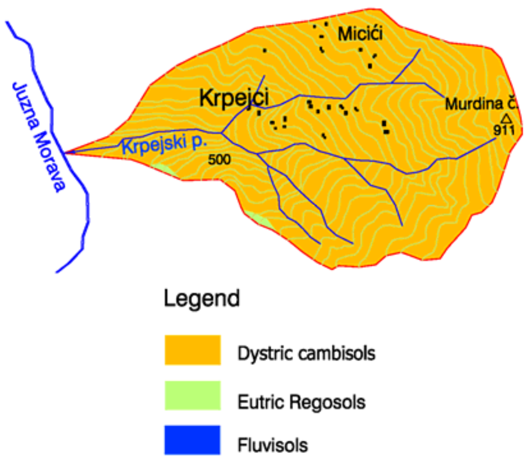


4.3 Parent rock

The basic rock complex is made of rocks of Vlasinski complex of the age class Ripheán-Cambrian: albite gneiss with chlorite account for 86.16%, and muscovite – chlorite schist account for 11.92%. They are characterized by the very intensive process of the surface decomposition, which is more expressed on the right bank, i.e. at the south exposures in the drainage basin. The rocks of the progressively metamorphic Vlasinski complex are also found - quartzite, which account for 1.54%, and in the lower part of the drainage basin quarternary formations (alluvium accounts for 0.38%).

In regard to the pedological cover, the dystric cambisol (96.9%), eutric cambisol (96.9%), eutric cambisol (3.06%) and fluvisol (0.04%) are present.





4.4 Vegetation cover of the drainage basin

The vegetation cover of the drainage basin is made of the forest of natural origin and artificially established stands, and to a lesser extent meadows and orchards. The agricultural crops occupy small areas (Table 2).

The forests of the dense canopy are located in the upper part of the drainage basin. The most frequent tree species is beech with the accompanying trees, mainly on the left bank, i.e. north exposure. Right slopes in the upper part of the drainage basin are covered by the mixed forest of oak, hornbeam, ash, and scrub species. The middle parts of the right slopes are covered by pine plantations, and the lower parts of the slopes, nearer to the drainage basin by the black locust. The presence of the great number of sweet chestnut, which was artifically established, was also reported.

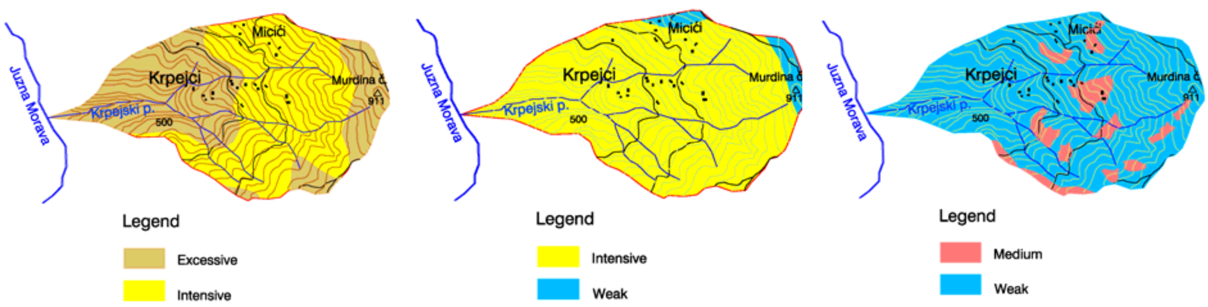
The high percentage of the reforestation of the drainage basin is the result of the migration of the population of this area, prohibition of the cattle-breeding and permanent establishment of the new plantations

Table 2. *Land use in the drainage basin 1953, 1970 and 2009*

Culture	1953		1970		2009	
	ha	%	ha	%	ha	%
Forests and shrubs	0,75	28,85	1,30	50,00	1,85	71,15
Orchards	0,22	8,46	0,18	6,92	0,09	3,47
Meadows and pastures	0,70	26,92	0,52	20,00	0,24	9,23
Ploughed and bare land	0,93	35,77	0,60	23,08	0,42	16,15
Total	2,60	100,00	2,60	100,00	2,60	100,00

4.5 Erosion condition

One of the important indicators of the direct results of the erosion control works is the change of the mean coefficient of erosion before and after the works. Based on this indicators, three erosion conditions from 1953 to present are presented.



EROSION MAP IN 1953 **EROSION MAP IN 1970** **EROSION MAP IN 2009**

The coefficient of erosion in 1970 was 0.81 (intensive erosion), which is by 22.1% lower than the coefficient erosion in 1953 (1.04 – excessive erosion), whereas the coefficient of erosion in 2009 is by 70.2% lower in comparison with the year 1953 (0.31 – weak erosion). The coefficient of erosion in 1970 is by 61.7% lower than the coefficient of erosion in 2009 (Table 3).

Table 3. *Erosion process intensity in the drainage basins befor and after ECW*

Drainage basin	Before ECW – 1953th			After ECW – 1970th			After ECW – 2009th		
	Category of erosion	Intensity	Coeff. of erosion (Z)	Category of erosion	Intensity	Coeff. of erosion (Z)	Category of erosion	Intensity	Coeff. of erosion (Z)
Krpejski potok	I	Excessive	1,04	II	Intensive	0,81	IV	Weak	0,31

4.6 Anthropogenic factor

The decrease in the population in the drainage basin is the result of the change in which the soil is used, mainly of the abandoning of the intensive soil cultivation, which directly influences the decreases of the intensity of erosion in this area (Table 4). Based on the population projection for 2021 (Statistical Office of the Republic of Serbia, 2007), cadastre municipality of Krpejce will be empty – without population.

Table 4. *Population per census years*

Cadastre municipality	Year /Population							
	1948	**1953**	**1961**	**1971**	**1981**	**1991**	**2002**	**Projection 2021**
Krpejce	262	172	110	118	116	74	47	0

4.7 Performed works

Based on the Register of the torrents from 1963 (23 Krpejski potok - C III 0.6; page 3) in the bed of Krpejski potok 10 (60)* transversal facilities were set, 222 m' of the vertical facilities, 4,100 (5,260) m^3 of excavation was done, 1,360 (2,790) m^3, 600 (800) m^3 of dry stone walls, and 120 m^3 of stone foundation (Jelic 1978). The technical works in the drainage basin refers to the 250 m^3 (1,680) of rustic partitions, 550 (8250) m' of woven fences and 4922 m' of terraces. It was determined in the field that in the main course, with the exception of the transversal facilities within the cunette, three partitions were made, and one old partitition for which the accurate time of construction is not known, was reported. The other transversal facilities which were set are located in the integral parts and tributaries. The traditional practice which implies that the facilities are not maintained after the construction was also confirmed in Krpejski potok drainage basin, since several damaged and partially destroyed partitions in the upper parts of the drainage basin were reported. This conditions will lead to the much greater investment in the reclamation of the constucted facilities, than it is necessary for the regular maintanance of them.

5. CONCLUSION

By the comparative analysis of the obtained results the positive effect of the performed erosion control works in the bed and Krpejski potok drainage basin was confirmed. The decrease of the adverse effect of the anthropogenic factor as a result of the demographic decline of the area was reported. Over the study period, the following trend of intensity of the erosion processes was reported: from Category I – excessive (in1953), via Category II –intensive (in 1970), it was reduced to Category IV – weak (in 2009).

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* the values in the brackets refer to the works necessary for the further improvement of the bed and drainage basin

ANALYSIS OF FORMULAS FOR THE CALCULATION OF THE SLOPE OF SILTATION OF DAM NO.1 IN THE TORRENT MELO

Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Mihailo RATKNIĆ, Sonja BRAUNOVIĆ[1]

Abstract: *The main goal of dam construction in stream channels is to prevent deep and lateral erosion. By dam construction, steep torrential channels are changed into gradual ones with the mitigated bed slope and decreased water depth and velocity, which prevents bank scouring and decreases the transport competency of a watercourse. To increase the effects of the designed dams on the suppression of erosion processes, it is essential to determine their distance correctly, which depends on dam height, bed slope, and slope of siltation. While dam height and bed slope are known values, slope of siltation should be estimated, i.e. calculated. Slope of siltation is calculated by several formulas, which are essentially the formulas for the calculation of the equilibrium bed slope in the specific conditions of torrent channel with erected dams. This paper compares the value of the slope of siltation calculated by the formulas by various authors, which are most commonly applied in practice, and the values obtained by geodetic surveying of the longitudinal profile of the slope of siltation of dam No.1 in the torrent Melo. The lowest deviation from the measured values of the slope of siltation was calculated by the Thiery's formula, followed by Velikanov's formula, and by regional analytical dependences (Biočev, Kostadinov and Velojić). The forecast of the slope of siltation should be carried out by the regional analytical dependences, which should be based on field research of the already formed slopes of siltation and which should include, in addition to bed slope, also an independent variable which characterises the sediment.*

Key words: dam, slope of siltation, bed slope, sediment.

ANALIZA FORMULA ZA PRORAČUN PADA ZAPLAVA PREGRADE br.1 U BUJICI MELO

Izvod: *Osnovna uloga izrade poprečnih objekata u koritu vodotoka je sprečavanje dubinske i bočne erozije. Izgradnjom pregrada strma korita bujičnih vodotoka pretvaraju se u stepenasta sa ublaženim padom dna i smanjenom dubinom i brzinom vode, čime se sprečava podrivanje obala i smanjuje transportna sposobnost toka. Da bi efekti projektovanih pregrada na smirivanje erozionih procesa bili što veći bitno je pravilno odrediti njihovo rastojanje koje zavisi od visine pregrade, pada dna korita i pada zaplava. Dok su visina pregrade i pad dna korita poznate veličine pad zaplava treba prognozirati, obračunati. Za obračun pada zaplava postoji više formula, koje su u suštini formule za određivanje pada izjednačenja u specifičnim uslovima bujičnog korita sa izgrađenim pregradama. U ovom radu je dato upoređenje vrednosti pada zaplava dobijene obračunom po formulama različitih autora, koje se najviše upotrebljavaju u praksi, i vrednosti dobijene geodetskim snimanjem uzdužnog profila pada zaplava pregrade br.1 u bujici Melo. Najmanje odstupanje od izmernih vrednosti pada zaplava dala je formula Thiery-a, a slede formula Velikanov-a i regionalne analitičke zavisnosti (Biočev, Kostadinov i Velojić). Za prognozu pada zaplava trebalo bi koristiti regionalne analitičke zavisnosti koje bi se zasnivale na terenskim istraživanjma već formiranih zaplava i koje bi sem pada korita vodotoka uključile i nezavisno promenjivu koja bi karakterisala nanos.*

Ključne reči: pregrada, pad zaplava, pad korita, nanos.

1. INTRODUCTION

The goals of dam construction in torrent channels are to lessen the longitudinal bed slope which leads to the reduction in water velocity, and in this way to the decrease in the destructive

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power and transport competency of a watercourse. In addition, the storage area is formed behind the construction for the retention of great quantities of sediment. One of the most significant issues to be solved in the determination of the distance between the dams in the system, is the forecast of the newly formed slope of sediment deposited behind the dam, known as the "slope of siltation” in torrent and erosion control theory and practice. In torrent management, the designers determine the slope of siltation based on their experience, based on the formulas by various authors and based on regional analytical dependencies. In Serbia, torrent management has been organised for already one hundred years. The forecast of the slope of siltation, and thus also the distance between them, is highly significant, because they are some of the most essential elements of the applied management methods and systems.

The aim of this paper is to compare the value of the slope of siltation calculated by the formulas by various authors with the values obtained by geodetic surveying of the longitudinal profile of the slope of siltation of dam No.1 in the torrent Melo.

2. STUDY AREA AND METHOD

The torrent Melo is the left tributary of the Trgoviški Timok. Its confluence is near the place Gornja Kamenica. The catchment of this torrent occupies the territory of the settlements Gornja Kamenica and Šesti Gabar. Its spring is below the peaks Šesti Gabar and Srezovica at the elevation of 650 m. The stream direction is southeast-northwest. Catchment area amounts to 5.25 km^2. The length of the main stem is 4.65 km, and the average bed slope is 7.5%. The catchment terrain configuration is hilly, average slope inclination is 40%. Hydrographic network is very much developed, it receives twelve tributaries, seven left and five right tributaries. The left tributaries are: Mrkonjin Do, Gulliesa I, Gulliesa II, Jevremov Do, Šuškin Do, Strašno Bučje II and Strašno Bučje I, and the right tributaries are: Srezavica, Kaškavi Do I, Kaškavi Do II, Jazanski Do and Kršanski Do.

Parent rock in which the channel is deeply cut consists of limestones, sandstones and slates. Soil types in the catchment are: dystric cambisol, calcomelanosol, calcocambisol, fluvisol and vertisol.

Vegetation cover consists predominantly of forests (oak, hornbeam, lime, hazel, ash and beech) and the plantations of Austrian pine and black locust, pastures, meadows, orchards (plum, apple, pear, walnut, cherry) and farmlands (maize, wheat, potato, oat and rye).

Before the implementation of erosion control works, very strong sheet and deep erosion processes were developed in the catchment. High quantities of sediment consisting of the streambank material were carried by water to the Trgoviški Timok, where a large debris cone was created at the confluence. The damage caused by this torrent affected agriculture, water management and forestry.

The works on the torrent regulation lasted from 1955 to 1966. Over this period, the implemented works in the catchment consisted of afforestation with Austrian pine and black locust on bench terraces, grassing, and orchard establishment on terraces. The works in the channel of the main stem consisted of 12 dams, i.e. 11 in stone masonry and 1 gabion check dam. In the tributaries, several small check dams were built in stone masonry and rustic check dams in mortarless stone.

The research was performed on dam No. 1 in the main stem of the torrent Melo, height 5.7 m, 581 metres upstream from the confluence in the Trgoviški Timok.

The data on natural watercourse were taken from the existing technical documents based on which the works were implemented.

The present state: length, width, slope of siltation and quantity of retained material behind the dam were obtained by geodetic surveying.

Particle size distribution of the sediment from the formed slope of siltation was determined on the samples taken in the field. The samples were sieved through a series of sieves and measured to form the particle-size distribution curve which supplied the data on characteristic sediment diameters. The value of the coefficient of uniformity was also calculated.

The slope of siltation was calculated by the formulas which are most commonly applied in practice at the national and international levels: Thiery (2), Pimpirev, Valentini, Jaggy, Valtyni, Chezy, Šamov, Strikler, Krey, Lane, Mirzazage, Schields, Egiazarov, Mayer-Peter, as well as the formulas of the regional analytical dependences: Biolčev, Kostadinov and Velojić (simple and multiple correlation) (Kostadinov, 1989).

The quantity of the retained sediment was calculated by the Kitin's formula (1975):

$$W = \frac{m \times h_k^2}{2 \times (I_t - I_z)}$$

where:

m - average slope of siltation width (m)

h_k - effective height of the dam (m)

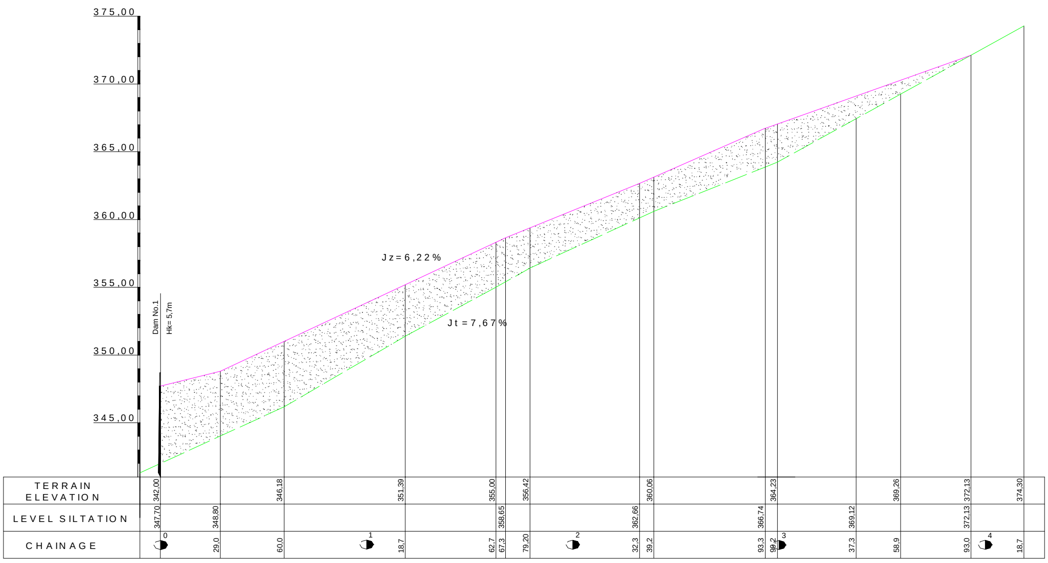
I_t - natural bed slope in decimal form

I_z- slope of siltation in decimal form

3. RESULTS

The longitudinal profile of the slope of siltation behind the dam No.1 in the torrent Melo was defined based on the available technical documents and the geodetic surveying data (Figure 1). It was concluded that the siltation was formed upstream of the dam with average slope I_z = 6.22 % and natural channel slope on the study stretch accounting for I_t = 7,67 %. The slope of siltation length was 393.0 m and the quantity of the retained bedload behind the dam was W=33,610.,34 m^3

Figure 1. *Longitudinal profile of the siltation - dam No. 1 in the torrent Melo*



The following hydraulic parameters of flow were obtained based on field and laboratory investigations:

- Cross sectional area F = 20.47 m^2
- Wetted perimeter O = 22.40 m

- Hydraulic radius	$R = 0.914$ m
- Mean depth of flow	$h = 1.00$ m
- Mean water velocity	$V_{sr} = 2.61$ ms^{-1}
- Manning's roughness coefficient	$n = 0.08$
- Manning's coefficient of velocity	$C = 12.31$
- Coefficient of flow torrentiality	$K = 0.80$
- Mean channel roughness	$\Delta_{sr} = 12.6$ cm
- Density of clean water	$\rho = 1.00$ tm^{-3}
- Mean density of torrential water	$\rho_0 = 1.25$ tm^{-3}
- Mean density of sediment	$\rho_n = 2.65$ tm^{-3}
- Coefficient of sediment friction	$f = 0.75$

Particle-size distribution curve of the sediment taken from the formed slope of siltation showed the following characteristic sediment diameters (Table 1) and coefficients of sediment uniformity (Table 2).

Diagram 1. *Sediment particle-size distribution curve*

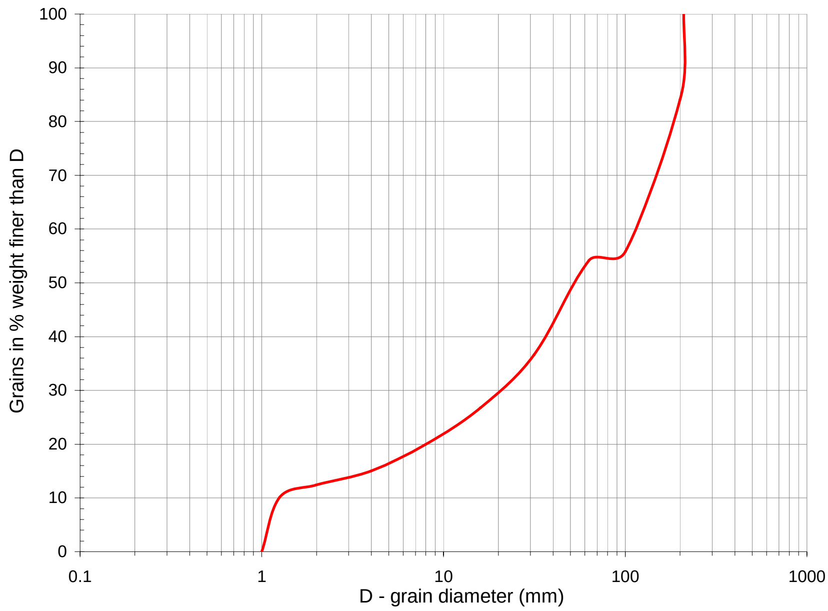


Table 1. *Characteristic sediment diameters d (mm)*

d_5	d_{10}	d_{25}	d_{30}	d_{50}	d_{60}	d_{75}	d_{90}	d_{95}	$d_{97,5}$	d_{max}	d_{sr}	d_e
1.2	1.3	14.3	21.2	52.5	117.0	171.0	205.0	206.5	208.0	210.0	126.0	36.67

The value of the coefficient of sediment uniformity after Allen-Hazen U = 90.0 indicates that the sample, i.e. the sediment particle sizes are defined as non-uniform (Popović, Kostadinov, 1987).

Table 2. *Coefficients of sediment uniformity*

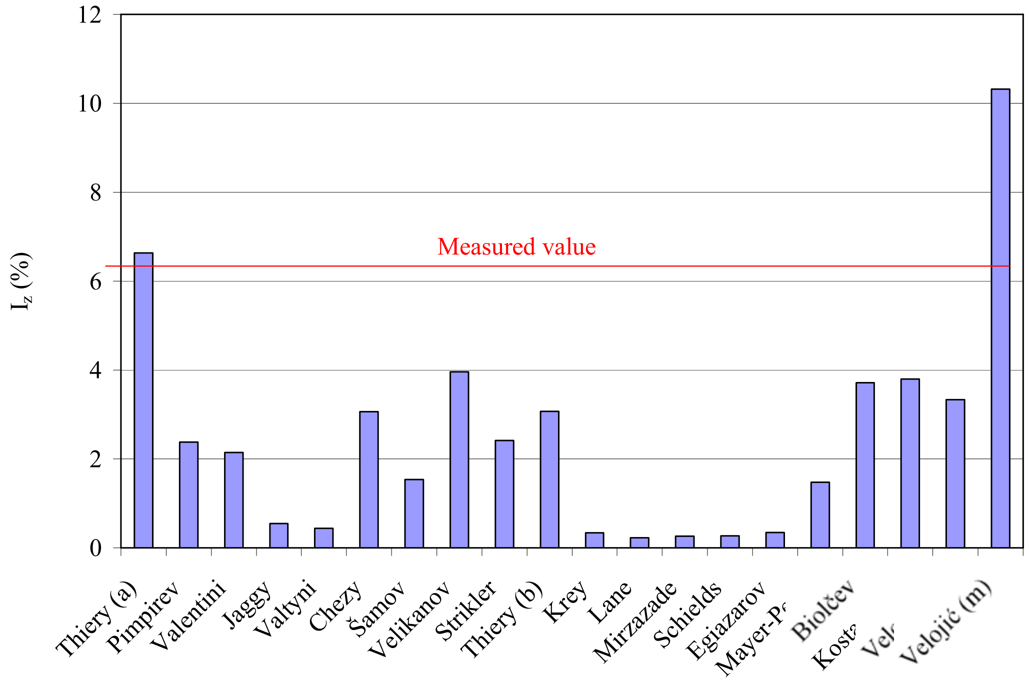
U	Km	Kd	Kk	s	s0
90.00	178.46	5.35	229.17	3.46	0.28

Based on the measured and calculated parameters, the slope of siltation was calculated by twenty formulas by various authors, most often applied in practice. The results of the calculations are presented in Table 3, and also in Diagram 2.

Table 3. *Results of the slope of siltation calculations*

No.	Methods	Slope of siltation		Deviations	
		Calculated value	Real value	Absolute	Percent
		%	%	%	%
1.	Thiery (a)	6.63	6.22	0.41	7
2.	Pimpirev	2.38	6.22	-3.84	62
3.	Valentini	2.14	6.22	-4.08	66
4.	Jaggy	0.55	6.22	-5.67	91
5.	Valtyni	0.44	6.22	-5.78	93
6.	Chezy	3.06	6.22	-3.16	51
7.	Shamov	1.54	6.22	-4.68	75
8.	Velikanov	3.96	6.22	-2.26	36
9.	Strikler	2.41	6.22	-3.81	61
10.	Thiery (b)	3.07	6.22	-3.15	51
11.	Krey	0.34	6.22	-5.88	95
12.	Lane	0.23	6.22	-5.99	96
13.	Mirzazade	0.26	6.22	-5.96	96
14.	Shields	0.27	6.22	-5.95	96
15.	Egiazarov	0.35	6.22	-5.77	93
16.	Mayer-Peter	1.48	6.22	-4.74	76
17.	Biolčev	3.71	6.22	-2.51	40
18.	Kostadinov	3.80	6.22	-2.42	39
19.	Velojić (simple)	3.33	6.22	-2.82	46
20.	Velojić (multiple)	10.32	6.22	4.10	66

Diagram 2. Values of the slope of siltation after various authors



4. ANALYSIS OF THE STUDY RESULTS

After the construction of the dam No.1 in the torrent Melo, the siltation formed in the upstream part was characterised by the average slope $I_z = 6.22\%$ which compared to natural bed slope along the stretch $I_t = 7,67$ %, accounted for 81 %.

The results of the slope of siltation calculations by twenty formulas reported by different authors show that only two formulas produced the values greater than the measured values, i.e. formulas by Thierry and Velojić-multiple, whereas the other formulas produced lower slope of siltation values than the measured values.

The nearest values to the measured value of the slope of siltation resulted from the calculation by Thiery's and Velkanov's formulas and the formulas of regional analytic dependencies: Kostadinov for the gorge Grdelička Klisura (Kostadinov, 1987), Biolčev for Southern Bulgaria (Biolčev et al., 1975) and Velojić-simple for the Nišava catchment (Velojić, 2000).

The deviations of the slope of siltation values calculated by these formulas accounted for about 46 % of the measured value.

The good results of the application of regional analytic dependency formulas should be assigned also to the relative vicinity of the study area, i.e. the similarity of the conditions in which the siltations were formed, primarily the similarity in the sediment particle-size distribution.

The formulas based on the Valentini's formula (No. 4 - Jaggy, No. 5 - Valtyni) and critical tangential stress for bedload detachment from the torrent bed (No. 11 - Krey , No.12 - Lane, No. 13 – Mirzazade, No.14 - Shields) produced a significantly lower calculated value of the slope of siltation than the measured value.

5. CONCLUSIONS

Based on the processed surveying data it was concluded that the slope of siltation formed upstream from the dam No. 1 in the torrent Melo was 393.0 m long, average slope $I_z = 6.22$ %, which accounted for 81 %.compared to the natural bed slope in the study stretch.

The results of the slope of siltation calculation by twenty formulas by various authors showed that the nearest values to the measured slope of siltation were given by the formulas after Thiery, Velkanov and the formulas of regional analytical dependencies. The other formulas produced the results which deviated significantly from the measured values of the slope of siltation in the field.

Although Thierry's formula produced the minimal deviation from the measured value, its application in practice is limited by the fact that it is difficult to determine exactly all the elements necessary for its application.

The calculated results show that the particle size distribution and bed slope have the crucial impact on the magnitude of the slope of siltation.

The forecast of the slope of siltation should be based on the regional analytical dependencies which should be based on field investigations on the already formed siltations and which should, in addition to bed slope, also include the independent variable which characterises the sediment. These formulas have a regional character, but the calculated results are significantly more accurate.

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ANALYSIS OF FORMULAS FOR THE CALCULATION OF THE SLOPE OF SILTATION OF DAM NO.1 IN THE TORRENT MELO

Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Mihailo RATKNIĆ, Sonja BRAUNOVIĆ

Summary

One of the most significant issues to be solved in the determination of the distance between the dams in the system, is the forecast of the newly formed slope of sediment deposited behind the dam, known as the "slope of siltation” in torrent and erosion control theory and practice.

The aim of this paper is to compare the value of the slope of siltation calculated by the formulas by various authors with the values obtained by geodetic surveying of the longitudinal profile of the slope of siltation of dam No.1 in the torrent Melo.

The slope of siltation was calculated by the formulas which are most commonly applied in practice at the national and international levels: Thiery (2), Pimpirev, Valentini, Jaggy, Valtyni, Chezy, Šamov, Strikler, Krey, Lane, Mirzazage, Schields, Egiazarov, Mayer-Peter, as well as the formulas of the regional analytical dependences: Biolčev, Kostadinov and Velojić (simple and multiple correlation) (Kostadinov, 1989).

The results of the slope of siltation calculations by twenty formulas reported by different authors show that only two formulas produced the values greater than the measured values, i.e. formulas by Thierry and Velojić-multiple, whereas the other formulas produced lower slope of siltation values than the measured values.

The nearest values to the measured value of the slope of siltation resulted from the calculation by Thiery’s and Velkanov’s formulas and the formulas of regional analytic dependencies: Kostadinov for the gorge Grdelička Klisura (Kostadinov, 1987), Biolčev for Southern Bulgaria (Biolčev et al., 1975) and Velojić-simple for the Nišava catchment (Velojić, 2000).

Although Thierry’s formula produced the minimal deviation from the measured value, its application in practice is limited by the fact that it is difficult to determine exactly all the elements necessary for its application.

The forecast of the slope of siltation should be based on the regional analytical dependencies which should be based on field investigations on the already formed siltations and which should, in addition to bed slope, also include the independent variable which characterises the sediment. These formulas have a regional character, but the calculated results are significantly more accurate.

ANALIZA FORMULA ZA PRORAČUN PADA ZAPLAVA PREGRADE BR.1 U BUJICI MELO

Svetlana BILIBAJKIĆ, Tomislav STEFANOVIĆ, Mihailo RATKNIĆ, Sonja BRAUNOVIĆ

Rezime

Jedan od najznačajnijih problema, koji se javljaju kod određivanja rastojanja između poprečnih objekata u sistemu, je prognoziranje novoformiranog pada nanosa nataloženog iza pregrade. U bujičarsko-erozionističkoj teoriji i praksi on je poznat kao "pad zaplava".

Cilj ovog rada je da se vrednosti veličine pada zaplava koje su dobijene obračunom po formulama različitih autora uporede sa vrednosću dobijene geodetskim snimanjem uzdužnog profila pada zaplava na pregradi br.1 u bujici Melo.

Za obračun pada zaplava primenjene su formule koje se najčešće upotrebljavaju u praksi kod nas i u inostrnastvu i to: Thiery-a(2), Pimpirev-a, Valentini-a, Jaggy-a, Valtyni-a, Chezy-a, Šamov-a, Strikler-a, Krey-a, Lane-a, Mirzazage-a, Schields-a, Egiazarov-a, Mayer-Peter-a kao i formule regionalnih analitičkih zavisnosti: Biolčev-a, Kostadinov-a i Velojić-a (prosta i višefaktorska korelacija) (Kostadinov, S., 1989).

Rezultati proračuna pada zaplava prema dvadeset formula različitih autora pokazuju da su samo dve formule dale vrednost pada zaplava veće o izmerene i to formule Thiery-a i Velojić-multiple, dok su ostale formule dale manju vrednost pada zaplava od izmerene.

Najbliže vrednosti izmerenom padu zaplava dale su formule Thiery-a, Velkanova i formule regionalnih analitičkih zavisnosti: Kostadinova za Grdeličku klisuru (Kostadinov, S.,1987), Biolčeva za južnu Bugarsku (Biolčev, A. et al., 1975) i Velojić-simple za sliv Nišave (Velojić, M., 2000).

Iako je dala minimalno odstupanje od izmerene vrednosti primena formule Thiery-a u praksi je otežana jer je teško odrediti tačno sve elemente neophodne za njenu primenu.

Za prognozu pada zaplava trebalo bi koristiti regionalne analitičke zavisnosti koje bi se zasnivale na terenskim istraživanjma već formiranih zaplava i koje bi sem pada korita vodotoka uključile i nezavisno promenjivu koja bi karakterisala nanos. Ove formule bi imale regionalni karakter, ali bi dobijeni rezultati bili znatno tačniji.

INFLUENCE OF ANTHROPOGENIC FACTORS ON ENVIRONMENT IN THE RASINA WATERSHED

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Abstract: *This paper presents the influence of demographic trends on the environment of the Rasina river watershed. Thanks to migrations from this hilly region, nowadays in the villages of researched watershed prevail older-age household members where the number of active population is continually being lessened. As the consequence of the decrease of active agriculture population and increase of their average age, many arable lands are no more plowed and converted to weeds.*

The significant impact to the decrease of erosion processes has been exerted also by smaller number of livestock in the researched region, especially sheep and goats, which is the result of administrative measures.

Key words: environment, natural factors, anthropogenic factors, migrations, degradation

1. INTRODUCTION

Worldwide (SDC 1994) five different types of physical human intervention are blamed for soil degradation: deforestation and removal of the natural vegetation; overgrazing; agricultural activities - the improper management of agricultural land; over-exploatation of the vegetative cover for domestic use; and (bio)industrial activities leading to chemical pollution.

The main cause of soil loss in the world is poor soil husbandry. In Serbia, the main factor in provoking soil erosion is human action. The hilly and mountainous regions of Serbia is predisposed to accelerated erosion. About 70 % of its area is steeply sloping. The basic demographic-economic problem of Serbia is the relationship between the size of the agricultural population and the area of soil at their disposal for agricultural production.

2. METHODS OF RESEARCH

The representative watershed selected for study is Rasina watershed. For the purpose of the influence of anthropogenic factors on the state of erosion, there were investigated demographic trends and activities of the population from the villages: Popova, Kaševar, Razbojna, Lepenac, Velika Grabovnica, Budilovina, Kobilje, Rogavčina and Jablanica.

The current status by these watersheds is compared with their condition of three decades ago, when high agricultural pressure was present. The method of Gavrilovic has been utilized for estimation the degree of erosion.

The impact of socio-economic factors upon the state of the erosion in the study areas was examined by the statistics data refered to the examined watersheds. These data were supplemented by local statistics. The statistics data obtains necessary informations about the household, number of inhabitans, their sex, age and economic structures, the state of the livestock funds etc.

3. RESULTS OF RESEARH

The development of erosion in the examined area can be divided into two periods: up to mid fifties and sixties, the period of greatest agrarian overpopulation when erosion was accelerating, and after the mid-fifties and sixties, when erosion was decelerating (Zlatic et al, 1998).

3.1. The Period up to mid-fifties and sixties of 20th century

This period was characterized by a continuous increase in population and household numbers. Oner general trend was a relatively great increase in the number of households, compared to the number of inhabitants, enacted mostly by division of the households.

The period is characterized by significant changes in the utilization of the agricultural soils. Throughout the examined watershed, changes encountered included large increases of the arable, meadow, orchard and vineyard areas at the expense of forest and pasture.

Table 1. *Number of inhabitants (NI) and number of households (NH) in selected villages of Rasina river watershed, 1948-2002*

Village	NI/NH	Year						
		1948	1953	1961	1971	1981	1991	2002
Popova	NI	650	662	580	455	368	269	224
	NH	117	118	129	117	123	97	96
Kaševar	NI	928	748	626	576	497	407	336
	NH	142	126	132	138	139	126	127
Razbojna	NI	638	678	681	597	578	537	479
	NH	99	108	144	143	158	156	141
Lepenac	NI	981	1023	1014	934	953	960	932
	NH	126	146	161	186	216	245	275
Velika Grabovnica	NI	748	768	791	733	691	619	651
	NH	85	91	108	111	134	136	158
Budilovina	NI	483	503	459	396	319	307	293
	NH	66	70	80	83	79	82	90
Kobilje	NI	553	610	622	542	481	513	496
	NH	78	88	124	121	121	136	141
Rogavčina	NI	951	831	1091	829	687	408	214
	NH	133	184	153	159	152	122	78
Jablanica	NI	1035	1054	951	853	783	655	642
	NH	208	215	230	223	237	221	212

Source: The Archives of Serbia (data of 1990-1921); Statistical office of the Republic of Serbia (data of 1948-2002)

3.2. Period after the mid-fifties of 20th century

During this period, the region was characterized by population migration and changes in the structure of agricultural production.

The three factors were significant in bringing about migration: (1) the first was farm incomes, which in region were very low; (2) the second was poor infrastructure; the region is being abandoned. Housing surface areas per capita are small, road connections are weak, especially in the mountainous region, (3) the third and most important factor were the changed socio-economic relations in the country.

Table 2. *State of erosion*

Category of erosion	Affected area above the dam "Celije"	
	km^2	%
I	0.00	0.00
II	16.29	2.67
III	199.85	32.81
IV	360.48	59.18
V	27.94	4.59

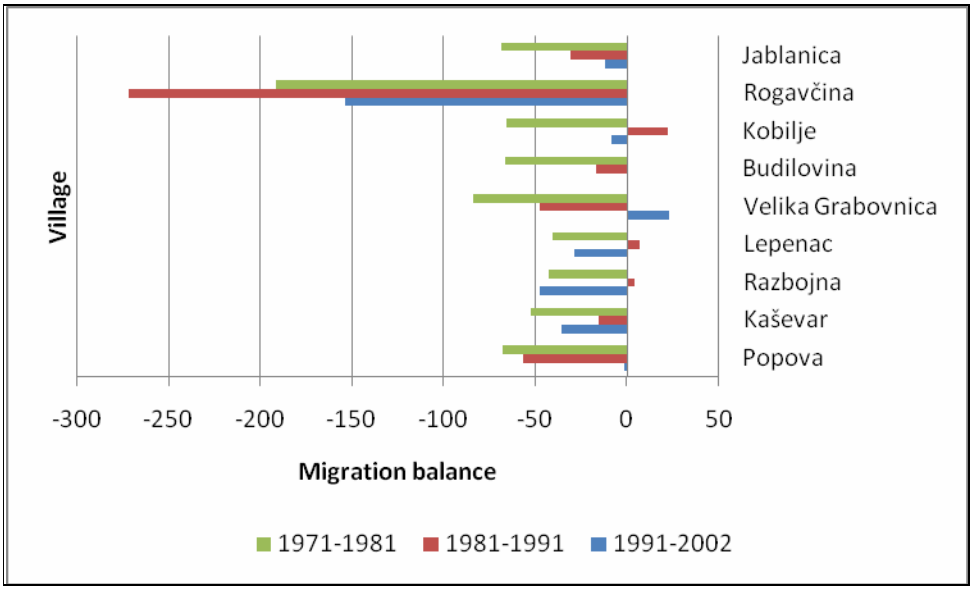
Source: Original

Sediment transport

- Surface area above the dam……………………………………………..609.15 km^2
- Mean coeficient of erosion………………………………… ……….Zsr = 0.39
- Hidrograph clase…………………………………………………...A
- Annual sediment transport..……………………………………….162.000 m^3*god
- Specific sediment transport………………………………………...265 m^3/km^2/god

Accordingly, the high pressure on the land decreased, primarily due to migrations. These trends reduced erosion processes to the weak erosion at present (Kostadinov, 1993) regarding mean coef. of erosion (Zsr=0.39) and the fact that there is the area of about 60% under weak erosion (table 2).

Graphic 1. *Migration Balance of population for selected villages of Rasina river watershed, 1971-2002.*



Source: Original

For the period of 1971 - 1981 migration balance was negative in all investigated villages. For the period 1981 – 1991 positive migration balance was evident in three villages: Kobilje, Lepenac and Razbojna and on average its amount was 11. During period 1991 – 2002 only Velika Grabovnica had positive migration balance (23).

The average amount of migration balance for all investigated villages during 1971 – 1981 was – 267, during 1981 – 1991 was -408 and in the period of 1991 – 2002 it was -683. One can conclude that average amount of migration balance in the research period was reduced 2.6 times. That situation caused decrease in number of inhabitants and increase in their average age.

Similary, the number of cattle in researched region has declined. It is evident decline of beeves, as well as decline in swines which made bad life conditions from economic point of view.

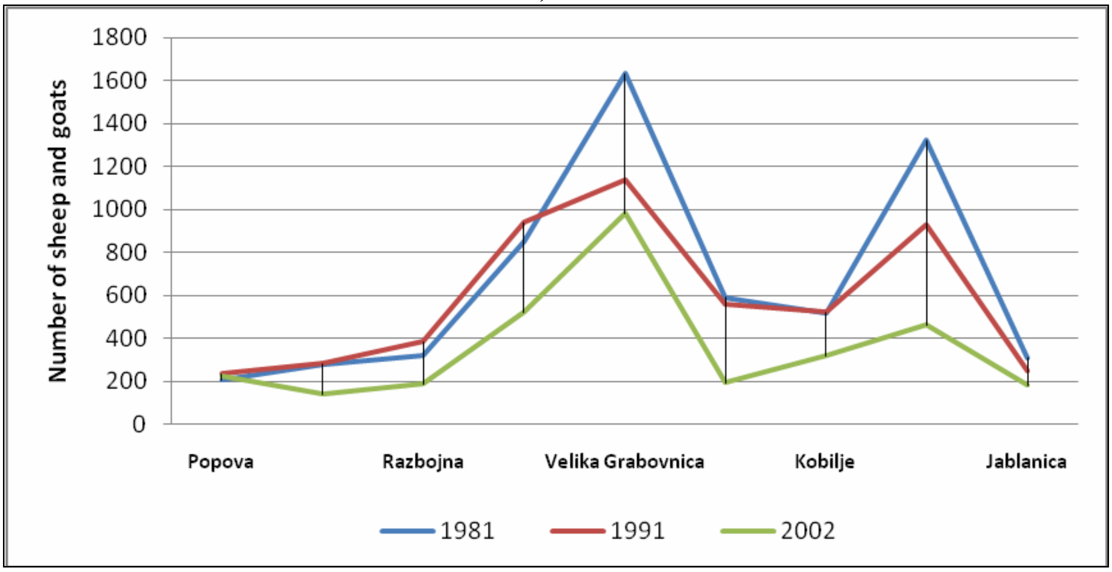
Table 3. *Livestock fund for selected villages of Rasina river watershed, 1981-2002.*

Village	Livestock fund								
	beeves			swines			poultry		
	1981	1991	2002	1981	1991	2002	1981	1991	2002
Popova	354	173	66	366	208	143	1499	1490	809
Kaševar	351	232	150	521	395	220	2412	2216	1516
Razbojna	284	224	108	566	515	164	1820	1785	1113
Lepenac	431	328	144	1318	897	344	3017	2677	2106
Velika Grabovnica	461	426	263	889	581	588	1831	1526	1576
Budilovina	216	157	70	447	311	55	912	854	705
Kobilje	213	97	60	290	215	93	1244	1090	1006
Rogavčina	449	279	155	525	312	120	1277	850	498
Jablanica	322	196	92	635	499	190	3145	2756	1710

Source: Statistical office of the Republic of Serbia

During 1981 – 2002 livestock fund (beeves, swines and poultry) had continually decreased. Number of beeves decreased from 3081 to 1108 (64%). Number of swines decreased from 5557 to 1917 (65.5%) and number of poultry decreased from 17157 to 11039 (35.7%). Unfortunately, this situation contributes to worse life and economical conditions.

Graphic 2. *Livestock fund – Number of sheep and goats for selected villages of Rasina river watershed, 1981-2002.*



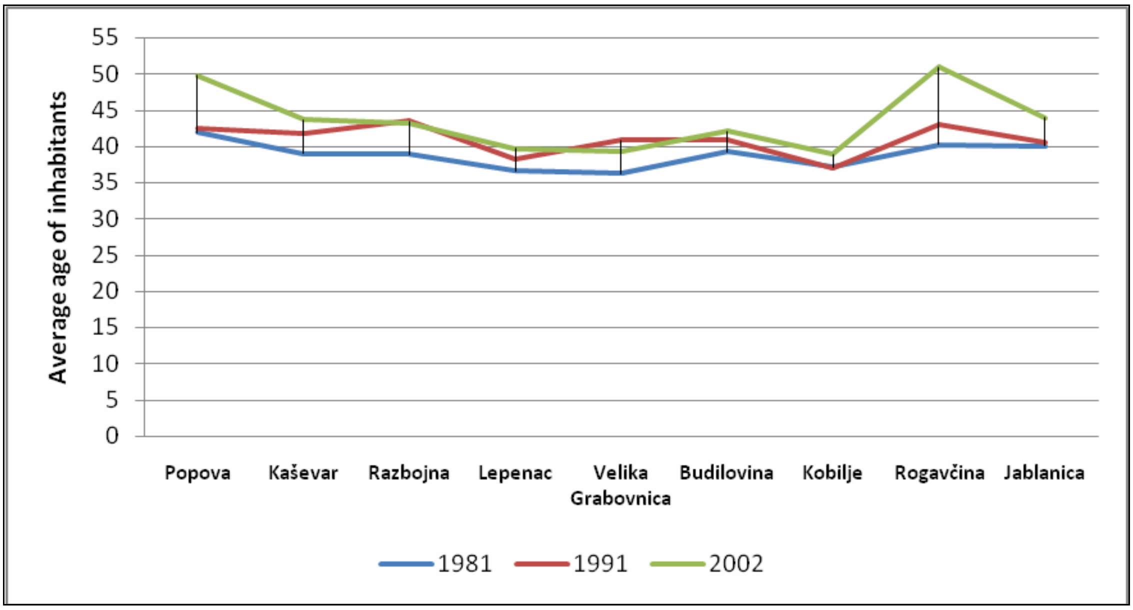
Source: Original

It is evident that number of sheep and goats in 1981 was 6030, in 1991 – 5224 and in 2002 – 3202. It means that reduction of sheep and goats was 46.9% in whole research period (in the period 1981 – 1991 reduction was 13.4%, and in 1991 – 2002 it was 38.7%).

3.3. Socio-economic prospects

Socio-economic changes over last four decades favoured the reduction of the erosion processes. The high agrarian pressure was reduced primarily by emigration. As people moved out, elderly households remained – as a result many arable fields fell from cultivation, becoming weedy or reconverted into pastures.

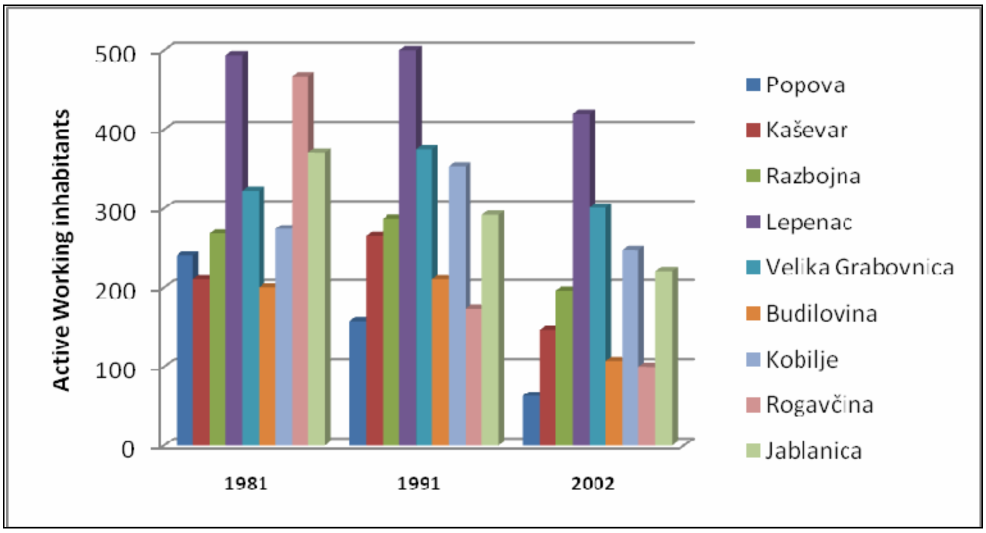
Graphic 3. *Average age of inhabitants in selected villages of Rasina river watershed, 1981-2002.*



Source: Original

Average age of population had increased in the research period and it was 38.8 years in 1981, 40.9 in 1991 and 43.5 in 2002. Average age of population in 1991 increased by 5.4% compared to 1981, or by 6.4% in 2002 in comparison to 1991. Average age of population in investigated area in 2002 was 7.9% higher in comparison with all the theritory of Serbia (40.3 years).

Graphic 4. *Number of labour-active inhabitants in selected villages of Rasina river watershed, 1981-2002.*



Source: Original

In 1981 there were 2.846 labour-active inhabitants (LAI) in the investigated villages of Rasina watershed. In 1991 there were 2624 LAI and in 2002 – 1801 LAI. It can be concluded that the whole amount of AWI in the period 1981-1991 decreased to 7.8%, and in the period 1991 - 2002 even to 31,4%.

Table 4. *Number of active agricultural inhabitants in selected villages of Rasina river watershed, 1981-2002.*

Village	Active agricultural inhabitants					
	1981		1991		2002	
	all	female	all	female	all	female
Popova	188	101	102	56	21	9
Kaševar	143	95	157	93	59	27
Razbojna	185	98	146	61	65	28
Lepenac	318	174	227	114	103	47
Velika Grabovnica	260	113	247	110	150	47
Budilovina	158	88	139	73	52	15
Kobilje	164	91	84	31	74	28
Rogavčina	330	216	75	19	73	39
Jablanica	247	123	152	59	49	22

Source: Statistical office of the Republic of Serbia

In the researched villages of Rasina river watershed in 1981 there were 1993 of active agricultural inhabitants (AAI), then in 1991 – 1329 AAI and in 2002 – 646 AAI. It means that total amount of AAI in the period of 1981 – 2002 decreased to 67.60%. In this period decreased the amount of active women agricultural inhabitants (AWAI) to 76.20% (for investigated villages it amounted 1099 in 1981, 616 in 1991 and 262 in 2002). The share of women in total amount of agricultural population has been reduced as follows: in 1981 it amounted 55.10%, in 1991 – 46.40% and in 2002 it amounted to 40.60%.

Picture 1. *State of land use and erosion*

Photo: Kostadinov S. (2009)

4. CONCLUSIONS

The natural conditions in the hilly Rasina watershed favour erosion processes. However, the main factors of accelerated erosion are anthropogenic. The period up to mid –fifties and sixties was characterized by high agrarian pressuand, and as its consequence, intensive erosion. The period after mid fifties and sixties has been characterized by rural depopulation and changes in the structure of agricultural production. As people have left their households, only elderly people remained and many arable fields fell from cultivation. These circumstances, together with biological and engineering measures, contributed to the reduction of the erosion. Nowadays, it appears necessary to organize production around the principles of soil management for sustainability. It is in this manner that the conservation of natural resources and environmental value will be supported, while enabling people to stay and survive in these regions.

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THE VARIABILITY OF THE QUANTITY OF ESSENTIAL OIL EXTRACTED FROM THE BOSNIAN PINE NEEDLES

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Abstract: *Needle-bearing twigs were collected from three Bosnian pine populations in Montenegro, at the end of the active vegetative season, and stored at -20°C. Essential oil extraction from two-year-old needles of* Pinus heldreichii *Christ. in* n-*pentane (1g of needles/1ml* n-*pentane) yielded an average of 0.39 ml of liquid extract, with significant individual (0.13 ml - 0.60 ml) and populational variability (0.31 ml - 0.43 ml). There was a weak positive correlation between the quantity of extract and needle mass (r = 0.30). Population Zeletin had the lowest quantity of extract (0.31 ml), as well as the lowest needle mass (0.12 g per needle). Population Bjelasica had the highest needle mass (0.18 g per needle). Population Lovćen had the highest quantity of extract (0.43 ml).*

Key words: needles, *n*-pentane, needle mass, variability, correlation

VARIJABILNOST KOLIČINE ETARSKOG ULJA EKSTRAHOVANOG IZ IGLICA MUNIKE

Izvod: *Grančice sa četinama munike sakupljene su iz tri populacije u Crnoj Gori na kraju vegetacione sezone i skladištene na -20°C. Ekstrakcijom etarskog ulja iz dvogodišnjih četina* Pinus heldreichii *Christ. u* n-*pentanu (1g četina /1ml* n-*pentana) dobijeno je u proseku 0.39 ml tečnog ekstrakta, sa značajnom individualnom (0.13 ml - 0.60 ml) i populacionom varijabilnošću (0.31 ml - 0.43 ml). Korelacija između količine ekstrakta i mase četina je bila slaba (r = 0.30). Populacija Zeletin je imala najmanju količinu ekstrakta (0.31 ml) i najmanju masu četina (0.12 g po četini). Populacija Bjelasica je imala najveću masu četina (0.18 g po četini). Populacija Lovćen je imala najveću količinu ekstrakta (0.43 ml).*

Ključne reči: četine, *n*-pentan, masa četina, varijabilnost, korelacija

1. INTRODUCTION

Pine needles contain a significantly lower quantity of essential oil than buds, twigs, cones (Kostov and Masarova, 1970; Papadopoulou and Koukos, 1996; Koukos *et al.*, 2000), and wood resin (Fengel and Wegner, 1984). In restoring many forests to an ecologically sustainable condition (after extreme droughts, wildfires, or/and insect outbreaks) a large number of small-diameter pine trees have to be felled (Kelkar *et al.*, 2006). On the other hand, unlike wood and energy production, the opportunity of water vapour distillation of volatile essential oil components, specifically pine oil and pine needle oil (Ciesla, 1998), is often overlooked. But, having in mind the total mass and organic matter content, in future, sustainable forestry should focus on coniferous needles which are not only alternative energy sources in biomass combustion, but also resources of volatile chemical compounds applicable in medicine (Krauze-

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Project No. TR18201A, Istraživanje mogućnosti proizvodnje biomase za energiju iz plantaža kratke ophodnje u okviru elektroenergetskih sistema Srbije (rukovodilac: Dr Dragana Dražić, naučni savetnik).
Translation: Mirjana Slavkovski

Baranowska *et al.*, 2002; Kwak *et al.*, 2006; Park *et al.*, 2008; etc.), aromatherapy, as well as in wood, pharmaceutical and food industries, etc. These compounds directly affect air quality (Su *et al.*, 2007). Volatile organic compounds (VOCs) have numerous ecological roles (attraction of honeybees and moths, attraction of seed dispersers, repelling effect on conspecific herbivores, attraction of aboveground and belowground predators and parasitoids, antimicrobial or antifungal effects of volatiles, activation of defenses in neighboring plants, reduction of seed germination, oxidative stress relief, thermotolerance, etc.) which depend on climate changes (Yuan *et al.*, 2009).

The composition of Bosnian pine oleoresins was researched by: Pejoski (1951, 1953, 1955), Mirov (1961), Iconomu and Valkanas (1966), Karapandžić and Jovanović (1972, 1975), Weißmann (1973), Fengel and Wegner (1984), Spanoudaki (1993) and Lange *et al.* (1994). The main ingredient of Bosnian pine terpentine is limonene, while among resin acids abietanic ones are dominant, the same as thunbergol and cembrol among neutral diterpenes (Lange *et al.*, 1994).

Young Bosnian pine shoots contain about 1.25% of essential oil and 41% limonene, while the cones contain 0.85% oil and as much as 76% limonene (Menković *et al.*, 1993). According to Chalchat *et al.* (1994) the percentage of oil in twigs varies among populations and declines with the age of the needles (1.32-1.7% in young trees and 1.0-1.2% in old trees).

The composition of Bosnian pine needles was researched by: Karapandžić (1964, 1966), Chalchat *et al.* (1994), Simić *et al.* (1996), Stevanović - Janežić and Vilotić (1998), Petrakis *et al.*. (2000, 2001), Naydenov *et al.* (2005), Marić *et al.* (2007) and Nikolić *et al.* (2007). In most of the abovementioned papers limonene was the dominant component (up to 67%), and sometimes germacrene D (Chalchat *et al.*, 1994; Simić *et al.*, 1996). The Bosnian pine's terpenic profile also contains α-pinene, β-caryophyllene, β-pinene, and in some cases even γ-muurolene (22%, Naydenov *et al.*, 2005). Needle oil content varies among populations and developmental stages while the ratio of the main terpenic components is stable (Simić *et al.*, 1996).

In practice, essential oils from the buds and cones of *Pinus heldreichii* are used in the treatment of rheumatic diseases (Jančić *et al.*, 1995). Essential oils obtained from the wood of the Bosnian pine are used for the synthesis of limonene (82.8%, Fengel and Wegner, 1984).

Besides traditional hydrodistillation, essential oil extraction can also be performed by other methods such as supercritical carbon dioxide extraction (SCF-CO_2), different solvent methods, etc. Extraction in *n*-pentane is excellent for the extraction of monoterpenes, and better than hydrodistillation for sesquiterpenes as well (Poiana *et al.*, 1998), and also some unstable compounds of essential oils (Mastelić and Jerković, 2003).

This paper aims to research the variable quantity of essential oil that can be extracted from Bosnian pine needles with *n*-pentane and to research the correlation between oil quantity and needle mass.

2. MATERIAL AND METHOD

2.1 Plant Material

Needle-bearing twigs from the lowest third of the tree crown were collected in late summer to early fall from 30 randomly selected trees in each of the three Montenegrin populations (Mt. Lovćen, Mt. Zeletin and Mt. Bjelasica). Habitat characteristics of the selected populations are described in more detail in Nikolić *et al.* (2007). The collected twigs were stored in plastic bags at -20 °C until extraction. Voucher specimens were deposited at the Institute of Forestry, Belgrade, Serbia.

2.2 Essential Oil Isolation

The needles were cut into 2-3 mm pieces, and essential oils were extracted with *n*-pentane (1 g of needles per milliliter of solvent) in glass vials. The extracts were kept at 4–6°C for 24 h, then filtered and the volume of extract obtained was measured. Then, the total amount of extract per 1g of needles was calculated.

2.3 Measurement of Needle Mass

First, the mass of twenty (two-year-old) needles (without fascicle) from every tree was measured and then mass per one needle was calculated.

2.4 Statistical Treatment

The calculation of arithmetic means and standard deviations (SD) one-way analyses of variance (ANOVA), multiple range test (95.0 percent LSD), and linear correlation were all carried out using Statgraphics Plus software (version 5.0; Statistical Graphics Corporation, USA).

3. RESULTS

An average of 0.39 ml of extract was obtained from 1g of needle-bearing twigs extracted in 1ml of *n*-pentane, with significant variations among populations (0.31 ml - 0.43 ml, SD: 0.09 - 0.11) as well as among trees (0.13ml - 0.60 ml) (Table 1). Differences between the Lovćen (0.43 ml) and Bjelasica (0.42 ml) populations were not significant, and the variations were smaller.

Table 1. *Amount of* n-*pentane extract of needles in Bosnian pine populations*

Population	Min	Max	Average	SD	Homogeneous Groups*
Lovćen	0.26	0.60	0.31	0.09	X
Zeletin	0.13	0.53	0.42	0.11	X
Bjelasica	0.25	0.56	0.43	0.09	X
Average	**0.13**	**0.60**	**0.39**	**0.11**	

* Method: 95.0 percent LSD

Population Zeletin yielded the lowest quantity of extract (0.31 ml, Table 1), which was statistically proven by LSD test (Table 1) and ANOVA test (Table 2). This population also exhibited the highest individual variations (Table 1).

Table 2. *ANOVA test for amount of* n-*pentane extract of needles in Bosnian pine populations*

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	0.275749	2	0.13787400	14.50	0.0000
Within groups	0.827047	87	0.00950628		
Total (Corr.)	1.102800	89			

Average mass per needle is 0.15 g, with significant variations among populations (0.12 g - 0.18 g, SD: 0.03 - 0.04) and among trees (0.06 g - 0.24 g) (Table 3).

Table 3. *Mass per needle in Bosnian pine populations*

Population	Min	Max	Average	SD	Homogeneous Groups*
Zeletin	0.06	0.18	0.12	0.03	X
Lovćen	0.10	0.23	0.15	0.03	X
Bjelasica	0.10	0.24	0.18	0.04	X
Average	**0.06**	**0.24**	**0.15**	**0.04**	

* Method: 95.0 percent LSD

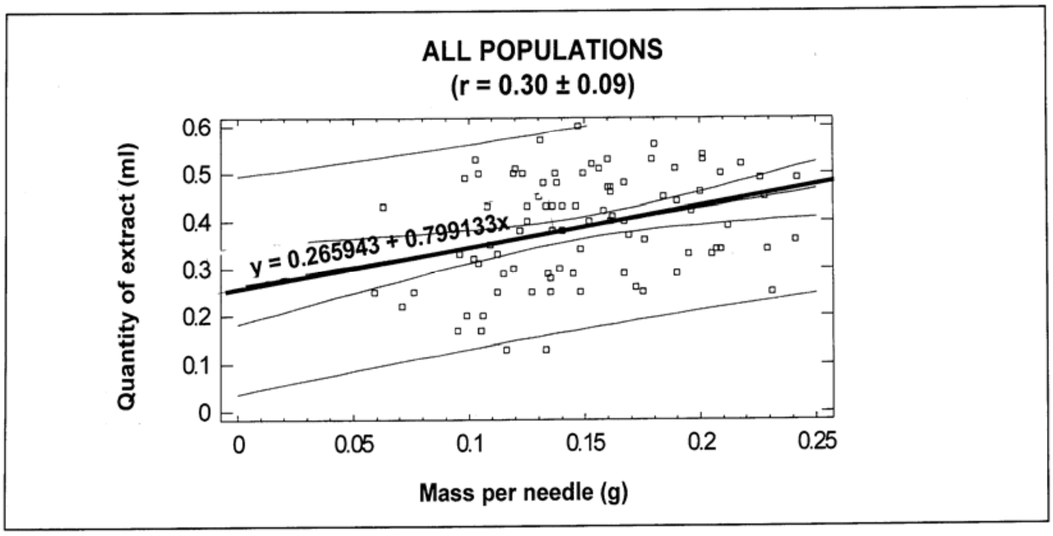
Population Zeletin has the lowest needle mass (0.12 g, Table 3), which is also statistically proven by LSD test (Table 3) and ANOVA test (Table 4). Population Bjelasica has the highest needle mass (0.18 g) even compared to the Lovćen population (0.16 g), and the most pronounced individual variation in this respect (Table 4).

Table 4. *ANOVA test for mass per needle in Bosnian pine populations*

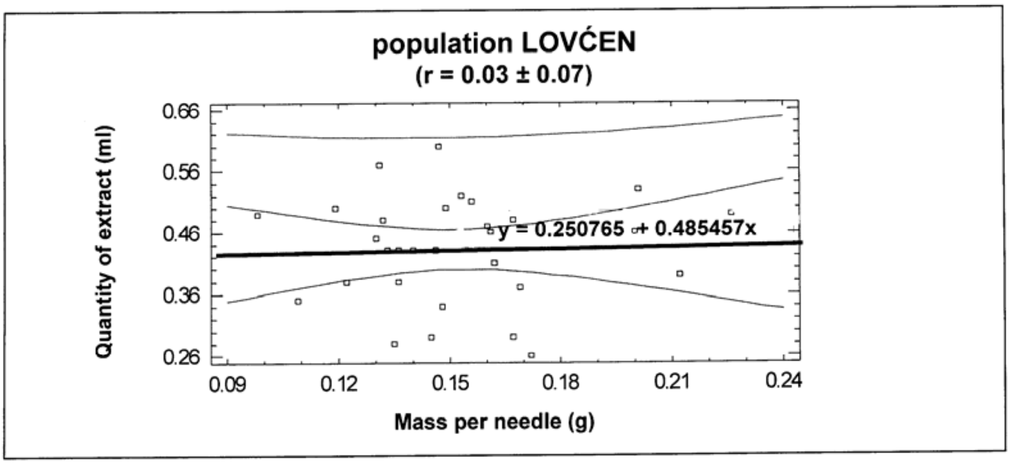
Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	0.0578606	2	0.0289303	25.22	0.0000
Within groups	0.0997893	87	0.0011470		
Total (Corr.)	0.1576500	89			

Comparing both of the measured characters, population Zeletin has the lowest extract mass and lowest needle mass, but the rank of the other two populations (Lovćen and Bjelasica) was not equal in both characteristics measured (Table 2 and Table 4). Linear correlation (*r*) between extract mass and needle mass is positive on the level of all the populations, but weak (0.30, Graph 1). In population Zeletin however, it is slightly higher (0.13, Graph 2), compared to the Lovćen and Bjelasica populations where it is actually non-existent (0.03 and 0.04, Graph 1 and Graph 3, respectively).

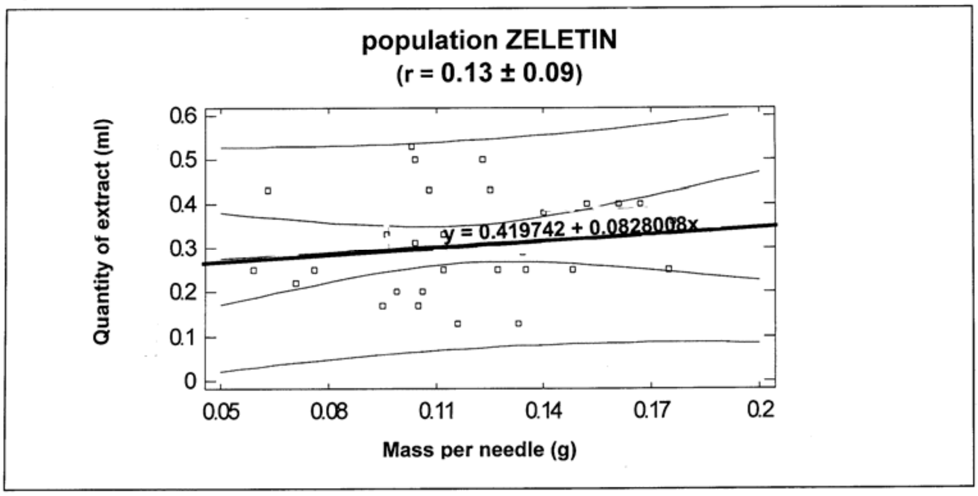
Graph 1. *Linear correlation between extract mass and needle mass of Bosnian pine – all populations*



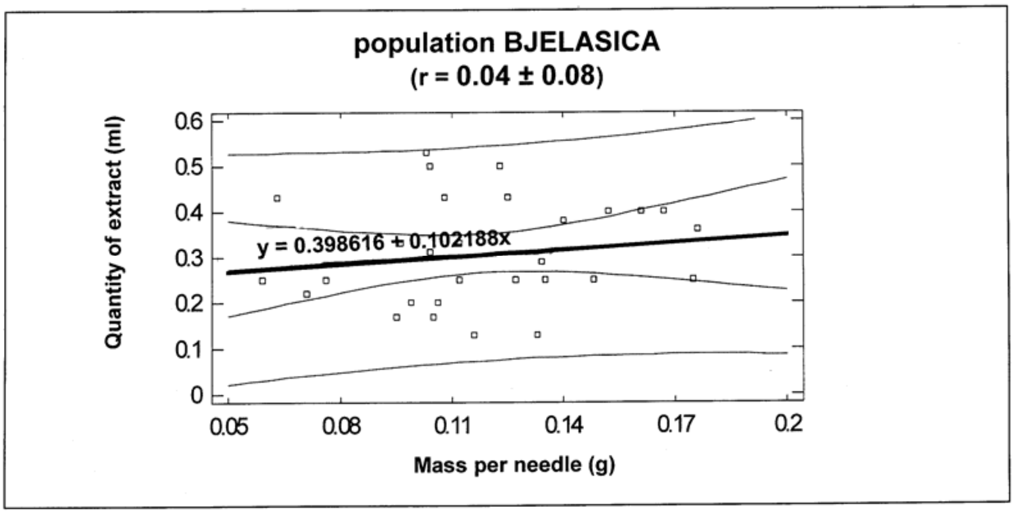
Graph 2. *Linear correlation between extract mass and needle mass of Bosnian pine – population Lovćen*



Graph 3. *Linear correlation between extract mass and needle mass of Bosnian pine – population Zeletin*



Graph 4. *Linear correlation between extract mass and needle mass of Bosnian pine – population Bjelasica*



4. DISCUSSION AND CONCLUSIONS

Despite the incontrovertible fact that the composition and production of essential oil and terpenes in plants are under strict genetic control, which was particularly well researched in the composition of genus *Mentha* (Reitsem, 1958, Fujito, 1960, etc., after Mimica-Dukić, 1995; Lincoln *et al.*, 1971, after Marin, 1995) and conifers, terpenes often vary individually in quantity and quality depending on the type of tissue (*Picea glauca,* von Rudloff, 1972; *Picea sitchensis*, Hrutfiord *et al.*, 1974), seasonal changes and the age of plant tissue (*Pinus ponderosa*, Zavarin *et al.*, 1971; von Rudloff, 1975; *Pinus sylvestris*, Udarov *et al.*, 1984; *Pseudotsuga menziesii*, *Abies concolor* and *Picea engelmannii*, Wagner *et al.*, 1989), degree of crown light exposure (*Pinus sylvestris*, Manninen *et al.*, 2002), position of leaves in the crown (*Picea abies*, Holubova *et al.*, 2001), numerous ecological factors (*Pinus caribea*, Barnola and Cedeño, 2000), manner of raw plant material processing (collection, storage) and essential oil isolation (various species, Muzika *et al.*, 1990). The differences in the quantity of essential oil extracted can vary significantly among populations (*Juniperus communis*, Matović and Pižurica, 1998). Ilijin-Jug (1995) and Isajev *et al.* (1999) even noted the appearance of an additional, third resin channel in Serbian spruce needles outside of its areal (in polluted environments). The resin channels in the needles can also be interrupted (several North American spruces from section *Casicta*, Weng and Jackson (2000). Various serious types of needle damage or disease (Veselinović *et al.*, 2008) can also damage the leaf tissue that produces essential oils.

The oil content in the Bosnian pine needles from Mt. Šara also varies depending on the population and the needles' developmental stage (0,28 % - 0,45 %), while the ratio of the main terpenic components, germacrene D and limonene, is stable (Simić *et al.*, 1996).

From the results listed in the paper it is clear that the quantity of extract that can be obtained from Bosnian pine needles is not strongly correlated to the needle mass as was expected at the beginning of the research. The reasons for it can be numerous starting from individual (age of the tree, the needles' morphological and anatomical characteristics, and particularly the number and continuity of resin channels) to various environmental influences (crown light exposure, temperature, humidity, air and ground pollution, various needle diseases or types of damage etc.), which can also partially influence the number and continuity of resin channels in the needles and thus the production of essential oil.

Future research should be directed primarily towards the study of the influence of the needles' morphometric and anatomic characteristics, as well as towards the percentage of dry matter in the total needle mass.

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THE VARIABILITY OF THE QUANTITY OF ESSENTIAL OIL EXTRACTED FROM THE BOSNIAN PINE NEEDLES

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Summary

Plant volatile organic compounds (VOCs) have numerous ecological roles (attraction of honeybees and moths, attraction of seed dispersers, repelling effect on conspecific herbivores, attraction of aboveground and belowground predators and parasitoids, antimicrobial or antifungal effects of volatiles, activation of defenses in neighboring plants, reduction of seed germination, oxidative stress relief, thermotolerance, etc.) which depend of climate changes (Yuan *et al.*, 2009). Besides traditional hydrodistillation, essential oil extraction can also be performed by other methods (extraction with SCF-CO_2, different solvent methods, etc). Extraction in *n*-pentane is excellent for the extraction of monoterpenes, and better than hydrodistillation for sesquiterpenes as well (Poiana *et al.*, 1998), and also some unstable compounds of essential oils (Mastelić and Jerković, 2003).

This paper aims to research the variable quantity of essential oil that can be extracted from Bosnian pine needles with *n*-pentane and to research the correlation between oil quantity and needle mass. Needle-bearing twigs

were collected from three Bosnian pine populations in Montenegro, at the end of the active vegetative season, and stored at -20°C. Essential oil extraction from two-year-old needles of *Pinus heldreichii* in *n*-pentane (1g of needles/1ml *n*-pentane) yielded an average of 0.39 ml of liquid extract, with significant individual (0.13 ml - 0.60 ml) and populational variability (0.31 ml - 0.43 ml). There was a weak positive correlation between the quantity of extract and needle mass (r = 0.30). Population Zeletin had the lowest quantity of extract (0.31 ml), as well as the lowest needle mass (0.12 g per needle). Population Bjelasica had the highest needle mass (0.18 g per needle). Population Lovćen had the highest quantity of extract (0.43 ml).

From the results listed in the paper it is clear that the quantity of extract that can be obtained from Bosnian pine needles is not strongly correlated to the needle mass. Future research should be directed primarily towards the study of the influence of the needles' morphometric and anatomic characteristics, as well as towards the percentage of dry matter in the total needle mass.

VARIJABILNOST KOLIČINE ETARSKOG ULJA EKSTRAHOVANOG IZ IGLICA MUNIKE

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Rezime

Isparljivi organski sastojci biljke (VOCs) imaju brojne ekološke uloge (privlačenje pčela i leptirova, privlačenje raznosača semena, efekat odbijanja istovrsnih herbivora, privlačenje nadzemnih i podzemnih predatora i parazita, antimikrobni i antifugalni efekti isparljivih materija, aktivacija odbrane od susednih biljaka, redukovanje klijanja semena, oslobađanje od oksidativnog stresa, termotolerancija, itd.) koje zavise od klimatskih promena (Yuan *et al.*, 2009). Osim tradicionalne hidrodestilacije ekstrakcija etarskog ulja se može vršiti i drugim metodama (ekstrakcija sa SCF-CO_2, različite rastvaračke metode, itd.). Ekstrakcijom u *n*-pentanu se odlično ekstrahuju monoterpeni, a bolje nego hidrodestilacijom i seskviterpeni (Poiana *et al.*, 1998), kao i neki nestabilni sastojci etarskih ulja (Mastelić and Jerković, 2003).

Cilj ovog rada je istraživanje varijabiliteta količine etarskog ulja koje se može ekstrahovati uz pomoć *n*-pentana iz iglica munike i ispitivanje zavisnosti količine ulja od težine četina. Grančice sa četinama munike sakupljene su iz tri populacije u Crnoj Gori na kraju vegetacione sezone i skladištene na -20°C. Ekstrakcijom etarskog ulja iz dvogodišnjih četina *Pinus heldreichii* u *n*-pentanu (1g četina /1ml *n*-pentana) dobijeno je u proseku 0.39 ml tečnog ekstrakta, sa značajnom individualnom (0.13 ml - 0.60 ml) i populacionom varijabilnošću (0.31 ml - 0.43 ml). Korelacija između količine ekstrakta i mase četina je bila slaba (r = 0.30). Populacija Zeletin je imala najmanju količinu ekstrakta (0.31 ml) i najmanju masu četina (0.12 g po četini). Populacija Bjelasica je imala najveću masu četina (0.18 g po četini). Populacija Lovćen je imala najveću količinu ekstrakta (0.43 ml).

Iz rezultata priloženih u ovom radu jasno se uočava da količina ekstrakta koja se može dobiti iz četina munike nije u jakoj vezi sa masom četina. Buduća istraživanja bi trebalo prvenstveno usmeriti ka proučavanju uticaja morfometrijskih i anatomskih osobina četina kao i procenta suve materije u ukupnoj masi četina.