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SUSTAINABLE FORESTRY **ODRŽIVO ŠUMARSTVO**
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Original scientific paper

THE SUSTAINABLE INTELLIGENT BUILDING SKINS -FACADE IMITATING THE TREE PROCCES OF FILTERING AIR, BIOMIMICRY ARCHITECTURE

Eneida HASKA[1], Halil Semih ERYILDIZ[1], Hajri HASKA[2]*

Abstract: *In recent years the facades of building have become incrisingly significant due to unconvencional choices of materials and the use of inovative technology. More and more the external surfaces are beeing percived and designet as an integral part of the building. This skin, a protective mantle defines not only the interior but also the adjoining exterior space. It is visiting card of the building. Today's way of doing architecture should be a vision initiative which includes new ways of thinking about the relationship between construction and the environment, discovering new forms and content, and the assertion that the art of construction is in a new phase which will definitely change the way of our living, always in accordance with the language of nature. In this study we will show examples of how new forms of architectural design imitating nature completely change the old fashioned way of design. Especially Intelligent Façade which is a very efficient form of our impact in nature.*

Keywords: green smart skins, adaptive building façade, filtering polluted air, tree imitation

1. INTRODUCTION

The 20th-century architecture began as a manifestation of the era of industrialization and technology, but in the 1990's it began to change rapidly with a new era of information and ecology. One of the most complex and problematic issues facing mankind in the following century is how to construct a habitat in

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harmony with nature, always having in mind a creative dialogue and not a choice that would be Utopian. By the time Late Modern reached its predominant influence, the parallels between industrial production and expression in form were very easily understood. Similarly, the end of the 20th century created very strong evidence of environmental / environmental technology and natural landscape transformed into architectural iconography of the ecology era. When we talk about, the smart facade skin and building envelope that is able to adapt to environmental circumstances dates back to the first opening. The idea of the smart and sustainable facade has only been around for a few decades, helped along by recent advances in chemical and material science. And over the past ten years we have seen this category boom.

2. UNDERSTANDING SUSTAINABLE DESIGN

2.1 Problems architecture is facing, benefits of sustainable design

One of the biggest problems facing environmental architecture, leaving aside the lack of a strong social attitude, is a professional choice to over-emphasize the advantages of technology and underestimate the social and aesthetic aspect.

"Architecture has a serious problem today in that people who are not alike don't communicate. I'm actually more interested in communicating with people I disagree with than people I agree with."

"To have a certain virtuosity of interpretation of every phenomenon is crucial. We're working in a world where so many different cultures are operating at the same time, each with their own value system. If you want to be relevant, you need to be open to an enormous multiplicity of values, interpretations, and readings. The old-fashioned Western 'this is' 'that is' is no longer tenable. We need to be intellectual and rigorous, but at the same time relativist."- At the 2016 AIA convention, the legendary architect Rem Koolhaas, the Pritzker Prize-winning Dutch architect gave the profession an honest appraisal of its failures.

The goal that harmonizes this situation is to view environmental technology as a working tool and natural science as a basic source of inspiration. The general categories that can characterize eco-friendly architecture could be defined as follows:

- Mixing landscape architecture,
- Composing or connecting object with garden or environment space,
- Using of the symbolism of nature in order to establish the relevance of architecture to its cultural context
- Support the new acceptance of "green architecture" and the merging of objects in context,
- Far-sighted ideas in architecture and urban planning that provide insight into the future, based on general social and political change that can have an impact on the art of construction and environmental policy, etc.

A number of architects have designed or conceptualized objects that represent striking models of ecological principles, contributing to eco-friendly

design and high levels of aesthetic design. In such cases it can be understood that the environment / environment is as important as the object, perhaps even more important, because the object must breathe and breathe in the space that surrounds it no matter what it is.

2.2 Principals creating Architecture

Throughout the years despite the fact that we had a great deal of changes in innovation, economy, culture and vitality parameters the primary chief in making engineering is as yet structuring and arranging "cover". At the end of the day, the basic point of building is to shield individuals from outer atmosphere conditions, for example, escalated sun powered radiation, extraordinary temperatures, precipitation and wind. In development, the structure skin is the essential subsystem through which winning outer conditions can be affected and controlled to meet the solace necessities of the client inside the structure. Like the skin and dress of people this garment, as well, satisfies the undertakings requested of it by playing out various capacities made conceivable by methods for the proper structure and development.

3. RESULTS AND DISSCUSION

3.1 The Building Skins of the future

New forms of generating energy will influence the design of the building skin as much as future developments in how we work and live. Actually, the shrewd exterior or building envelope that adjusts to ecological conditions goes back to the main window. In any case, the contemporary thought of the shrewd exterior has just been around for a couple of brief decades, helped along by late advances in concoction and material science. Furthermore, in the course of recent years, we've seen the classification blast.

Underneath, look at probably the most intriguing structure veneers to run over the screen as of late: From a warm metal screen that twists up when it's hot, to a titanium dioxide-secured divider that scours the quality of contaminations.

3.2 Biomimicry Architecture

Biomimicry is the impersonation of the models, frameworks, and components of nature to take care of complex human issues; biomimicry in engineering and assembling is the act of planning structures and items that reproduce or co-pick forms that happen in nature. There are ultrastrong manufactured bug silks, glues demonstrated after gecko feet, and wind-turbine cutting edges that copy whale balances. We are living in times where architects and designers through technology can imitate the function of a tree. Through architecture and intelligent building skins we can filter the smog that is damaging our lungs in air. Every big city in the world is affected from smog because of traffic and overpopulation,

3.3 A Facade That Eats Smog

The ascent in air contamination levels is driving a portion of the world's most exceedingly awful influenced urban communities to think about innovative arrangements in building and foundation structure. Air pollution is currently the greatest ecological reason for death, as indicated by the World Health Organization (WHO). Information discharged in 2016, indicated that a stunning 6.5 million individuals kicked the bucket in 2012 because of contaminated air, essentially in and around significant urban communities.

The Western Pacific and South East Asian locales bore the vast majority of the weight with 2.4 and 2.2 million passing, separately.

Figure 1. *The "smog-eating" installation at Mexico City's Manuel Gea González Hospital (image courtesy of Elegant Embellishments).*

While numerous countries are striving to confine emanations regularly in accordance with universal understandings a portion of the most exceedingly awful influenced urban communities are currently looking to mechanical arrangements in building and framework plan.

In 2011, the synthetic organization Alcoa disclosed a momentous innovation that could clean the air around it. The material contained titanium dioxide, which adequately "scoured" the demeanor of poisons by discharging supple free radicals that could dispose of toxins. The stuff has shown up on boulevards, attire, and design from that point forward most as of late, on the sun screen of a New Mexico City clinic, the Torre de Especialidades.

Figure 2. *The "smog-eating" installation at Mexico City's Manuel Gea González Hospital (image courtesy of Elegant Embellishments).*

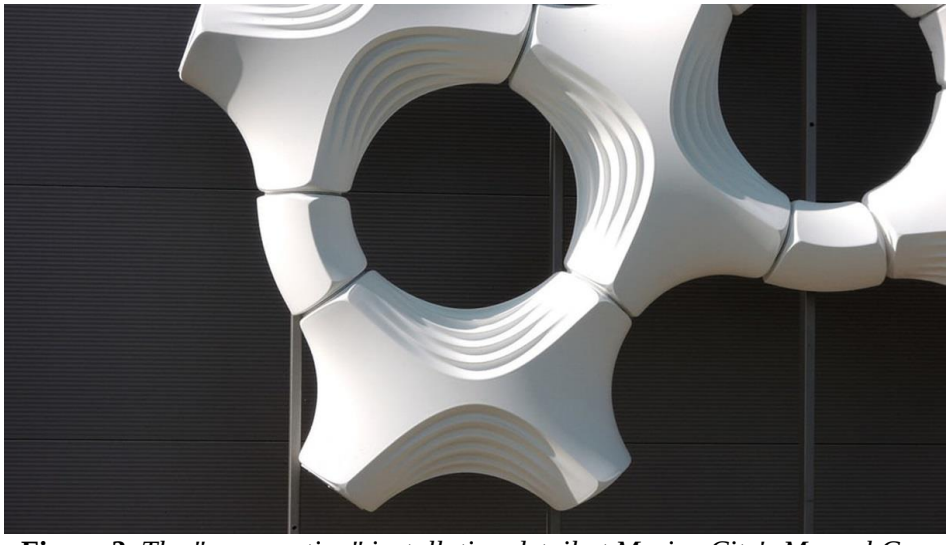

Figure 3. *The "smog-eating" installation detail at Mexico City's Manuel Gea González Hospital (image courtesy of Elegant Embellishments).*

The medical clinic is shrouded in a 300-foot-long skin of Prosolve370e tiles, created by a German firm called Elegant Embellishments. The innovation depends on a similar procedure: As air channels around the wipe formed structures, UV-light-initiated free radicals decimate any current poisons, leaving the air cleaner for the patients inside. As indicated by Fast Company, even the state of the sun screen is huge: It makes disturbance and hinders wind current around the

structure, while dissipating the UV light expected to actuate the compound response.

Manuel Gea González Hospital in Mexico City is one such model. The structure's proprietors have made the stride of including another "brown haze eating" façade covering more than 2,500 square meters.

The framework, planned and created by Elegant Embellishments, comprises of thermoformed shells covered in photocatalytic titanium dioxide. This covering responds with light to kill components of air contamination, discrediting the impacts of up to 1,000 vehicles every day as per its engineers.

Figure 4. *The façade of Manuel Gea González Hospital is said to negate the effects of up to 1,000 cars a day (image courtesy of Elegant Embellishments).*

Another model is the amazing Palazzo Italia – or Italy Pavilion – which was the focal point of the 2015 Milan Expo. The structure's six-story outside façade was clad in more than 700 "i.active BIODYNAMIC boards".

Photocatalytic titanium dioxide in the concrete again responds with light to kill certain toxins noticeable all around changing over them to latent salts, consistently filtering the atmosphere.The material adds around 4-5% to development costs and different instances of its utilization are springing up over the assembled condition; incorporating a photocatalytic roadway in The Netherlands and an "exhaust cloud eating sonnet" imprinted on a flag and held tight the side of a structure in Sheffield, UK. The standard's material contains the photocatalytic substance and is said to neutralize the effect of 20 vehicles every day.

The pennant relates near "reactant attire"; another idea a work in progress by originator Helen Story and polymer scientific expert Tony Ryan that adds titanium dioxide nano-particles to clothing cleanser.

Figure 5. *Milan's Palazzo Italia also employs photocatalytic titanium dioxide to neutralise pollutants in the air (images courtesy of Nemesi).*

Unmistakably while such "brown haze eating" arrangements are both inventive and powerful, they need far reaching selection so as to have an important effect. The innovation must be applied in adequate scale to coordinate the present degrees of air contamination created the world over on the off chance that it is to effectively check it.

Figure 6. *Smog on the Los Angeles skyline. "Smog-eating" solutions need widespread adoption in order to make meaningful impact.*

4. CONCLUSION AND SUGGESTIONS

For the first time in the history of architecture, nature and social welfare and non-decorations, styles, luxuries or other superficial elements come first. This new way of thinking, awakens our hope that the bottom line of human society is unconscious, and finally the conviction of what is really important to us is beginning to be created. This new wave of architecture design human society is finally witnessing has a slight tendency to strip away the veil of luxury and complexity, sparking interest in improving the health and mental condition of human society. At the same time, by intervening in the improvement of our social status, it also promotes a global improvement of nature. In my opinon the architectural and more humane revolution begins with the beginnings of sustainable and smart architecture. More than ever, the architects have the chance to make the world a better place.

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THE SUSTAINABLE INTELLIGENT BUILDING SKINS -FACADE IMITATING THE TREE PROCCES OF FILTERING AIR, BIOMIMICRY ARCHITECTURE

Eneida HASKA, Halil Semih ERYILDIZ, Hajri HASKA

Summary

In recent years the facades of building have become incrisingly significant due to unconvencional choices of materials and the use of inovative technology. More and more the external surfaces are beeing percived and designet as an integral part of the building. This skin, a protective mantle defines not only the interior but also the adjoining exterior space. It is visiting card of the building. Today's way of doing architecture should be a vision initiative which includes new ways of thinking about the relationship between construction and the environment, discovering new forms and content, and the assertion that the art of construction is in a new phase which will definitely change the way of our living, always in accordance with the language of nature. In this study we will show examples of how new forms of architectural design imitating nature completely change the old fashioned way of design. Especially Intelligent Façade which is a very efficient form of our impact in nature.

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VARIABILITY OF RESIN CANAL DIAMETER IN THE NEEDLES OF DIFFERENT DOUGLAS-FIR PROVENANCES

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Abstract: *Douglas-fir is the most commonly grown allochthonous species in the forests of Europe. Growth speed, adaptive power, favorable wood properties, as well as low sensibility to pests are the attributes that have contributed the most to the success and occurrence of Douglas-fir plantations in Europe. Introduction program of an exotic species includes testing of its provenances in new ecosystems and localities. In Serbia, testing of the genetic potentials of Douglas-fir, native to North America, has begun by seting up provenance trials on several locations. Afforestation with exotic tree species must be justified and it should fulfill the aims of the introduction. Therefore, it is neccessary to test all the traits of the introduced species to show the effects of ecological factors. The aim of this research was to determine the ecological adaptations of Douglas-fir in Serbia by studying its anatomic characteristics. In the paper, the influence of locality conditions on the diameter of resin canals in the needles of different Douglas-fir provenances was investigated on the sites where the provenance tests were set up. A two-way ANOVA was performed, by investigating the effects of site and provenance factors on the diameter of resin canals. Resin canals serve as an important diagnostic taxonomic characteristic in conifers, while resin itself has important physiological and protective role in conifers.*

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Key words: Douglas-fir, provenance, introduction, resin canals, Serbia

VARIJABILNOST PREČNIKA SMOLNIH KANALA U ČETINAMA RAZLIČITIH PROVENIJENCIJA DUGLAZIJE

Izvod: *U šumama Evrope najzastupljenija introdukovana vrsta četinara je duglazija. Veliki kapacitet produktivnosti i adaptivnosti, kao i kvalitet drveta i mali broj štetočina, prednosti su koje su doprinele da se ova vrsta uspešno primenjuje u šumskim kulturama Evrope. Program introdukcije egzotične vrste podrazumeva testiranje njenih različitih provenijencija u novim ekosistemima i lokalitetima. U Srbiji, program testiranja genetskog potencijala duglazije, poreklom iz Severne Amerike, započet je osnivanjem provenijeničnih testova na više lokacija. Koncept pošumljavanja sa egzotičnim vrstama drveća mora biti opravdan i da ispuni cilj introdukcije. Iz tog razloga, potrebno je testirati sve karakteristike introdukovane vrste, koje će prikazati uticaj ekoloških faktora. Cilj ovog istraživanja je da se utvrde ekološke adaptacije duglazije u Srbiji proučavanjem njenih anatomskih karakteristika. U radu su istraživani efekti stanišnih uslova lokaliteta, gde su osnovani provenijenični testovi duglazije u Srbiji, na prečnik smolnih kanala u četinama duglazije različitih provenijencija. Obavljena je dvofaktorijalna analiza varijanse, ispitivani su faktori lokaliteta i provenijencija, kao i njihov uticaj na prečnik smolnih kanala. Smolni kanali su važna taksonomska karakteristika četinara, dok sadržaj smole ima važnu fiziološku i zaštitnu ulogu u njima.*

Ključne reči: duglazija, provenijencije, introdukcija, smolni kanali, Srbija

1. INTRODUCTION

Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco, fam. Pinaceae] occurs in all ecosystems of Europe, providing with fast and high-quality wood production, landscape diversity, as well as lucrative materials for medicinal and industrial use. Its natural range of distribution is in the northern part of Canada and the Pacific coast, up to 3,000 m a. s. l. on Rocky Mts. Its wide geographical range in terms of latitude, longitude (from New Mexico to Vancouver) and altitude has produced a number of provenances.

In the publication "*Douglas-fir – an option for Europe*" (Spiecker *et al.*, 2019), the authors emphasise the fact that this species has highly adaptive genetic variability, and it is very suitable for introduction. The first seeds were introduced in Europe by David Douglas in 1827 and then planted at Dropmore Park (Buckinghamshire, UK), where there is a tree which is usually considered the oldest Douglas-fir of Europe (Da Ronch *et al.*, 2016; Elwes and Henry, 1969).

Douglas-fir is an up-and-coming, highly productive introduced species, not only in Europe but also in the world; hence, it was a subject of numerous studies and a topic of many scientific conferences (Chen *et al.*, 1986; Hermann and Lavender, 1987, 1990).

In Serbia, the study and the testing of Douglas-fir provenances from Canada and the United States of America has begun in 1978 at the Institute of Forestry, Belgrade, by setting up provenance trials on different sites (Lavadinović

and Koprivica, 1996, 1996a, 1999, 2000; Lavadinović and Isajev, 2005; Lavadinović, 2005; Lavadinović *et al.*, 2010, 2011, 2015, 2017, 2018).

Resin canals are a common, distinguishing feature in conifers (Fahn, 1979; Page, 1989). Resin canals are relatively large intercellular spaces surrounded by an epithelium of secretory parenchyma cells (Fahn, 1979) that occur in many organs of coniferophytes. In Pinaceae, they are found in xylem, bark, needles and seeds (Lin *et al.*, 1995; Farjon, 1998; Wu and Hu, 1997). In addition to pines, a number of other conifer species, including Douglas-fir, exhibit resin canals in their needles. Apart from the needles, the resin ducts are distributed in the cortex, primary xylem and secondary xylem of stems. In the needles, two lateral, abaxial ducts occur in the mesophyll (Wu and Hu, 1997). The two adaxial resin ducts of *Pseudotsuga menziesii* needles are located in direct contact with epidermis. They present a central midvein with variable diameter, surrounded by a thin endodermis. Each canal is sometimes partially surrounded by sclerenchyma fibers with lignified walls (Pădure *et al.*, 2008).

Resin canals exude a complex of secondary metabolites (resin or pitch) as a result of injury from wind, fire or attack by wood-boring insects. There are many commercial purposes for resin, including lacquers, varnishes and turpentine (Kramer and Kozlowski, 1979). The resin itself is an organic liquid containing terpenes, resin acids and other compounds. Needle resin serves as defense against insects and other animals, which confront the distasteful substance when boring into the conifer's leaves. Resin is antiseptic and aromatic and prevents the development of fungi and deters insects. The resins may disrupt the feeding, digestion or metabolic function of the attacker (https://www.hunker.com).

Resin canals also serve as an important diagnostic taxonomic characteristic in conifers (Lin *et al.*, 2000; Frankis, 1989). Specifically, the cross-sectional number of resin canals in conifer needles can be used to distinguish genetic variation among families and subspecies (Helmers, 1943; Keng and Little, 1962) and is thus commonly used as an index in forest breeding programs (Richardson, 1998., Lin *et al.*, 2001).

The aim of this research was to determine the ecological adaptations of Douglas-fir in Serbia by studying its anatomic characteristics. The influence of locality conditions on the diameter of resin canals in the needles of different Douglas-fir provenances was investigated on the sites where the provenance tests were set up.

2. MATERIAL AND METHODS

Provenance trial plantations in Serbia were established as a starting material for the provenance tests. The experimental plots on Mt. Juhor (near the city of Jagodina) and Tanda (near Bor) were set in order to begin with the testing program of introduced species.

The plantations were established using seedlings produced in the nursery of the Institute of Forestry, Belgrade. The seedlings were raised from seed which has been collected in one part of the native range of Douglas-fir’s distribution in North America. The origin of the provenances is shown in Table 1.

The experiment on Mt. Juhor was set on the site of mountain beech forest (*Fagetum moesiacae montanum* Jov. 1976) on acid brown soil (dystric cambisol) over gneiss. The "Tanda" sample plot is located in FMU "Stol" (FAS "Bor") on the site of Hungarian and Turkey oak forest (*Quercetum frainetto-cerris* Rud. 1949) on acid brown soil and sierozem (Lavadinović, 2009).

Table 1. *Geographical coordinates of the tested Douglas-fir provenances*

Provenance code	Mark	Latitude (ºN)	Longitude (ºE)	Altitude (m)
Oregon 205-15	1	43.7	123.0	750
Oregon 205-14	2	43.8	122.5	1200
Oregon 202-27	3	45.0	122.4	450
Oregon 205-38	4	45.0	121.0	600
Washington 204-07	9	49.0	119.0	1200
Oregon 205-13	10	43.8	122.5	1050
Oregon 205-18	11	44.2	122.2	600
Oregon 202-22	12	42.5	122.5	1200
Washington 202-17	15	47.6	121.7	600
Oregon 201-10	16	44.5	119.0	1350
Washington 201-06	17	49.0	120.0	750
Oregon 202-19	18	45.3	123.8	300
Oregon 205-11	20	45.0	123.0	150
New Mexico 202-04	22	32.9	105.7	2682
New Mexico 202-10	23	36.0	106.0	2667
Oregon 202-31	24	44.3	118.8	1500
Oregon 205-29	26	42.6	122.8	900
Oregon 205-08	27	42.7	122.5	1050
Oregon 204-04	30	45.0	121.5	300
Washington 205-17	31	47.7	123.0	300

Source: Lavadinović and Koprivica (1996)

For the purposes of the analysis of site influence on the variability of anatomical structure of Douglas-fir needles collected on both sites where the provenance tests were set, samples were taken only from selected provenances. The selection of provenances was based on previous research of the variability of mensurational parameters in Douglas-fir (Lavadinović, 2009). In each locality three groups of provenances were formed: 1 – the best, 2 – medium and 3 – the worst. The paper analyzes two provenances from each category – the best (18 and 31), medium (16 and 17) and the worst (9 and 24).

Fresh needles were fixed in 50% ethyl alcohol to make permanent anatomical cross-sections, which contained 30 randomly chosen needles. The median anatomical sections were cut to a thickness of 17 μm, using a microtome. After that, they were stained with Safranin red and Toluidine blue and washed with water. Ethyl-alcohol dehydration was then performed by increasing the concentration of alcohol from 50% to 96%. Post-fixation of the sections was performed with xylene, which required several hours to complete. Finally, the needles were glued to the cover glass using Canadian balsam, covered with the glass and dried in an oven at 60°C (Lavadinović *et al.*, 2017). Morpho-anatomic features were measured three weeks later. Taking into account the sample sizes of

the groups being compared, all the obtained numerical data were analyzed using the two-way ANOVA and LSD test.

3. RESULTS AND DISCUSSION

The results of the two-way analysis of variance (site x provenance) for the property diameter of the needle resin canals of Douglas-fir are given in Table 2. Based on the results presented, it can be concluded that there are:

a) statistically significant differences between the mean values of resin canal diameters in the needles collected on Mt. Juhor and Tanda sites;
b) statistically significant differences between the mean values of resin canal diameters in the needles of some provenances analyzed;
c) significant influence of the interaction of "site" and "provenance" factors on the mean values of resin canal diameters.

Table 2. *A two-way analysis of variance (site x provenance) for the property diameter of the needle resin canals of Douglas-fir*

Source of variation	Sum of squares	The degree of freedom	Variance	F-ratio	*p-value*
A: Site	13634.6	1	13634.6	87.16	0.000
B: Provenance	52465.9	5	10493.2	67.08	0.000
Interaction AB	42525.4	5	8505.08	54.37	0.000
Errors	54435.8	348	156.425		
Total	163062.0	359			

3.1. The effect of site on the diameter of resin canals

Based on to the results presented in Table 3, it can be concluded that there are statistically significant differences between the mean values of resin canal diameters of the needles collected on Mt. Juhor and Tanda. The mean resin canal diameter determined for the provenances at Tanda site (91.1 μm) is significantly greater than that determined for the needles collected on Mt. Juhor (78.79 μm). In addition, variability of the resin canal diameters of the analyzed provenances was detected on both sites, as shown in Graphs 1 and 2.

Table 3. *An LSD test of site influence on the diameter of resin canals*

Site	Sample size	Mean values	Standard error of the difference between the means	Homogeneous groups
Juhor	180	78.79	0.932216	X
Tanda	180	91.1	0.932216	X
Comparison			Differences	+/– Limit
Juhor–Tanda			*–12.3083	2.59295

*statistically significant difference

3.2. The effect of provenance on the diameter of resin canals

The LSD test was used to determine whether there is a relation between the genefond of the introduced provenances and the variability of resin canal diameter in the needles of Douglas-fir. The results are presented in Table 4.

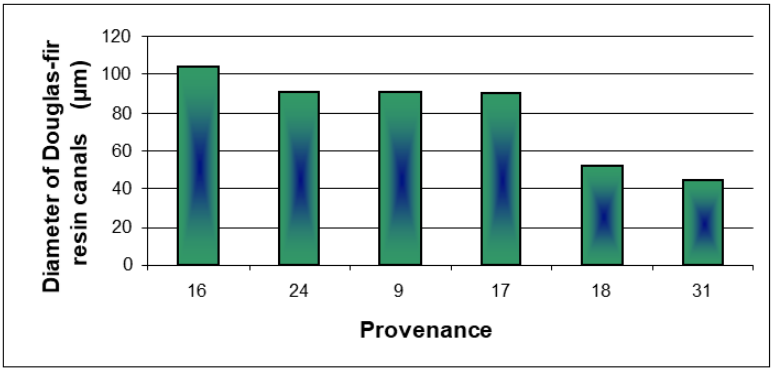
The results presented in Table 4 indicate that there are statistically significant differences between the resin canal diameters of Douglas-fir; however, the results of the LSD test show that some of the provenances analyzed (31, 18, 24, 16, 9 and 17) were homogeneous, i.e. the mean values of the resin canal diameters were not statistically significant for the same provenances.

Table 4. *An LSD test of provenance influence on the diameter of resin canals*

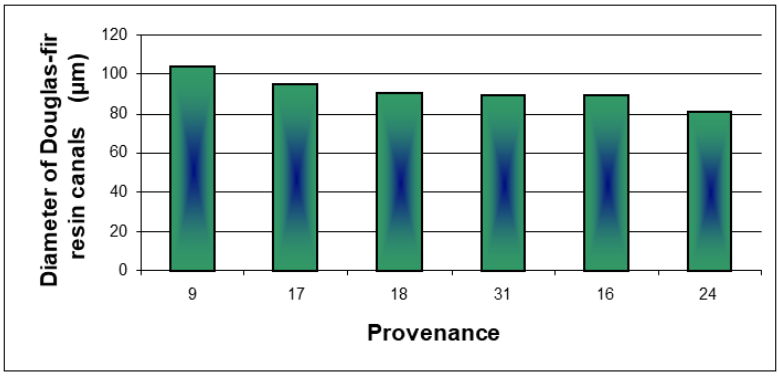
Provenance	Sample size	Mean values	Standard error of the difference between the means	Homogeneous groups
31	60	67.250	1.61465	X
18	60	70.925	1.61465	X
24	60	85.875	1.61465	X
16	60	89.625	1.61465	X
9	60	97.250	1.61465	X
17	60	98.750	1.61465	X

Comparison	Differences	+/– Limit
9–16	* 7.625	4.49111
9–17	–1.5	4.49111
9–18	* 26.325	4.49111
9–24	* 11.375	4.49111
9–31	* 30.0	4.49111
16–17	* –9.125	4.49111
16–18	* 18.7	4.49111
16–24	3.75	4.49111
16–31	* 22.375	4.49111
17–18	* 27.825	4.49111
17–24	* 12.875	4.49111
17–31	* 31.5	4.49111
18–24	*–14.95	4.49111
18–31	3.675	4.49111
24–31	* 18.625	4.49111

*statistically significant difference



Graph 1. *Variability of resin canal diameter between different provenances on Mt. Juhor*



Graph 2. *Variability of resin canal diameter between different provenances on Tanda site*

The results are comparable with those published by Pădure *et al.* (2008). In the study of the relationships of *Pseudotsuga menziesii* populations in Romania, several anatomical characters were found to be significant, including resin duct diameters in the needles. Resin ducts varied in diameter from 31,25 to 68,70 µm (Pădure *et al.*, 2008). Therefore, it can be concluded that allmost all provenances analyzed in our study (except for 31) had greater average resin duct diameters than those presented in the literature.

4. CONCLUSIONS

Douglas-fir is an introduced conifer species that should take a significant place in the ecosystems of Serbia. As it comes from a wide natural range of distribution, the proper provenance selection is a necessary step in the confirmation of its genetic potentials in new ecological conditions. The genetic control of its anatomical and morphological traits could be tested by provenance trials. In the context of genetic improvement programmes of introduced tree species, Institute of Forestry, Belgrade, has assessed different Douglas-fir provenances in Serbia.

In the present study, the hypothesis that there are significant differences between the mean values of resin canal diameters of the needles of Douglas-fir on different experimental plots in Serbia has been confirmed. In some provenances, it was determined that there are significant differences between the mean values of resin canal diameters and that the interaction of "site" and "provenance" factors has significant influence on the mean values.

The results of this study will contibute to better selection of suitable provenances for the introduction of Douglas-fir in Serbia. In addition, the strategy of the introduction of exotic tree species will contribute to better afforestation programs and will provide high-quality raw materials for the wood industry.

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VARIABILITY OF RESIN CANAL DIAMETER IN THE NEEDLES OF DIFFERENT DOUGLAS-FIR PROVENANCES

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Summary

Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco, fam. Pinaceae] occurs in all ecosystems of Europe, providing with fast and high-quality wood production, landscape diversity, as well as lucrative materials for medicinal and industrial use. Its natural range of distribution is in the northern part of Canada and the Pacific coast, up to 3,000 m a. s. l. on Rocky Mts. Its wide geographical range in terms of latitude and longitude (from New Mexico to Vancouver), as well as altitude, has produced a number of provenances.

The successful introduction of Douglas-fir depends on the selection of the most suitable provenances. In Serbia, two provenance trial plantations of the species has been established in order to test its adaptability to the climatic and environmental conditions of new habitats.

In this paper, the analysis of variability of resin canal diameter in the needles of different Douglas-fir provenances was conducted on two sites in Serbia. It was determined that there are significant differences between the mean values of resin canal diameters of some provenances and that the influence of the interaction of "site" and "provenance" factors on the mean values was also significant. Resin has a protective role in conifers.

The results of the present study will contribute to better selection of suitable provenances for the introduction of Douglas-fir in Serba.

VARIJABILNOST PREČNIKA SMOLNIH KANALA U ČETINAMA RAZLIČITIH PROVENIJENCIJA DUGLAZIJE

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Rezime

Duglazija [*Pseudotsuga menziesii* (Mirb.) Franco, fam. Pinaceae] je zastupljena u svim ekosistemima Evrope, obezbeđujući kvalitetan i brz prirast drvne mase, pejzažnu raznolikost, kao i unosan materijal za medicinsku i hemijsku industriju. Prirodno je rasprostranjena u severnom delu Kanade i priobalnom delu Pacifika, sve do 3000 m nadmorske visine Stenovitih planina. Ovako širok vertikalni i horizontalni areal (od Novog Meksika do Vankuvera) raspolaže velikim brojem provenijencija.

Za introdukciju duglazije potreban je pravilan izbor provenijencije. U Srbiji su postavljeni provenijenični ogledi s ciljem testiranja adaptivnosti ove vrste na klimatske i stanišne uslove novih lokaliteta.

U radu su izvedena istraživanja prečnika smolnih kanala u četinama duglazije različitih provenijencija na dva lokaliteta u Srbiji. Konstatovano je da postoje razlike u srednjim vrednostima prečnika smolnih kanala kod pojedinih provenijencija, kao i to da kod pojedinih provenijencija interakcija između faktora „lokalitet" i „provenijencija" utiče na srednju vrednost prečnika smolnih kanala. Uloga smole u četinarima je zaštitna.

Ovim istraživanjem će se doprineti većoj pouzdanosti pri izboru odgovarajućih provenijencija u programu introdukcije duglazije u Srbiji.

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ANALYSIS OF MORPHOLOGICAL QUALITY PARAMETERS OF ONE-YEAR OLD BARE ROOT SESSILE OAK (*Quercus petraea* (Matt.) Liebl) SEEDLINGS

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Abstract: *The paper analyzes the morphological quality parameters of one-year-old sessile oak (Quercus petraea (Matt.) Liebl) seedlings and their interrelations. Based on the performed analyzes, it was determined which of the measured morphological parameters, with minimal time and resources spent, gives the most accurate estimate of the quality of one-year old seedlings.*

For the conducted research, seedlings were produced in the nursery of the Institute of Forestry in Belgrade, in uniform environmental conditions from seed collected in seed stand RS-2-2-qpe-22-169. The seedlings were produced in the same nursery seedbed, and the sample for analysis was taken by dividing the seedbed into four sections and taking 30 seedlings from each section by random sampling. The following morphological parameters were measured: root collar diameter, height of seedlings, weight of above and underground part of seedling in absolutely dry condition and root volume. Based on the measured values, height ratios were calculated as follows: height:root collar diameter, weight of aboveground part of seedling: weight of underground part of seedling, and quality index.

The height of the seedlings and root collar diameter are good indicators of quality, which is confirmed by the positive correlative relationships with other measured morphological parameters. A stronger dependence has been found in the root collar diameter, especially with the quality index, so it can be recommended as a good indicator of the quality of the one-year old sessile oak seedlings. The quality index has been confirmed as the most comprehensive morphological indicator of the seedling quality.

Key words: sessile oak, seedlings, quality, morphological parameters.

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АНАЛИЗА МОРФОЛОШКИХ ПАРАМЕТАРА КВАЛИТЕТА ЈЕДНОГОДИШЊИХ САДНИЦА КИТЊАКА (*Quercus petraea* (Matt.) Liebl) СА ГОЛИМ КОРЕНОМ

Извод: *У раду су анализирани морфолошки параметри квалитета једногодишњих садница храста китњака (*Quercus petraea (Matt.) Liebl*) и њихови међусобни односи. На основу обављених анализа утврђено је који од мерених морфолошких параметара, уз минимално трошење времена и средстава даје најтачнију процену квалитета једногодишњих садница.*

За спроведена истраживања саднице су произведене у расаднику Института за шумарство у Београду, у уједначеним условима средине од семена сакупљеног у семенској састојини RS-2-2-qpe-22-169. Саднице су произведене у истој леји, а узорак за анализе је узет тако што је леја подељена на четири дела и из сваког дела је методом случајног узорка узето по 30 садница. Мерени су следећи морфолошки параметри: пречник у кореновом врату, висина садница, маса надземног и подземног дела садница у апсолутно сувом стању и запремина корена. На основу измерених вредности израчунати су односи висина:пречник у кореновом врату, маса надземног:маса подземног дела саднице и индекс квалитета.

Висина садница и пречник у кореновом врату су добри показатељи квалитета, што је потврђено позитивним корелативним везама са осталим мереним морфолошким параметрима. Јача зависност је утврђена код пречника у кореновом врату, нарочито са индексом квалитета, па се он може препоручити као добар показатељ квалитета једногодишњих садница китњака. Индекс квалитета се потврдио као најобухватнији морфолошки показатељ квалитета садница.

Кључне речи: китњак, саднице, квалитет, морфолошки параметри.

1. INTRODUCTION

The seedling quality in general has been object of researches for many years, and a finding of the most efficient and at the same time most cost-effective method is an essential element in the nursery production. The seedling quality is one of the main indicators of the afforestation success, since it can predict the field performance of the seedlings and their ability to survive under the different mechanical and environmental stress (Wilson and Jacobs, 2006). The primary objective of the seedling quality assessment is to quantify the levels of the morphological and physiological traits that result in an accurate assessment of the seedling status in terms of assessing the potential for future growth (Wilson and Jacobs, 2006).

According to the Serbian Law on Forest Reproductive Material ("Official Gazette of RS", no. 135/2004, 8/2005), seedlings of hardwood species produced must meet the quality criteria according to the current standard SRPS D.Z2.112:1968. The quality assessment is mostly based on the morphological parameters (Mohammed 1997; Saha et al., 2012) and rarely on the physiological ones (Wilson and Jacobs, 2006). The most frequently used characteristics are the height of the seedlings and the root collar diameter (Ivetić et al., 2017), primarily because of ease and efficiently measurement. The root collar diameter can be

considered as the best single parameter for predicting the success of the seedling performance in the field, as it is always positively correlated with survival, while the seedling height can have either positive or negative effect (Ivetić, 2013; Ivetić et al., 2017). Other seedling quality parameters such as mass and volume of the root are less commonly used because they are more destructive to seedlings and more complicated to perform. Ratios height:root collar diameter (HD), weight of aboveground part of seedling: weight of underground part of seedling (SR), and quality index (QI) are not used in the assessment of the seedling quality in the nursery production in Serbia (Ivetić et al., 2017).

The sessile oak forests cover 4.9% of the all forests of Serbia according to their species affiliation (Banković et al., 2008; Ratknic and Rakonjac, 2010). Sessile oak is one of the two most common species of oak in the nursery production of Serbia. Most common types of sessile oak (Quercus petraea (Matt.) Liebl) seedlings are bare root, 1+0, 2+0, 3+0 (Ivetić et al., 2017).

This study aims to determine which of the morphological parameters of the one-year-old sessile oak seedlings are most indicative to measure the most accurate quality assessment with minimal time and expense.

2. MATERIALS AND METHODS

For the conducted research seedlings were produced in the nursery of the Institute of Forestry in Belgrade, in uniform environmental conditions from seed collected in the seed stand RS-2-2-qpe-22-169. The seed sowing was carried out in April 2017 in a nursery seedbed (1x10 m). The row spacing was 15 cm, the rows were parallel to the longer side of the row. At the end of the growing season, in October, the seedbed was divided into four parts; per 30 seedlings were taken from each part by random sampling for analysis. The seedlings were carefully removed to minimize the root damage. The following morphological parameters were measured: root collar diameter, height of seedlings, weight of above and underground part of seedling in dry condition and root volume. Based on the measured values, the following ratios were calculated - height:root collar diameter (sturdiness quotient), weight of aboveground part of seedling: weight of underground part of seedling, and quality index.

The height of the seedlings was measured by a ruler with an accuracy of 0.1 cm and the root collar diameter by a digital nonius with an accuracy of 0.01 mm. For weight measurement purposes, the above-ground part was separated from the roots and separately dried in a Binder type oven at 105 ° C for 48 hours. The weight of the aboveground part and the weight of the root were measured on an electronic balance with an accuracy of 0,01 g. The core coefficient was calculated by Roller 1977 and the quality index by Dickson et al. 1960. The root volume was measured by the water extrusion method (Burdett, 1979).

The measured data were statistically processed in the Statistica 7 software package (StatSoft, Inc. 2004). For the measured morphological parameters, mean, standard deviation, minimum and maximum values were calculated. The interdependence of the measured parameters was determined by calculating a linear correlation coefficient, and the influence of the position of seedlings in the seedbed on

morphological parameters was examined using one-way analysis of variance (One-Way ANOVA).

3. RESULTS AND DISCUSSION

The mean value of the root collar diameter of the measured seedlings is 3.52 mm, with ranging from 2.09 to 5.48 mm. The average height of the seedlings is 14.8 cm, and the measured values range from 6.5 to 24 cm. The weight of the above-ground part of the seedlings ranges from 0.29 to 3.52 g with a mean value of 1.62 g. The root weight ranged from 0.52 to 7.59 g with a mean of 3.18 g. Higher weight of the aboveground part indicates the higher capacity of photosynthesis and growth potential, while the root system weight represents the potential for higher growth and survival percentage (Ivetić, 2013), but the weight measurement is destructive for the seedlings, which limits the wider application of this parameter.

The root volume ranges from 1 to 13 cm3, with the mean value of 4.8 cm3. The mean HD ratio is 4.24 and can be considered satisfactory for the one-year-old sessile oak seedlings. The ratio between the weight of the above-ground part and the root weight in the dry condition ranges from 0.11 to 2.25. The mean of this ratio is 0.72 (2:3). The seedling quality index has high variability and ranges from 0.21 to 2.86, with a mean of 1.25 (Table 1).

Table 1. *Descriptive statistics parameters of mean values for measured morphological parameters of one-year old sessile oak seedlings*

	Mean	**Minimum**	**Maximum**	**Std.Dev.**
D (mm)	3.52	2.09	5.48	0.74
H (cm)	14.8	6.5	24	4.35
SM (g)	1.62	0.29	3.52	1.21
RM (g)	3.18	0.52	7.59	3.61
RV (cm^3)	4.8	1	13	4.9
HD	4.24	1.24	6.37	0.98
SD	0.72	0.11	2.25	0.52
QI	1.25	0.21	2.86	0.61

Legend: D - Diameter, **H** - Average height, **SM** - Weight of the aboveground part, **RM** - Root weight, **RV** - Root volume, **HD** - Height: diameter ratio, **SD** - Weight ratio of the aboveground and underground parts, **QI** - Quality index.

Table 2. *Correlation coefficients between the examined quality indicators of one-year old sessile oak seedlings*

	D	**H**	**SM**	**RM**	**RV**	**HD**	**SR**	**QI**
D	1.00	0.52	0.44	0.51	0.56	-0.48	-0.21	**0.74**
H		1.00	0.39	0.57	0.48	0.22	-0.19	**0.71**
SM			1.00	0.65	0.71	0.09	0.11	0.62
RM				1.00	0.83	-0.19	-0.41	0.59
RV					1.00	-0.11	-0.32	0.56
HD						1.00	0.12	-0.35
SR							1.00	0.26
QI								1.00

Table 2 shows the correlation coefficients between the examined quality indicators of the one-year old sessile oak seedlings. The strongest correlation was found between the root collar diameter and the quality index (0.74). The height of

the seedlings is also strongly correlated with the quality index (0.71). The correlation coefficient between the root collar diameter and the height of the seedlings is 0.52. The quality index is in a strong, positive correlation with all measured parameters, except for the sturdiness quotient.

The mass of the above-ground part of the seedlings is in a positive, significant correlation with all observed parameters except the HD and SR ratios. The strongest correlation it has with the quality index (0.80) and the weakest with the diameter in the root neck (0.38) (Table 2).

In order to determine the influence of the position of seedlings in the nursery seedbed on the investigated morphological parameters, a one-way analysis of variance (One-Way ANOVA) was performed. The obtained results indicate the absence of the position influence on the observed parameters of the seedlings (Table 3).

Table 3. *Analysis of variance - influence of the position of seedlings in the nursery seedbed on the quality indicators of one-year old sessile oak seedlings*

	SS	**MS**	**F**	**p**
D	1.653	0.7124	0.5121	0.6231
H	13.21	5.251	0.2314	0.8322
SM	0.203	0.1154	0.1121	0.9129
RM	42.113	25.6214	1.1124	0.1257
RV	31.721	13.335	0.8116	0.4935
HD	2.703	1.116	0.5158	0.6423
SR	1.715	0.813	1.906	0.1501
QI	0.438	0.211	0.517	0.5820

The measured one-year old sessile oak seedlings according to the measurement data obtained are within the range of values prescribed by the standard for hardwood seedlings. Although the most commonly used quality indicators are seedling height and root collar diameter, the quality index has proven to be the most comprehensive morphological indicator of the seedling quality. The quality index in previous studies has been positively correlated with the growth and survival of seedlings in the field (Tsakaldimi et al. 2012; Ivetić et al. 2016; Popović et al. 2015; Popović et al. 2017). The quality index is very extensive and combines seedling biomass with the height and root collar diameter (Dickson et al., 1960), which may be an obstacle to the wider application of this parameter. HD ratio combined with individual values of height and root collar diameter contributes to the accuracy of predicting the success of seedling survival and growth in the field (Ivetić et al., 2016). The low HD ratio indicates a greater potential for seedlings to survive after exposure to transplant stress (Ivetić et al. 2016), although there are some conflicting results (Tsakaldimi et al. 2012; Devetaković et al. 2017).

4. CONCLUSION

Based on all the data analyzed, the height of the seedlings and the root collar diameter justify their wide application in the evaluation of the seedling quality. This is supported by the strong positive correlation of these two parameters with the quality index, which is the most comprehensive morphological indicator of the seedlings quality.

The obtained results need to be verified in future researches, both on the sessile oak and on other hardwood species, after which these results will be more significant. The first confirmation and verification of the results should be done after transplanting the seedlings in the field and investigating the success of their growth and survival.

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ANALYSIS OF MORPHOLOGICAL QUALITY PARAMETERS OF ONE-YEAR OLD BARE ROOT SESSILE OAK (*Quercus petraea* (Matt.) Liebl) SEEDLINGS

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Summary

Sessile oak is one of the two most common species of oak in nursery production of Serbia. According to the Serbian Law on Forest Reproductive Material, seedlings of hardwood species produced must meet the quality criteria according to the current standard SRPS D.Z2.112:1968 ("Official Gazette RS", no. 135/2004, 8/2005). The quality of the seedlings is largely an indicator of the success of afforestation (Wilson and Jacobs, 2006). This study aims to determine which of the morphological parameters of one-year-old sessile oak seedlings are the most indicative to measure the most accurate quality assessment with minimal time and expenses.

For the conducted research seedlings were produced in the nursery of the Institute of Forestry in Belgrade, in uniform environmental conditions from seed collected in seed

stand RS-2-2-qpe-22-169. The following morphological parameters were measured: root collar diameter, the height of seedlings, seedlings mass above and below ground in dry condition and root volume. Based on the measured values, ratios were calculated height:root collar diameter, mass above ground:mass of underground part of seedling and quality index. The sturdiness quotient was calculated by Roller 1977 and the quality index by Dickson et al. 1960. Root volume was measured by the water extrusion method (Burdett, 1979).

The measured data were statistically processed in Statistica 7 software package (StatSoft, Inc. 2004). For the measured morphological parameters, mean, standard deviation, minimum and maximum values were calculated. The interdependence of the measured parameters was determined by calculating a linear correlation coefficient, and the influence of the position of seedlings in the seedbed on morphological parameters was examined using one-way analysis of variance.

Measured one-year old sessile oak seedlings according to the measurement data obtained are within the range of values prescribed by the standard for hardwood seedlings. Although the most commonly used quality indicators are seedling height and root diameter, the quality index has proven to be the most comprehensive morphological indicator of seedling quality. The strongest correlation was found between the root collar diameter and the quality index (0.74). The quality index is in a strong, positive correlation with all measured parameters, except for the sturdiness quotient. A one-way analysis of variance results indicate the absence of position influence on seedlings observed parameters.

Based on all the data analyzed, the height of the seedlings and the root collar diameter justify their wide application in the evaluation of seedling quality. This is supported by the strong positive correlation of these two parameters with the quality index, which is the most comprehensive morphological indicator of seedlings quality.

АНАЛИЗА МОРФОЛОШКИХ ПАРАМЕТАРА КВАЛИТЕТА ЈЕДНОГОДИШЊИХ САДНИЦА КИТЊАКА (*Quercus petraea* (Matt.) Liebl) СА ГОЛИМ КОРЕНОМ

Vladan POPOVIĆ, Aleksandar LUČIĆ, Ljubinko RAKONJAC, Ivona KERKEZ JANKOVIĆ

Резиме

Храст китњак једна је од две најчешће врсте храста у расадничкој производњи Србије. Према Закону о шумском репродуктивном материјалу Републике Србије (“Sl. glasnik RS”, no. 135/2004, 8/2005), саднице лишћарских врста морају да испуњавају критеријуме квалитета према важећем стандарду SRPS D.Z2.112:1968. Квалитет садница у великој мери је показатељ успешности пошумљавања (Wilson and Jacobs, 2006). Циљ овог истраживања је да се утврде који од морфолошких параметара једногодишњих садница китњака су најиндикативнији за најтачнију процену квалитета уз минимално трошење времена и средстава.

За спроведена истраживања саднице су произведене у расаднику Института за шумарство у Београду, у уједначеним условима средине од семена сакупљеног у семенској састојини RS-2-2-qpe-22-169. Мерени су следећи морфолошки параметри: пречник у кореновом врату, висина садница, маса надземног и подземног дела садница у сувом стању и запремина корена. На основу измерених вредности израчунати су односи висина:пречник у кореновом врату, маса надземног:маса подземног дела саднице и индекс квалитета. Коефицијент једрине израчунат је по Roller 1977, а индекс квалитета по Dickson et al. 1960. Запремина корена је измерена методом истискивања воде (Burdett, 1979).

Мерени подаци су статистички обрађени у програмском пакету Statistica 7 (StatSoft, Inc. 2004). За истраживане морфолошке параметре израчунати су средња вредност, стандардна девијација, минималме и максималне вредности. Међузависност истраживаних параметара утврђена је рачунањем линеарног коефицијента корелације, а утицај положаја садница у леји на морфолошке параметре испитан је применом једнофакторијале анализе варијансе (One-Way ANOWA).

Мерене једногодишње саднице храста китњака према добијеним подацима мерења налазе се у опсегу вредности које су прописане стандардом за саднице тврдих лишћара. Иако су најчешће коришћени показатељи квалитета висина саднице и пречник кореновог врата, индекс квалитета се показао као најобухватнији морфолошки показатељ квалитета садница. Најјача корелација пронађена је између пречника кореновог врата и индекса квалитета (0,74). Индекс квалитета је у снажној, позитивној корелацији са свим измереним параметрима, осим са коефицијентом једрине. Једнофакторијална анализа варијансе указује на одсуство утицаја положаја садница на истраживане параметре.

На основу свих анализираних података, висине садница и пречник кореновог врата оправдавају своју широку примену у процени квалитета садница. У прилог томе иде и јака позитивна повезаност ова два параметра са индексом квалитета, који прдставља најобухватнији параметар кавлитета.

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FLORISTIC CHARACTERISTICS OF DRY PASTURES AND ROCKY GROUNDS THE SECOND YEAR AFTER THE WILDFIRE ON VIDLIČ MOUNTAIN

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Abstract: *In this paper, the influence of wildfire on dry pastures and rocky grounds the second year after the fire is followed. The results of field studies are presented in the form of phytocoenological table, by applying clustering techniques (WPGMA) and correspondence analysis (CA). Regrouping of the relevés, in comparison with the first year after fire, indicates that specific and more individual directions in vegetation succession have occurred. The situation remained unchanged, only for the rocky sites affected by the fire, at higher altitudes, in the zone of beech forests where the relevés were still standing separately on the graph, as in the previous season, indicating stability in floristic composition, probably caused by faster moving of the fire over the rocky substrate. The quantitative increase in the number of species and diversity index in comparison to the previous season was registered.*

Keywords: wildfire, dry pastures, rocky ground, diversity

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FLORISTIČKE KARAKTERISTIKE SUVIH PAŠNJAKA I KAMENJARA DRUGE GODINE POSLE POŽARA NA PLANINI VIDLIČ

Izvod: *U radu je prikazan uticaj požara na suve pašnjake i kamenjare na planini Vidlič druge godine posle požara. Rezultati terenskih istraživanja su prikazani u vidu fitocenološke tabele, primenom klaster analize (WPGMA) i korespondentne analize (CA). Pregrupisavanje fitocenoloških snimaka, u poređenju sa prvom godinom posle požara, ukazuje na specifične i individualne pravce u sukcesiji vegetacije. Situacija je ostala nepromenjena samo na stenovitim opožarenim površinama na većim nadmorskim visinama u zoni bukovih šuma, gde fitocenološki snimci i dalje stoje odvojeno na grafiku od ostalih kao i prethodne sezone, što ukazuje na stabilnost u florističkom sastavu, što je najverovatnije uzrokovano brzim prelaskom požara preko stenovite podloge. Zabeleženo je kvantitativno povećanje broja vrsta i indeksa diverziteta u odnosu na prethodnu sezonu.*

Ključne reči: požar, suvi pašnjaci, kamenjari, diverzitet

1. INTRODUCTION

Dry pastures and rocky grounds represent open habitats, specific in terms of their floristic composition and vegetation characteristics. In the southeastern Serbia they have been the subject of a number of studies (Jovanović-Dunjić, R., 1955, 1956; Diklić, N., 1962; Diklić, N., Nikolić, V., 1964). They belong to the alliance *Festucion valesiacae* Klika 1931 (class *Festuco-Brometea* Br.-Bl. et Tüxen ex Soó 1947) and alliance *Seslerion rigidae* Zoly. 1939 (class *Festuco-Seslerietea* Barbero et Bonin 1969) with a distinct steppe features which at the same time include certain floristic elements with Mediterranean and sub-Mediterranean distribution. The latter indicates the complexity of living conditions prevailing in these areas. Marković, M. *et al.* (2015) presented vegetation patterns of dry pastures and rocky grounds on the limestone terrain of Mt. Vidlič in the southeastern Serbia.

On the territory of the Natural Park "Stara Planina", a particularly high incidence of forest fires was recorded in July when about 3,000 ha of open space were affected by the wildfire (Živanović, S. *et al.*, 2019). The wildfire on Mt. Vidlič caught, among others, dry pastures and rocky ground on large areas of over 1,000 ha. Taking into consideration the openness of the habitat, the fire quickly swept across skeletal soil causing enormous damage to the xerophilic vegetation.

In the summer, the period of most frequent wildfires, the habitats of thermophilic meadows and rocky grounds are the driest. When a fire occurs, dry plants catch fire easily and their above ground parts burn very quickly. The fire does not last long on such habitat, because there are no mesophilic species to allow the fire to smolder. Because of the above, the fire, so to speak, passes over the substrate and the soil does not even catch fire or is affected by the fire to a small depth.

Our general hypothesis is that the effect of wildfires on plant communities and their diversity will be weaker if carbonate rocks are more pronounced and represent a larger part in the composition of the substrate. We assume that a well-developed rocky fraction, typical for limestone areas, plays an important role in the

fire which passed quickly over the substrate, and therefore the effect on change of vegetation is less pronounced. The soil is less affected and damaged by the fire. The underground organs and seeds in the soil will be better preserved. Some of the perennial plants or even the whole fragments of communities could survive among larger rocks in the area affected by the fire. (Marković, M. *et al*., 2018).

2. MATERIAL AND METHODS

The field research of the areas of dry pastures and rocky grounds affected by the fire on Mt. Vidlič were conducted in 2009. The plant material collected during the field research was deposited in the Herbarium of the Department of Biology and Ecology, Faculty of Sciences and Mathematics, University of Nis: Herbarium Moesiacum (HMN). The identification of the collected plant material was performed according to Josifović, M. (1970-1986) and Йорданов, Д. (1963-1995), and the nomenclature was adjusted in accordance with Flora Europaea (Tutin, T.G. *et al.*, 1964-1980, 1993).

The results of the phytocoenological studies of dry pastures and rocky grounds affected by the fire performed on the field using the method of Braun-Blanquet (1964) were presented in the form of phytocoenological table. Nine relevés were sampled.

The analysis of phytocoenological data was carried out using the classification method of Statistica 8.0 software package by applying clustering techniques (WPGMA) (StatSoft, 2007). This analysis uses combining abundance and cover of each species per relevé. Firstly, the combined values were transformed according to the numeric scale proposed by Westhoff, V., Van der Marrel, E. (1973). Alpha diversity of species in the community was determined using the software package of the "Flora" program (Karadžić, B., Marinković, S., 2009). Biodiversity indices were calculated according to Whitaker: the total number of species and Simpson's diversity index (Whitaker, R.H., 1972).

The results of the study of the floristic composition of dry pastures and rocky grounds the second year after the wildfire were compared with the already published results relating to the first year after the wildfire (Marković, M., Rakonjac, Lj., 2017). For the second year after the fire three relevés (**g**., **h.**, **i.**) were added compared to the previous season.

3. RESULTS AND DUSCISSIONS

Relevés of dry pastures and rocky grounds affected by the fire on Mt. Vidlič have been sampled at altitudes of 524 to1280 m, with exposures: S, E, SW and SE, terrain inclination 10 to 50°, and number of species from 33 to 73 (Table 1) and the value of Simpson's diversity index ranging from 0.965 to 0.986. In 9 relevés (**a.-i.**) 235 species and subspecies in total were recorded. Per individual relevé, 110 species and subspecies were recorded which indicates great diversity.

Annual plant species *Sideritis montana* that was dominant in the first year after the fire on semi-open habitats on sites **a.** and **d.** was replaced by plants from the grass family: *Festuca valesiaca, Dichanthium ischaemum, Melica ciliata, Chrysopogon gryllus.* The abundance and coverage of the annual plant species

Sideritis montana decreased, which was assumed to be related to its short reproductive cycle. The increase in the presence of plant species from the grass family indicates that the area affected by the fire gradually returns to its original state which existed prior to the wildfire. In other relevés, changes in the composition of dominant species are not so distinct. It should be emphasized that the number of woody species increased in both layers compared to the first year after the fire.

The stand on the site **b.** is located on the open habitat of rocky ground affected by the fire, in the zone of beech forests exposed to the east. The soil is shallow, brown, comprising limestone, eroded, permeated by geological substrate, of fine granulometric composition with larger rocks appearing to a lesser extent. This stand dominated by the species *Hieracium pilosella*, with its abundance and coverage remaining the same both the first and the second year after the fire (Table 1). The changes in floristic composition of this stand in the second year after the fire compared to the first year after the fire are insignificant, which, in our opinion, is related to its distance from closed communities under the beech forest. Hence, relevé **b.** has been sampled on open habitat, unlike relevé **a.**, which has been sampled on semi-open habitat. In addition, it is noted that the soil in the stand on site **b.** is shallower than on site **a.**, so the fire passed over the substrate faster and damaged the vegetation to a lesser extent. Due to the openness of the habitat and lesser depth of the soil substrate, the changes in the second year after the fire compared to the first year after the fire are less pronounced in the stand on site **b.**, than on site **a**.

Table 1. *Dry pastures and rocky grounds on Vidlič Mountain the second year after the wildfire (2009)*

Locality	V.Od.	Basarski kamik				Vučje				D
Altitude (m)	900	1100	1150	1220	1280	710	558	524	843	e
Exposure	S	E		S				SW	SE	g
Terrain inclination (°)	35		10	40	50	10	30	25	10	r
Relevé area (m^2)	100									e
Geological substrate	Limestone									e
Type of soil	Shallow skeletal rendzina									
General vegetation coverage (%)	60		80	60	50	60	70		60	o
Vegetation height (cm)	30				40	90	70		160	f
Date	13 June 2009	21 June 2009		23 July 2009		5 August 2009	6 June 2009			p
Relevé number	**a**	**b**	**c**	**h**	**i**	**d**	**e**	**f**	**g**	r
Floristic composition:										e.
Shrub layer:										
Crataegus monogyna Jacq.	+.1	.	+.1	+.1	.	+.1	+.1	+.1	+.1	IV
Rosa canina L.	.	+.1	.	+.1	+.1	.	+.1	+.1	1.1	IV
Ononis pusilla L.	+.1	.	.	.	.	+.1	.	+.1	+.1	III
Pyrus pyraster	+.1	.	.	.	.	.	+.1	.	+.1	II

Burgsd.										
Malus sylvestris Miller	.	+.1	.	+.1	.	.	.	.	.	II
Sorbus aria (L.) Crantz	.	.	.	+.1	+.1	.	.	.	.	II
Prunus spinosa L.	.	.	.	+.1	.	.	+.1	.	.	II
Carpinus orientalis Miller	.	.	.	+.1	.	.	.	.	+.1	II
Pinus sylvestris L.	.	+.1	.	.	.	.	.	.	.	I
Genista ovata Waldst. & Kit.	.	.	.	1.3	.	.	.	.	.	I
Cytisus procumbens (Waldst. & Kit. ex Willd.) Sprengel	.	.	.	+.2	.	.	.	.	.	I
Quercus cerris L.	.	.	.	+.1	.	.	.	.	.	I
Clematis vitalba L.	.	.	.	+.1	.	.	.	.	.	I
Rosa pimpinellifolia L.	.	.	.	.	1.1	.	.	.	.	I
Rosa glutinosa Sibth. & Sm.	.	.	.	.	1.1	.	.	.	.	I
Chamaecytisus ciliatus (Wahlenb.) Rothm.	.	.	.	.	+.2	.	.	.	.	I
Genista sericea Wulfen	.	.	.	.	+.2	.	.	.	.	I
Corylus avellana L.	.	.	.	.	+.1	.	.	.	.	I
Cotoneaster integerrimus Medicus	.	.	.	.	+.1	.	.	.	.	I
Populus tremula L.	.	.	.	.	+.1	.	.	.	.	I
Chamaecytisus jankae (Velen.) Rothm.	.	.	.	.	+.1	.	.	.	.	I
Ulmus glabra Hudson	.	.	.	.	.	.	.	+.1	.	I
Vinca herbacea Waldst. & Kit.	.	.	.	.	.	.	.	.	+.1	I
Cornus sanguinea L.	.	.	.	.	.	.	.	.	+.1	I
Acer monspessulanum L.	.	.	.	.	.	.	.	.	+.1	I
Syringa vulgaris L.	.	.	.	.	.	.	.	.	+.1	I
Herbaceous layer:										
Teucrium chamaedrys L.	1.1	+.1	2.2	+.1	1.1	1.1	+.2	1.3	1.1	V
Asperula cynanchica L.	+.1	+.1	1.1	+.1	+.1	+.1	1.1	+.1	.	V
Euphorbia cyparissias L.	1.1	+.1	+.1	+.1	+.1	+.1	.	+.1	1.1	V
Fragaria vesca L.	+.1	.	+.1	+.1	.	.	+.1	+.1	+.2	IV
Medicago sativa L. subsp. *falcata* (L.) Arcangeli	1.1	.	2.2	.	.	+.1	1.1	+.1	+.1	IV
Eryngium campestre L.	+.1	.	+.1	.	.	+.1	+.1	+.1	+.1	IV
Satureja kitaibelii Wierzb.	2.2	.	.	+.2	.	1.2	+.2	+.1	2.3	IV
Festuca valesiaca Schleicher ex Gaudin	2.3	.	.	.	+.2	+.2	+.2	3.4	+.2	IV
Asperula purpurea	.	1.1	1.1	1.1	.	.	2.2	+.1	+.1	IV

(L.) Ehrend.										
Carduus candicans Waldst. & Kit. subsp. *candicans*	+.1	+.1	.	+.1	.	+.1	.	.	+.1	III
Centaurea biebersteinii DC. subsp. *australis* (Pančić) Dostál	+.1	.	+.1	.	+.1	.	.	+.1	+.1	III
Sideritis montana L.	1.1	.	.	1.1	.	+.1	+.1	+.1	.	III
Teucrium montanum L.	+.2	.	.	.	+.2	+.2	+.2	+.2	.	III
Petrorhagia saxifraga (L.) Link	.	+.1	+.1	.	.	+.1	+.1	+.1	.	III
Arenaria serpyllifolia L. subsp. *serpyllifolia*	.	.	+.1	.	+.1	+.1	.	+.1	+.1	III
Leontodon hispidus L.	.	.	.	+.1	+.1	+.1	+.1	.	+.1	III
Linaria rubioides Vis. & Pančić subsp. *nissana* Niketić & Tomović	.	.	.	+.1	+.1	1.1	.	+.1	+.1	III
Hypericum perforatum L.	.	+.1	+.1	+.1	+.1	.	.	.	.	III
Leontodon crispus Vill.	.	+.1	.	.	+.1	+.1	.	+.1	.	III
Achillea millefolium L.	.	+.1	+.1	.	+.1	.	+.1	.	.	III
Chondrilla juncea L.	.	+.1	+.1	.	.	.	+.1	+.1	.	III
Sanguisorba minor Scop.	.	+.1	+.1	.	.	.	.	+.1	+.1	III
Anthyllis vulneraria L.	.	.	1.1	+.1	+.1	.	.	.	+.2	III
Achillea crithmifolia Waldst. & Kit.	.	.	+.1	+.1	.	.	+.1	.	+.1	III
Erysimum diffusum Ehrh.	.	.	.	+.1	+.1	.	+.1	+.1	.	III
Acinos arvensis (Lam.) Dandy	.	.	.	1.1	.	+.1	+.2	.	+.1	III
Geranium dissectum L.	.	.	.	+.1	.	.	+.1	+.1	+.1	III
Melica ciliata L.	.	.	.	.	+.1	2.3	+.1	.	+.1	III
Thymus glabrescens Willd.	.	.	.	.	+.2	.	+.2	1.3	1.3	III
Acinos alpinus (L.) Moench subsp. *majoranifolius* (Miller) P. W. Ball	2.2	.	+.1	.	.	.	.	+.1	.	II
Artemisia alba Turra	1.2	.	.	.	+.2	.	.	.	+.2	II
Potentilla cinerea Chaix ex Vill.	+.1	.	.	.	+.2	.	.	.	+.1	II
Sedum acre L.	+.1	.	.	.	.	+.1	.	+.1	.	II
Convolvulus cantabrica L.	+.1	.	.	.	.	+.1	.	.	+.1	II
Carex caryophyllea Latourr.	.	1.1	2.2	+.1	.	.	.	.	.	II
Hieracium pilosella L.	.	3.3	1.2	.	.	.	.	+.1	.	II
Potentilla argentea L.	.	+.1	+.1	.	.	.	.	+.1	.	II
Hieracium praealtum Vill. ex	.	+.1	+.1	.	.	.	.	+.1	.	II

Gochnat subsp. *bauhinii* (Besser) Petunnikov										
Minuartia verna (L.) Hiern	.	.	1.1	+.1	1.1	.	.	.	.	II
Trifolium campestre Schreber	.	.	+.1	.	.	+.1	+.1	.	.	II
Vincetoxicum hirundinaria Medicus	.	.	.	+.1	+.1	+.1	.	.	.	II
Medicago lupulina L.	.	.	.	+.1	+.1	.	+.1	.	.	II
Allium flavum L.	.	.	.	+.1	+.1	.	+.1	.	.	II
Sedum album L.	.	.	.	+.2	+.1	.	.	+.1	.	II
Galium album Miller	.	.	.	+.1	.	+.1	+.1	.	.	II
Digitalis lanata Ehrh.	.	.	.	+.1	.	.	+.1	.	+.1	II
Cleistogenes serotina (L.) Keng	.	.	.	.	+.1	+.1	+.1	.	.	II
Stipa capillata L.	.	.	.	.	.	+.1	2.2	2.2	.	II
Hypericum rumeliacum Boiss.	.	.	.	.	.	+.1	.	+.1	+.1	II
Potentilla recta L.	+.1	.	.	+.1	.	.	.	.	.	II
Orlaya grandiflora (L.) Hoffm.	+.1	.	.	.	.	+.1	.	.	.	II
Logfia minima (Sm.) Dumort.	+.1	.	.	.	.	.	.	+.1	.	II
Verbascum phlomoides L.	+.1	.	.	.	.	.	.	+.1	.	II
Scleranthus perennis L. subsp. *Perennis*	+.1	.	.	.	.	.	.	.	+.1	II
Tragopogon pterodes Pančić ex Petrović	+.1	.	.	.	.	.	.	.	+.1	II
Anthoxanthum odoratum L.	.	+.2	1.1	.	.	.	.	.	.	II
Rumex acetosella L.	.	+.1	+.1	.	.	.	.	.	.	II
Aira elegantissima Schur	.	+.1	+.1	.	.	.	.	.	.	II
Vulpia myuros (L.) C. C. Gmelin	.	+.1	+.1	.	.	.	.	.	.	II
Carlina acaulis L.	.	+.1	.	.	+.1	.	.	.	.	II
Brachypodium pinnatum (L.) Beauv.	.	+.2	.	.	+.3	.	.	.	.	II
Plantago lanceolata L.	.	.	+.1	.	.	.	.	+.1	.	II
Sesleria rigida Heuffel ex Reichenb.	.	.	.	+.2	2.3	.	.	.	.	II
Jovibarba heuffelii (Schott) Á. & D. Löve	.	.	.	+.1	+.2	.	.	.	.	II
Campanula rotundifolia (Desf.) Boiss. & Reuter	.	.	.	+.1	+.2	.	.	.	.	II
Campanula trichocalycina Ten.	.	.	.	+.1	+.1	.	.	.	.	II
Seseli rigidum Waldst. & Kit.	.	.	.	+.1	+.1	.	.	.	.	II
Arabis recta Vill.	.	.	.	+.1	+.1	.	.	.	.	II
Trifolium alpestre L.	.	.	.	+.1	+.1	.	.	.	.	II

Cerastium banaticum (Rochel) Heuffel	.	.	.	+.1	+.1	.	.	.	.	II
Scabiosa argentea L.	.	.	.	+.1	+.1	.	.	.	.	II
Trifolium montanum L.	.	.	.	+.1	1.1	.	.	.	.	II
Rhinanthus alectorolophus (Scop.) Pollich	.	.	.	+.1	+.1	.	.	.	.	II
Hieracium gymnocephalum Griseb. ex Pant.	.	.	.	+.1	+.1	.	.	.	.	II
Dianthus petraeus Waldst. & Kit.	.	.	.	+.1	+.1	.	.	.	.	II
Euphorbia seguierana Necker subsp. *niciciana* (Borbás ex Novák) Rech.	.	.	.	+.1	.	.	+.2	.	.	II
Onobrychis alba (Waldst. & Kit.) Desv.	.	.	.	+.1	.	.	.	.	+.1	II
Hyacinthella leucophaea (C. Koch) Schur	.	.	.	+.1	.	.	.	.	+.1	II
Muscari neglectum Guss. ex Ten.	.	.	.	+.1	.	.	.	.	+.1	II
Agropyron cristatum (L.) Gaertner	.	.	.	.	+.1	+.1	.	.	.	II
Helianthemum nummularium (L.) Miller	.	.	.	.	1.1	.	+.1	.	.	II
Linaria genistifolia subsp. *sofiana* (Velen.) Chater & D.A. Webb	.	.	.	.	+.1	.	+.1	.	.	II
Ptilostemon afer (Jacq.) W. Greuter	.	.	.	.	+.1	.	+.1	.	.	II
Trifolium badium Schreber	.	.	.	.	+.1	.	.	+.1	.	II
Dichanthium ischaemum (L.) Roberty	.	.	.	.	.	3.3	1.2	.	.	II
Allium moschatum L.	.	.	.	.	.	+.1	+.1	.	.	II
Bromus squarrosus L.	.	.	.	.	.	+.1	+.1	.	.	II
Koeleria nitidula Velen.	.	.	.	.	.	+.2	.	.	1.1	II
Althaea hirsuta L.	.	.	.	.	.	+.1	.	.	+.2	II
Cuscuta europaea L.	.	.	.	.	.	+.1	.	.	1.2	II
Carlina vulgaris L.	.	.	.	.	.	.	+.1	+.1	.	II
Xeranthemum annuum L.	.	.	.	.	.	.	+.1	+.1	.	II
Poa compressa L.	.	.	.	.	.	.	+.1	+.1	.	II
Poa pratensis L.	.	.	.	.	.	.	+.1	+.1	.	II
Linaria vulgaris Miller	.	.	.	.	.	.	.	+.1	+.1	II
Agrostis capillaris L.	.	.	.	.	.	.	.	+.1	+.1	II
Alyssum alyssoides (L.) L.	.	.	.	.	.	.	.	+.1	+.1	II

Astragalus onobrychis L.	.	.	.	.	.	.	.	+.2	+.1	II
Thymus striatus Vahl	.	+.2	.	.	.	.	.	.	.	I
Danthonia decumbens (L.) DC.	.	+.2	.	.	.	.	.	.	.	I
Koeleria splendens C. Presl	.	.	1.2	.	.	.	.	.	.	I
Trifolium arvense L.	.	.	1.1	.	.	.	.	.	.	I
Stachys recta L.	.	.	.	2.2	.	.	.	.	.	I
Sesleria argentea (Savi) Savi	.	.	.	1.3	.	.	.	.	.	I
Thalictrum aquilegiifolium L.	.	.	.	.	+.3	.	.	.	.	I
Micromeria cristata (Hampe) Griseb.	.	.	.	.	+.2	.	.	.	.	I
Cerastium decalvans Schlosser & Vuk.	.	.	.	.	+.2	.	.	.	.	I
Chrysopogon gryllus (L.) Trin.	.	.	.	.	.	1.3	.	.	.	I
Carex humilis Leysser	.	.	.	.	.	+.2	.	.	.	I
Calamintha nepeta (L.) Savi	.	.	.	.	.	.	2.3	.	.	I
Medicago minima (L.) Bartal.	.	.	.	.	.	.	2.2	.	.	I
Centaurea calcitrapa L.	.	.	.	.	.	.	1.1	.	.	I
Galium mollugo L.	.	.	.	.	.	.	.	2.2	.	I
Festuca panciciana (Hackel) K. Richter	.	.	.	.	.	.	.	+.2	.	I
Thymus pulegioides L.	.	.	.	.	.	.	.	.	+.2	I

Legend: V. Od. – Visočki Odorovci, Degree of pre. – Degree of presence

Only in one relevé with the value of +.1 the following species were recorded:

Relevé a: *Bromus erectus* Hudson, *Thymus pannonicus* All., *Allium scorodoprasum* L. subsp. *rotundum* (L.) Stearn, *Ornithogalum pyramidale* L., *Petrorhagia illyrica* (Ard.) P. W. Ball & Heywood, *Thlaspi perfoliatum* L., *Paeonia tenuifolia* L., *Globularia punctata* Lapeyr., *Linum bienne* Miller, *Fragaria viridis* Duchesne, *Stachys germanica* L.;

Relevé b: *Euphrasia pectinata* Ten., *Thymus alpestris* Tausch ex A. Kerner, *Luzula campestris* (L.) DC., *Lotus corniculatus* L., *Crepis sancta* (L.) Babcock, *Scabiosa ochroleuca* L., *Dactylorhiza sambucina* (L.) Soó;

Relevé c: *Rhinanthus rumelicus* Velen., *Vicia sativa* L. subsp. *nigra* (L.) Ehrh., *Euphrasia salisburgensis* Funck, *Briza media* L., *Scabiosa columbaria* L. subsp. *columbaria*;

Relevé d: *Bupleurum praealtum* L., *Lactuca saligna* L., *Viola odorata* L., *Helleborus odorus* Waldst. & Kit., *Campanula glomerata* L., *Cerastium brachypetalum* Pers., *Thymus longicaulis* C. Presl, *Helianthemum ledifolium* (L.) Miller, *Helianthemum salicifolium* (L.) Miller, *Lactuca viminea* (L.) J. & C. Presl, *Allium sphaerocephalon* L.;

Relevé e: *Cichorium intybus* L., *Onobrychis arenaria* (Kit.) DC., *Arabis sagittata* (Bertol.) DC., *Trifolium striatum* L., *Sedum urvillei* DC., *Lens nigricans* (Bieb.) Godron,

Scrophularia canina L., *Cuscuta epithymum* (L.) L., *Picris hieracioides* L., *Carduus acanthoides* L., *Myosotis arvensis* (L.) Hill;

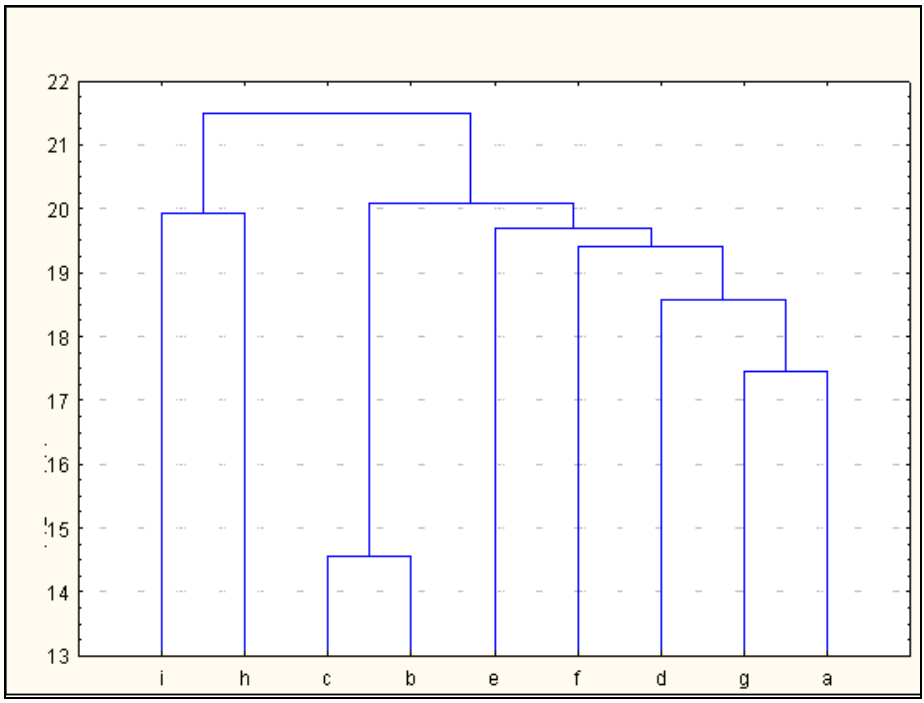
Relevé f: *Scandix australis* L., *Lathyrus nissolia* L., *Trifolium scabrum* L., *Achillea clypeolata* Sibth. & Sm., *Coronilla scorpioides* (L.) Koch, *Thesium arvense* Horvatovszky, *Erodium cicutarium* (L.) L'Hér., *Cerastium semidecandrum* L., *Torilis leptophylla* (L.) Reichenb., *Allium paniculatum* L.;

Relevé g: *Ajuga chamaepitys* (L.) Schreber subsp. *chia* (Schreber) Arcangeli, *Viola kitaibeliana* Schultes, Stipa pulcherrima C. Koch, *Linum tenuifolium* L., *Crupina vulgaris* Cass., *Aethionema saxatile* (L.) R. Br., *Euphorbia falcata* L., *Lathyrus cicera* L., *Thesium divaricatum* Jan ex Mert. & Koch, *Alopecurus pratensis* L., *Alyssum minus* (L.) Rothm.;

Relevé h: *Salvia nemorosa* L., *Silene bupleuroides* L., *Arabis hirsuta* (L.) Scop., *Fagus moesiaca* (K. Malý) Czech., *Torilis japonica* (Houtt.) DC., *Verbascum vandasii* (Rohlena) Rohlena, *Verbascum thapsus* L., *Campanula sparsa* Friv. subsp. *sphaerothrix* (Griseb.) Hayek, *Astragalus depressus* L., *Scilla bifolia* L., *Malcolmia orsiniana* (Ten.) Ten. subsp. *angulifolia* (Boiss. & Orph.) A. L. Stork;

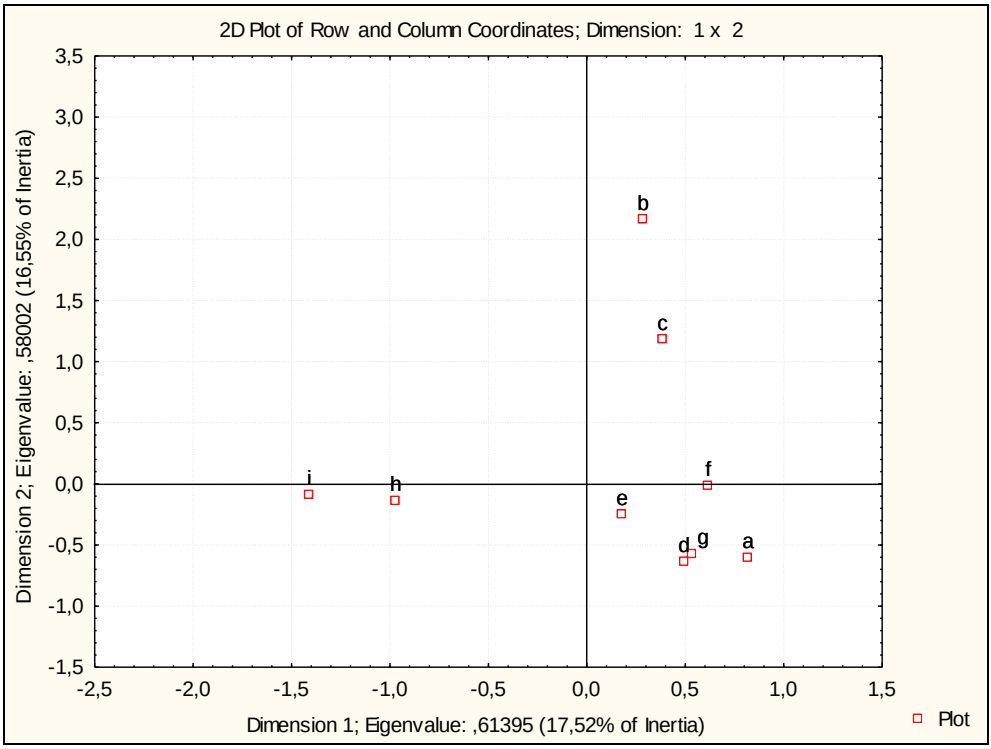
Relevé i: *Poa nemoralis* L., *Veronica spicata* L. subsp. *orchidea* (Crantz) Hayek, *Geranium robertianum* L., *Achillea serbica* Nyman, *Seseli libanotis* (L.) Koch, *Campanula bononiensis* L., *Euphrasia illyrica* Wettst., *Saxifraga paniculata* Miller, *Ferulago sylvatica* (Besser) Reichenb., *Geranium macrorrhizum* L., *Lamium garganicum* L., *Veratrum nigrum* L., *Viola mirabilis* L., *Primula veris* L., *Veronica austriaca* L. subsp. *austriaca*, *Draba lasiocarpa* Rochel.

On the dendrogram of vegetation of fire affected dry pastures and rocky grounds of Mt. Vidlič in the second year after the wildfire (2009) (Graph 1) separation of relevés by floristic similarity may be observed. Relevés **a.** and **g.** are on the same branch, and relevés **d.** and **f.** are similar, but separated specially and placed on implanted branches. Relevé **e.**, which was on the same branch with relevé **f.** in the previous year, is now singled out on separate branch. This means that there is a change compared to the previous year. Regrouping of relevés indicates that the directions of succession are specific and individual. The situation remains unchanged only on fire affected rocky areas on higher altitudes in the zone of beech forests, where relevés **b.** and **c.** still stand separated from others on the graph, as well as in the previous season, which indicates stability in floristic composition. The latter is most probably caused by quick passing of the fire over the rocky substrate.



Graph 1. Cluster *analysis of the vegetation of dry pastures and rocky grounds affected by the wildfire the second year after the fire*

Based on the correspondence analysis (CA) it can be observed that relevés **a., d., e., f.** and **g.** situated in the zone of oak forests and scrubs of hornbeam and at the altitude of up to 900 m are more closely grouped (Graph 2) unlike relevés **b.** and **c.**, and especially **h.** and **i**. The latter four relevés are sampled in the zone of beech forest on Basarski kamik. According to their close spatial position they should be similar at this stage of succession. However, they are separated on the graph due to different exposure, although all other aspects of their habitats are similar. (Table 1, 2). Namely, the stands on sites **b.** and **c.** are exposed to the east (E), while **h.** and **i.** are exposed to the south (S), which probably affects their floristic composition. Therefore, except the altitude, other orographic factors (exposure and terrain inclination) are also included when separating communities into groups.



Graph 2. *Correspondence analisys of vegetation formed on fire affected dry pastures and rocky grounds the second year after the wildfire*

In Table 2 alpha diversity of fire affected dry pastures and rocky grounds of Mt. Vidlič in the second year after the fire s presented. Except in the first relevé, compared to the previous season (2008) an increase in the number of species and diversity index is recorded (Marković, M., Rakonjac, Lj., 2017). In the second year after the fire the average value of the number of species on fire affected dry pastures and rocky grounds of Mt. Vidlič (51.67) is recorded compared to the previous season (41.17). The average value of diversity index (0.9769) increased accordingly compared to the previous season (0.9707). The increase in number of species occurred due to immigration of species from adjacent areas not affected by the fire.

Table 2. *Dry pastures and rocky grounds on Vidlič Mountain the second year after the wildfire (2009)*

Relevé	Altitude (m)	Exposure	Terrain inclination (°)	Number of species	Diversity index
a	900	S	35	38	0.97
b	1100	E	35	33	0.965
c	1150	E	10	36	0.969
d	710	S	10	48	0.976
e	558	S	30	56	0.98
f	524	SW	25	57	0.98
g	843	SE	10	59	0.982
h	1220	S	40	65	0.984
i	1280	S	50	73	0.986

4. CONCLUSION

On the fire affected dry pastures and rocky grounds in the second year after the wildfire on Mt. Vidlič on a number of sites the dominant species are the ones from the family of grasses: *Dichanthium ischaemum, Melica ciliata, Chrysopogon gryllus*. Statistical analyses (Cluster analysis-WPGMA and correspondence analysis-CA) showed that the situation remained unchanged only on fire affected rocky areas on higher altitudes in the zone of beech forests, which indicates stability in floristic composition. The latter is most probably caused by quick moving of fire over the rocky substrate. However, on lower altitudes, in the zone of oak forests and scrubs of hornbeam, regrouping occurred on the graphs which indicates significant changes compared to the previous season. Namely, *Therophyta* species *Sideritis montana*, which was dominant in the first year after fire, was replaced by plants from the family of grasses in the studied stands in the second year after the fire. Due to immigration of species from adjacent areas undamaged by the fire, the average value of the number of species and diversity increased compared to the previous season.

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FLORISTIC CHARACTERISTICS OF DRY PASTURES AND ROCKY GROUNDS THE SECOND YEAR AFTER THE WILDFIRE ON VIDLIČ MOUNTAIN

Ljubinko RAKONJAC, Marija MARKOVIĆ, Biljana NIKOLIĆ, Aleksandar LUČIĆ

Summary

The second year after the wildfire on Vidlič Mountain was characterized by an increasing number of perennial plants, giving the advance to grass species. From the dendrogram of vegetation similarity two years later diversification among plots according to their floristic composition can be observed. Relevés **a.** and **g.** are placed at the same branch, while **f.** and **d.** are separated. Relevé **e.**, which was previousely on the same branch with **f.**, was later separated on special branch. Regrouping of the relevés indicated that specific and more individual directions in succession have occurred. The situation remained unchanged only for the rocky sites affected by fire, at higher altitudes (**b.** and **c.**), still

standing separately as in previous season, indicating stability in floristic composition, probably caused by less severe fire impact. Based on CA-analysis, the samples that belong to the oak forest belt (**a**., **d.-g.**), are more closely grouped in contrast to plots **b.** and **c.**, and especially **h.** and **i.**, that show rather unexpected position in the graph. According to their close spatial position, they should be more similar at this stage of succession. Otherwise, they became distinct as a reaction on specific exposure, since all of the other aspects of their habitats are similar. Namely, plots **b.** and **c.** were exposed to the east, while **h.** and **i.** were exposed to the south, which probably influenced their floristic composition. However, excluding altitude, some other orographic variables (e.g. exposure and terrain inclination) were also involved as valuable, in communities diferentiation toward later stages of succession.

The presence of limestone rocks in the soil directly improved vegetation survival and post-fire recovery. Well represented rocky fraction, typical for the limestone areas, could play an important role in the following phenomena: the fire was moving faster, and therefore, its impact could be less severe; the soil layer could be only shallowly affected; the seed bank in the ground was better preserved; some of the more durable plant forms, or even the whole community fragments, could survive in sheltered places between the larger rocks of the fire impacted area.

The quantitative increase in the number of species, richness and Simpson's index was registered in comparison to the previous values. The increase in species richness reflects more intense process of species immigration from surounding preserved vegetation toward burned plots. Hence, during the second year, diversity of fire affected xeric vegetation on the mountain was improved and more stable in most of the cases.

FLORISTIČKE KARAKTERISTIKE SUVIH PAŠNJAKA I KAMENJARA DRUGE GODINE POSLE POŽARA NA PLANINI VIDLIČ

Ljubinko RAKONJAC, Marija MARKOVIĆ, Biljana NIKOLIĆ, Aleksandar LUČIĆ

Rezime

Druga godina posle požara na planini Vidlič je karakteristična po povećanju broja višegodišnjih vrsta, pogotovo biljaka iz porodice trava. Iz dendrograma vegetacije druge godine posle požara može se uočiti razdvajanje fitocenoloških snimaka prema floističkoj sličnosti. Snimci **a**. i **g**. su grupisani na istoj grani, dok su snimci **f.** i **d.** razdvojeni. Fitocenološki snimak **e.** koji je prethodne godine bio na istoj grani sa fitocenološkim snimkom **f.** sada se izdvaja na posebnoj grani. Pregrupisavanje fitocenoloških snimaka ukazuje da na to da je došlo do specifičnih i individualnih pravaca u sukcesiji. Situacija je ostala nepromenjena samo na stenovitim opožarenim površinama na većim nadmorskim visinama (**b.** i **c.**), koji i dalje stoje odvojeno na grafikonu od ostalih, kao i prethodne sezone, što ukazuje na stabilnost u floističkom sastavu, što je najverovatnije uzrokovano brzim prelaskom požara preko stenovite podloge. Na osnovu CA-analize vidimo da su grupisani zajedno fitocenološki snimci, koji se nalaze u zoni hrastovih šuma (**a**., **d.-g.**), dok se posebno izdvajaju fitocenološki snimci **b.** i **c.**, a posebno **h.** i **i.** koji pokazuju neočekivanu poziciju na grafikonu. Prema njihovom bliskom prostornom položaju, oni bi u ovoj fazi sukcesije trebali biti sličniji. Međutim, došlo je do njihovog razdvajanja zbog različitih ekspozicija, jer su svi ostali aspekti njihovih staništa slični. Naime, fitocenološki snimci **b.** i **c.** su uzimani na istočnoj ekspoziciji, dok su fitocenološki snimci **h.** i **i.** uzimani na južnoj ekspoziciji, što je imalo uticaja na njihov floristički sastav. Dakle, osim

nadmorske visine i druge orografske karakteristike (ekspozicija i nagib terena) takođe učestvuju u diferencijaciji zajednica idući prema kasnijim fazama sukcesije.

Prisustvo krečnjačkih stena u tlu direktno je uticalo na preživljavanje vegetacije i oporavak nakon požara. Dobro zastupljena kamenita frakcija, tipična za krečnjačke površine, ima značajnu ulogu u: požaru koji je brzo prešao preko podloge, pa je stoga uticaj na promenu vegetacije manje izražen; zemljište je manje zahvaćeno i oštećeno požarom; semena u tlu će biti bolje sačuvana; neke od višegodišnjih biljaka ili čak čitavi fragmenti zajednica mogu da prežive između većih stena u oblast zahvaćenoj požarom.

Zabeleženo je kvantitativno povećanje broja vrsta i Simpsonovog indeksa diverziteta u poređenju sa prethodnom sezonom. Povećanje bogatstva vrsta odražava intenzivniji proces imigracije vrsta sa susednih neopožarenih površina. Dakle, druge godine posle požara, kserofilna vegetacija na planini pokazuje veći diverzitet i stabilizaciju florističkog sastava u većini sastojina.

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TESTING OF SOIL DISTRIBUTION, VIABILITY, AND INFECTIVITY OF AZYGOSPORES OF THE ENTOMOPATHOGENIC FUNGUS *Entomophaga maimaiga*

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Abstract: *Entomophaga maimaiga is one of the best-known gypsy moth pathogens with increasing importance in the biological control aimed at reducing the population of this defoliator. The territory of the Republic of Serbia is a very favorable gypsy moth habitat, and the problems caused by its larvae during the periods of outbreaks are so great that they can lead to forest defoliation and forest health deterioration.*

In the Republic of Serbia, E. maimaiga was first recorded in 2011 (as a new species in the microflora of Serbia) during the gypsy moth outbreak (2009-2014), which was the last to date. In 2011, numerous dead caterpillars were found on and around trees in oak and beech stands of the Belgrade and Valjevo regions in Serbia. Subsequent laboratory analyses revealed that they contained azygospores and conidia of this fungus. The assisted introduction of E. maimaiga was carried out in Compartments 28 and 30 of the FMU Avala on Mt. Avala in 2011. It led to an epizootic in the following year and stopped the outbreak of the gypsy moth in the area.

Since it has been seven years since the outbreak, we tested the viability and infectivity of E. maimaiga azygospores obtained from the soil samples from Avala Mountain where its assisted introduction was carried out. We used larvae from the laboratory gypsy moth population and applied the bioassay method. The results show that azygospores are present in the given soil samples, they are viable and their infectivity is conserved. It can be concluded that in the case of an outbreak of gypsy moth populations in the future, they will exhibit their entomopathogenic effect.

Keywords*:* Avala, soil, *Entomophaga maimaiga*, azygospores, infectivity

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ISPITIVANJE PRISUSTVA U ZEMLJIŠTU, VIJABILNOSTI I INFEKTIVNOG POTENCIJALA AZIGOSPORA ENTOMOPATOGENE GLJIVE *Entomophaga maimaiga*

Izvod: *Entomophaga maimaiga je jedan od najpoznatijih patogena gubara i zauzima sve veći značaj u biološkim merama borbe, koje imaju za cilj smanjenje brojnosti populacija ovog defolijatora. Teritorija Republike Srbije je veoma povoljno stanište za gubara, te su i problemi koje njegove larve izazivaju u periodima gradacije veliki, dovodeći do golobrsta i slabljenja zdravstvenog stanja šuma.*

U Republici Srbiji E. maimaiga je prvi put uočena 2011. godine (nova vrsta u mikoflori Srbije), kada je bila u toku gradacija gubara (2009-2014), poslednja do danas. U Srbiji, u hrastovim i bukovim sastojinama u regionu Beograda i Valjeva, 2011. godine nađene su brojne mrtve gusenice gubara na stablima i oko njh, za koje se kasnije, laboratorijskim analizama, utvrdilo da sadrže azigospore i konidije ove gljive. Potpomognuta introdukcija E. maimaiga vršena je 2011. godine na planini Avala, u Gazdinskoj jedinici Avala, odeljenjima 28 i 30, i već naredne je uzrokovala epizootiju, te dovela do sloma gradacije gubara na tom prostoru.

S obzirom da je od tada prošlo 7 godina, metodom bioeseja ispitivali smo vijabilnost i infektivni potencijal azigospora E. maimaiga iz uzoraka zemljišta sa planine Avala, gde je vršena njena potpomognuta introdukcija, na larvama iz laboratorijske populacije gubara. Rezultati su pokazali da su azigospore prisutne u datim uzorcima zemljišta, kao i da su vijabilne i da je njihov infektivni potencijal očuvan, te se može zaključiti da će u slučaju naredne gradacije populacija gubara, one ispoljiti entomopatogeni efekat.

Ključne reči: Avala, zemljište, *Entomophaga maimaiga*, azigospore, infektivni potencijal

1. INTRODUCTION

Entomophaga maimaiga Hamber, Shimauzu & Soper (Entomophtorales: Entomophtoraceae) is a natural, obligate pathogen of the best-known forest pest – gypsy moth *Lymantria dispar* L. (Lepidoptera: Erebidae). Gypsy moth is a significant defoliator of deciduous forests in the temperate zone of the northern hemisphere. Its populations are characterized by a cyclical occurrence, with alternating periods of latency and outbreak. The damage caused to forests by gypsy moth larvae in outbreaks is considerable and has far-reaching consequences. They deteriorate the overall forest health, weaken trees and make them susceptible to infections caused by other organisms. This problem is particularly pronounced in the Republic of Serbia because it has the considerable area covered by deciduous forests and the climate is suitable for the development of the gypsy moth, with the climate change trends indicating that it will be so in the future (Stojanović et al., 2016). Therefore, it is of great importance for the conservation of forest ecosystems that *E. maimaiga* has been discovered and recognized as an exceptional biological agent of high host specificity (Hayek, 1999). It is self-sustaining and capable of regulating the abundance of gypsy moth populations, and therefore economically viable in the biological fight against gypsy moth (Belme, 1995).

E. maimaiga belongs to the *Entomophaga aulicae* species complex, within which it has been identified as a separate species based on the differences in isozymes, its ability to infect *L. dispar*, as well as the results of analyses that compared the restriction fragment length polymorphism (Walsh et al., 1990).

Two different types of asexual spores are produced during the life cycle of *E. maimaiga*: conidia and azygospores. Azygospores are multinucleate, light yellow structures containing lipid drops. They are formed in late spring, or early summer in the cadavers of gypsy moth caterpillars. They are round and average 32.1 μm in diameter (Hajek, 1999), surrounded by a thick, double-cell wall since they are overwintering organisms. As caterpillar cadavers can remain attached to the tree or fall off to the ground, these spores can be found in the soil, litter, and tree bark. Research conducted by Hajek et al. (1998) has shown that the largest number of azygospores can be found around the stem base in the radius of 10 cm and then their density decreases. The research has also confirmed that they are most abundant in the organic soil layer, while their number decreases with increasing depth. At the beginning of spring, azygospores germinate and infect the host, proliferating in its hemolymph. They disturb the normal cellular metabolism and cause the nutrient depletion of the organism, which ultimately leads to the death of gypsy moths. Such a course of events is also referred to as primary transmission and is thought to be the cause of death of larvae of earlier instars. It has been observed that azygospores can persist in the soil for up to 12 years (Hajek et al., 2000; Hajek et al., 2004), allowing the fungus to survive at times when the host is absent or inactive.

After the death of the host, hyphae release conidia that are capable of infection, and their hosts are larvae of later developmental stages. This type of infection is referred to as secondary transmission and is very important in amplifying the primary *E. maimaiga* attack on the gypsy moth. It serves to spread infection in the larval population in the spring, thus significantly increasing the overall positive effect in controlling the pest abundance. Besides the presence of the host, successful infection requires adequate environmental conditions, among which moisture is particularly important. The availability of water in a liquid or gaseous state is essential for the germination of azygospores, therefore it can be concluded that high rainfall at the beginning of the annual cycle of the moth and the fungus is crucial.

E. maimaiga was introduced as a biocontrol agent of the gypsy moth into the United States in the period from 1910 to 1911. (Speare, Colley, 1912) and Bulgaria in 1999 (Pilarska et al., 2000) and from there it has been constantly spreading across North America and Europe.

In the Republic of Serbia, *E. maimaiga* was first recorded in 2011 (Tabaković-Tošić et al., 2012), during the gypsy moth outbreak (2009 – 2014), which was the last to date. Numerous dead gypsy moth caterpillars were found on and around trees in oak and beech stands of the Belgrade and Valjevo regions in Serbia in 2011. Subsequent laboratory analyses revealed that they contained azygospores and conidia of this fungus. These images could also be seen in 13 regions across Serbia in the coming years (Tabaković-Tošić, 2014a; Tabaković-Tošić, 2015).

The assisted introduction of *E. maimaiga* was carried out in Compartments 28 and 30 of FMU Avala on Mt. Avala in 2011 (Tabaković-Tošić, 2014b). It led to an epizootic in the following year and stopped the outbreak of the gypsy moths in the area. As it has been seven years since the outbreak, we tested the viability and infectivity of *E. maimaiga* azygospores obtained from the soil samples from Avala Mountain where its assisted introduction was carried out. We used larvae from the laboratory gypsy moth population.

2. MATERIAL AND METHODS

2.1. Material

Experimental *L. dispar* larvae were obtained from egg masses of their natural environment in central Serbia. Egg masses were collected during September 2018 and kept in the refrigerator at 4ºC before they were used. The eggs were placed to hatch in an air-conditioning chamber at a temperature of 20°C. After hatching, the caterpillars were also grown under constant ambient conditions, at a temperature of 22°C. The light regime was in the ratio of 16 to 8 hours (light: dark). Gypsy moth larvae were fed daily with specially-formulated artificial food prepared from wheat germs, casein, Salt mixture Wesson, sorbic acid, methyl parabens, appropriate vitamins, agar, and distilled water, according to a given recipe. Third-instar larvae were used in the experiment.

Two types of soil were used in the experiments. Commercial soil (humus) was used in the experiments representing positive and negative controls. The second type included soil samples collected in late February 2019 in oak and beech forests of FE Belgrade, Avala Forest Administration, FMU Avala where *E. maimaiga* was introduced in two locations in 2011 – compartments 28 and 30. Five trees were selected in each location. Soil samples were augured from the base of the trees at a depth of 1 – 5 cm, with prior clearing of the litter as close to the root shoot as possible. The sample included the organic layer. The drill was washed and sterilized with 95% ethanol every time before the auguring. The collected soil samples were stored in the laboratory under natural light conditions and at a temperature of 15°C, with minor variations.

2.2. Methods

The research applied the bioassay method. Three experiments were performed. They included 3 experimental units in 5 replications.

In each experiment, 5 third-instar gypsy moth caterpillars were placed in each of 15 plastic boxes measuring 10 x 10 cm and containing about 100 cm^3 of soil. In the first 10 days of the experiment, the soil was moistened with 10 ml of distilled water per day.

The experiments differed in the initial steps of soil preparation.

The first experiment was a negative control and contained gypsy moth larvae exposed to sterilized soil. The purchased soil (humus) had been sterilized at 180°C for 2 hours before it was used. The purpose of this experiment was to prove that the larvae did not contain *E. maimaiga* spores.

In the second experiment, we used the soil taken from Mt. Avala. The samples from compartment 28 were mixed and shredded and then placed in plastic containers. The same procedure was applied to compartment 30 soil samples.

The third experiment was a positive control. The purchased soil (humus) was sterilized at 180°C for 2 hours. After the sterilization, *E. maimaiga* azygospores originating from homogenized cadavers of infected gypsy moth caterpillars (20 caterpillar cadavers per 1500 cm^3 of soil) were added. The caterpillars were collected in nature and the microscopic analysis proved them to be abundant in *E. maimaiga* azygospores. This experiment aimed to determine the susceptibility of gypsy moth larvae to *E. maimaiga* infection.

The gypsy moth larvae used in the experiments were grown under ambient conditions identical to those before the experiments were set up.

The development of larvae was monitored daily. Once a dead individual was observed, it was placed in a separate sterile petri dish with moist filter paper and stored for 7 days in an air-conditioning chamber under identical ambient conditions to allow the development of azygospores. Afterwards, the Petri dishes were moved to the refrigerator, where they stayed for further 5 months at 4°C. At the end of this period, all cadavers were subjected to microscopic analysis. A BTC light microscope that magnifies up to 125 times was used. The presence of *E. maimaiga* infection was marked positive if azygospores were observed in the bodies of dead larvae. The species were identified based on the size, shape, and structural characteristics of different fungal life forms. For this purpose, we used a Motic BA410E light microscope equipped with a 10.0 Mp Moticam digital camera. The digital photographs were processed and analyzed using Motic Images Plus 2.0 digital microscope image processing software.

3. RESULTS AND DISCUSSION

The results of this study reveal the viability and infectivity of *E. maimaiga* azygospores on Mt. Avala, 8 years after its onset and 7 years after the epizootic in this area.

The negative control, in which *L. dispar* caterpillars were exposed to sterilized soil, had a mortality rate of 4%. Microscopic analysis of dead larvae showed the absence of any *E. maimaiga* life form. The cause of their death is unknown.

The results of the examination of the presence of *E. maimaiga* azygospores in *L. dispar* larvae exposed to soil samples from the experimental site of compartment 28 on Mt. Avala are shown in Table 1 (A). It can be seen from the results that the caterpillar mortality amounted to 90.66%. Azygospores of *E. maimaiga* were found in 36% of the total number of larvae in the experiment. Regarding the total number of dead caterpillars, azygospores were found in 39.7% of them.

Table 1. *The presence of E. maimaiga azygospores in the dead larvae of L. dispar exposed to compartments 28 (A) and 30 (B) soil samples, as well as in the positive control (C) .*

Experimental unit	Dead larva sequence number	*E. maimaiga* azygospores														
		Replication														
		I			II			III			IV			V		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	1	-	+	-	-	-	+	-	-	-	-	-	-	+	+	-
	2	-	-	-	+	/	+	+	-	+	+	-	-	+	-	-
	3	+	-	-	-	/	-	/	-	-	+	-	-	+	-	-
	4	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-
	5	+	-	-	-	-	+	-	-	-	+	-	-	-	-	-
2	1	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-
	2	+	-	-	-	-	-	/	-	+	-	-	-	+	+	-
	3	/	-	-	+	-	-	+	-	+	-	+	-	+	-	-
	4	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	5	-	-	-	-	+	+	-	-	+	-	-	-	-	-	/
3	1	-	-	-	-	-	-	-	/	-	-	-	-	-	-	/
	2	+	-	-	+	-	-	+	/	-	-	-	-	-	-	/
	3	-	/	-	+	-	-	+	/	-	/	-	-	/	/	/
	4	/	/	-	-	-	-	+	/	+	+	/	-	-	/	/
	5	/	/	-	+	/	-	-	/	-	-	/	-	+	/	/

Legend:
(/) a gypsy moth caterpillar that successfully completed the larval stage and resumed development
(-) A dead gypsy moth caterpillar in which the presence of azygospores was not detected
(+) A dead gypsy moth caterpillar in which the presence of azygospores was detected

The results of testing the presence of *E. maimaiga* azygospores in *L. dispar* larvae exposed to soil samples from the experimental site of compartment 30 are shown in Table 1(B). The mortality of caterpillars amounted to 78.66%. Azygospores of *E. maimaiga* were found in 8% of the total number of larvae in the experiment. Of the total number of dead caterpillars, 10.16% had the azygospores of the fungus.

The positive control in which the gypsy moth larvae were exposed to sterilized soil and *E. maimaiga* azygospores derived from homogenized cadavers of infected caterpillars produced the results presented in Table 1(C). The caterpillars had a mortality rate of 92%. Azygospores of *E. maimaiga* were recorded in 14.66% of the total number of larvae in the experiment. Regarding the total number of dead caterpillars, azygospores were found in 15.94% of them.

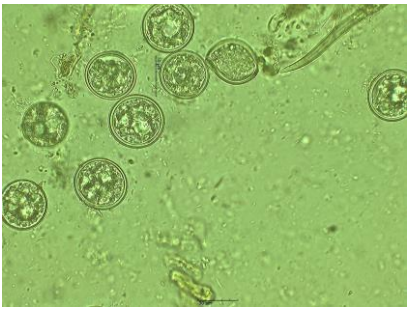

Figure 1. *E. maimaiga azygospores (40x magnification)*

Figure 2. *Mature azigospores of E. maimaiga with lipid drops (100x magnification)*

Confirmation that the observed azygospores belong to the *E. maimaiga* species was obtained by observing the spore morphology (Figure 1). They are round, about 30 μm in diameter, with a clearly defined cell wall, about 2 μm thick. Several lipid drops were observed internally (Figure 2).

The experiments performed clearly proved the presence of *E. maimaiga* azygospores in the soil taken from compartments 28 and 30. Their properties, namely the viability and infectivity, were examined simultaneously due to the nature of the method used. Gypsy moth larvae could be infected only with viable azygospores.

The results of the experiments in which gypsy moth larvae were exposed to soil samples obtained from compartments 28 and 30 indicate a high mortality rate in both compartments (90.66% and 78.66%, respectively), but the mortality caused by the fungus was lower (39. 7% and 10.16% respectively). The cause of death of the gypsy moth larvae which did not detect the presence of *E. maimaiga* azygospores during microscopy is unknown. No life forms of other pathogenic organisms were observed. High caterpillar mortality was expected, but it was expected to be caused by *E. maimaiga* infection. There are several explanations for the low percentage of the infection with the fungal larvae. One option is that *E. maimaiga* is the cause of caterpillar mortality, but that there was not enough time to form azygospores.

It is also possible that the concentration of *E. maimaiga* spores was very low at the examined sites. Another possibility is that we could not provide laboratory conditions required for the gypsy moth infection to occur. Namely, the infection in nature requires high air humidity in the form of water droplets (Hajek et al., 1990; Weseloh and Andreadis, 1992) over a period of two days, which is difficult to provide under laboratory conditions. In this case, the viable spores that were present in the soil samples, but did not cause infection, could not be detected using this method. It is also possible that the azygospores had reduced infectivity.

If we compare the results of the experiments that used the soil samples from Mt. Avala, it can be observed that compartment 28 had a higher rate of larval mortality (90.66%) than compartment 30, as well as a higher rate of mortality caused by *E. maimaiga* (39.7%). Such results may have been caused by the lower concentration of spores in the soil samples from compartment 30 or the environmental conditions necessary for the infection of gypsy moth larvae were not fully ensured.

4. CONCLUSIONS

Despite the small number of dead *L. dispar* caterpillars with the presence of fungal azygospores, which would prove them to be the cause of their death, they provide clear evidence that the viability and infectivity of *E. maimaiga* spores have been preserved since the last calamity in this area. Based on the results, it can be assumed that in the next outbreak of gypsy moth populations, azygospores will infect gypsy moth larvae under favourable environmental conditions.

It would be desirable to conduct the monitoring of dispersion and mapping of *E. maimaiga* in the territory of the Republic of Serbia to estimate its total share in the prevention of gypsy moth outbreaks and to develop valid forest management

plans aimed at timely implementation of appropriate protection measures, in line with the current Forestry Development Strategy of Serbia.

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TESTING OF SOIL DISTRIBUTION, VIABILITY, AND INFECTIVITY OF AZYGOSPORES OF THE ENTOMOPATHOGENIC FUNGUS *Entomophaga maimaiga*

Mara TABAKOVIĆ-TOŠIĆ, Sanja JOVANOVIĆ, Marija MILOSAVLJEVIĆ

Summary

Entomophaga maimaiga is one of the best-known gypsy moth pathogens with increasing importance in the biological control aimed at reducing the population of this defoliator. The territory of the Republic of Serbia is a very favorable gypsy moth habitat, and the problems caused by its larvae during the periods of outbreaks are so great that they can lead to forest defoliation and forest health deterioration.

In the Republic of Serbia, E. maimaiga was first recorded in 2011 (as a new species in the microflora of Serbia) during the gypsy moth outbreak (2009-2014), which was the last to date. In 2011, numerous dead caterpillars were found on and around trees in oak and beech stands of the Belgrade and Valjevo regions in Serbia. Subsequent laboratory analyses revealed that they contained azygospores and conidia of this fungus. The assisted introduction of E. maimaiga was carried out in Compartments 28 and 30 of the FMU Avala on Mt. Avala in 2011. It led to an epizootic in the following year and stopped the outbreak of the gypsy moth in the area.

Since it has been seven years since the outbreak, we tested the viability and infectivity of E. maimaiga azygospores obtained from the soil samples from Avala Mountain where its assisted introduction was carried out. We used larvae from the laboratory gypsy moth population and applied the bioassay method. The results show that azygospores are present in the given soil samples, they are viable and their infectivity is conserved. It can be concluded that in the case of an outbreak of gypsy moth populations in the future, they will exhibit their entomopathogenic effect.

ISPITIVANJE PRISUSTVA U ZEMLJIŠTU, VIJABILNOSTI I INFEKTIVNOG POTENCIJALA AZIGOSPORA ENTOMOPATOGENE GLJIVE *Entomophaga maimaiga*

Mara TABAKOVIĆ-TOŠIĆ, Sanja JOVANOVIĆ, Marija MILOSAVLJEVIĆ

Rezime

Entomophaga maimaiga je jedan od najpoznatijih patogena gubara i zauzima sve veći značaj u biološkim merama borbe, koje imaju za cilj smanjenje brojnosti populacija ovog defolijatora. Teritorija Republike Srbije je veoma povoljno stanište za gubara, te su i problemi koje njegove larve izazivaju u periodima gradacije veliki, dovodeći do golobrsta i slabljenja zdravstvenog stanja šuma.

U Republici Srbiji E. maimaiga je prvi put uočena 2011. godine (nova vrsta u mikoflori Srbije), kada je bila u toku gradacija gubara (2009-2014), poslednja do danas. U Srbiji, u hrastovim i bukovim sastojinama u regionu Beograda i Valjeva, 2011. godine nađene su brojne mrtve gusenice gubara na stablima i oko njh, za koje se kasnije, laboratorijskim analizama, utvrdilo da sadrže azigospore i konidije ove gljive. Potpomognuta introdukcija E. maimaiga vršena je 2011. godine na planini Avala, u Gazdinskoj jedinici Avala, odeljenjima 28 i 30, i već naredne je uzrokovala epizootiju, te dovela do sloma gradacije gubara na tom prostoru.

S obzirom da je od tada prošlo 7 godina, metodom bioeseja ispitivali smo vijabilnost i infektivni potencijal azigospora E. maimaiga iz uzoraka zemljišta sa planine Avala, gde je vršena njena potpomognuta introdukcija, na larvama iz laboratorijske populacije gubara. Rezultati su pokazali da su azigospore prisutne u datim uzorcima zemljišta, kao i da su vijabilne i da je njihov infektivni potencijal očuvan, te se može zaključiti da će u slučaju naredne gradacije populacija gubara, one ispoljiti entomopatogeni efekat.

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FIRST RECORD OF ENTOMOPATHOGENIC FUNGUS *Entomophaga aulicae* IN THE POPULATIONS OF BROWNTAIL MOTH IN BOSNIA AND HERZEGOVINA*

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Abstract: *Browntail moth, is a well-known pest of broadleaf forests of Bosnia and Herzegovina. Although it is extremely polyphagous, it prefers to consume the leaves of various species of oaks. Browntail moth occurs periodically in high numbers (outbreak). Entomopathogenic fungus Entomophaga aulicae (Reichardt and Bail) Humber (Zygomycotina: Entomophtorales, Entomophtoraceae) is widespread Holarctic species, with many host insects from order Lepidoptera, where are some of the most economically harmful, outbreaking species of forest defoliators.*

In sessile oak forests of eastern Bosnia and Herzegovina, the population density of browntail moth was determined by using route measurement during the growing season in the period 2015-2016. Browntail moth newly litters (40) were collected in four oak stands located in the region of Foča, Višegrad and Rogatica (PE Forests of the Republic of Srpska, Forest Estates Maglić, Panos and Sjemeć). In the litters, there were an average of 3,1 of dead old caterpillars and 4.7 pupae.The evaluation of E. aulicae infections was recorded as positive when hyphal bodies, primary conidia, or resting spores were detected on the surface of cadavers and puparia or in their tissues. The species identification was based on the size, shape and structural characteristics of different life forms of the fungus.

By the microscopical studies of the causes of the mortality of the browntail moth larvae and pupae, the presence of hyphal bodies, primary conidia and resting spores of the E. aulicae were confirmed in them. The dimension of the resting spores (n=257) are 32.4 – 48.5 µm, a.v. 44.1 µm, primary conidia (n=54) 26.7–38.6 x 21.0-43.1 µm, a.v. 34.1-29.3 µm. Hyphal bodies were not measured.

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As entomopathogenic fungus on two development stages of the host, larvae and pupae, presented results indicate that E. aulicae is a promising microbial control agent.

Key words: *Euproctis chrysorrhoea*, *Entomophaga aulicae*, epizootics, biological control

PRVI NALAZ ENTOMOPATOGENE GLJIVE *Entomophaga aulicae* U POPULACIJAMA ŽUTOTRBE U BOSNI I HRECEGOVINI

Izvod: *Žutotrba, Euproctis chrysorrhoea (L.) (Lepidotera: Erebidae),dobro je poznata štetočina listopadnih šuma u Bosni i Hercegovini. Iako je izrazito polifaga, radije se hrani lišćem raznih vrsta hrastova. Povremeno se javlja u prenamnoženju (gradaciji). Entomopatogena gljiva Entomophaga aulicae (Reichardt and Bail) Humber (Zygomycotina: Entomophtorales, Entomophtoraceae) je široko rasprostranjena holarktička vrsta, sa velikim brojem domaćina – insekata iz reda Lepidoptera, među kojima su i pojedine ekonomski vrlo štetne, šumske, gradogene vrste defolijatora.*

U području istočne Bosne i Hercegovine, u šumama hrasta kitnjaka, u periodu 2015-2016. godine, populaciona gustina žutotrbe je kontrolisana primenom maršrutnog metoda. Sa četiri ogledne površine u području Foče, Višegrada i Rogatice (JP Šume Republike Srpske, šumska gazdinstva Maglić, Panos i Sjemeć) obavljeno je uzorkovanje 40 (4 x 10) novoformiranih guseničijih gnezda. U gnezdima je bilo prosečno 3,1 uginula larva starijeg razvojnog stupnja i 4,7 lutki. Infekcija entomopatogenom gljivom E. aulicae beležena je kao pozitivna u slučajevima kada je na površini, ili u tkivima, uginulih gusenica i lutki, utvrđeno prisustvo hifa, primarnih konidija i trajnih spora. Identifikacija vrste zasnivala se na veličini, obliku i strukturnim karakteristikama navedenih životnih formi gljive.

Mikroskopskim istraživanjima uzroka smrtnosti larvi i lutki žutotrbe, potvrđeno je prisustvo hifa, primarnih konidija i spora E. aulicae. Pomoću posebnog programa obavljeno je njihovo merenje. Dimenzije trajnih spora (n=257) su 32.4 – 48.5 µm, prosečno 44.1 µm, primarnih konidija (n=54) 26.7–38.6 x 21.0-43.1 µm, prosečno 34.1-29.3 µm. Hife nisu merene.

Kako je ustanovljeno da ova entomopatogena gljiva inficira dva razvojna stadija domaćina, larve i lutke, prezentovani rezultati pokazuju da je E. aulicae obećavajući mikrobiološki agens u sistemu klasične biološke borbe protiv žutotrbe.

Ključne reči: *Euproctis chrysorrhoea*, *Entomophaga aulicae*, epizoocija, biološko suzbijanje

1. INTRODUCTION

Browntail moth, *Euproctis chrysorrhoea* (Linnaeus, 1758) (Lepidotera: Erebidae), is a well-known pest of broadleaf forests of Central and Southern Europe. In the United States of America, it was introduced along with gypsy moth. Although it is extremely polyphagous and feeds on the leaves of most hardwood forest, fruit and ornamental trees, it prefers to consume the leaves of various species of oaks. Browntail moth occurs periodically in high numbers (outbreak) on a relatively small area of a few hundred hectares.

Naturally occuring entomopathogens are important regulatory factors in insect population. Entomopathogenic organisms, various types of viruses, microsporidia, bacteria, protozoa, fungi, nematodes, which can under favourable conditions cause massive insect mortality and are of great breeding capacity,

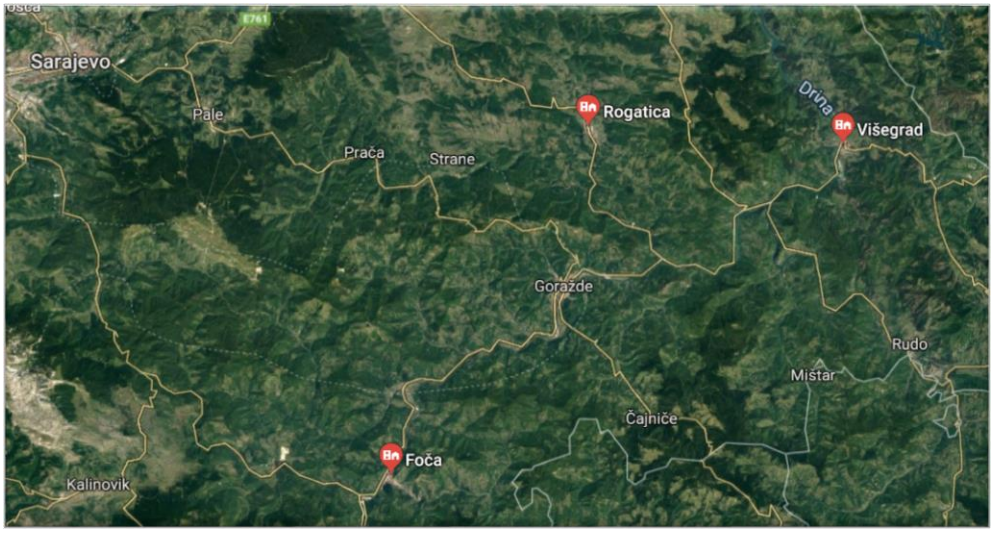
normally live in nature. Epizootics caused by naturally occurring viral and fungal pathogens are often responsible for spectacular crashes of insect pest populations.

Entomopathogenic fungus *Entomophaga aulicae* (Reichardt and Bail) Humber (Zygomycotina: Entomophtorales, Entomophtoraceae) is widespread Holarctic species, with many host insects from order Lepidoptera, where are some of the most economically harmful, outbreaking species of forest defoliators [*Lambdina fiscellaria* Guenée, 1857; *Choristoneura fumiferana* (Clemens, 1865); *Euproctis chrysorrhoea* Linnaeus, 1758; *Estigmene acrea* (Drury, 1773)].

2. MATERIAL AND METHODES

In sessile oak forests of eastern Bosnia and Herzegovina, the population density of browntail moth was determined by using route measurement during the growing season in the period 2015-2016.

Brown tail moth newly litters (40) were collected in four oak stands (Table 1.) located in the region of Foča, Višegrad and Rogatica (PE Forests of the Republic of Srpska) (Picture 1.).



Picture 1. *Google Map of the region of Foča, Višegrad and Rogatica*

Table 1. *The main characteristics of the sample plots*

Plot	Forest Estate	Management Unit	Forest Compartment	Coordinates (X, Y)	Altitude (m)	Tipe of	
						Soil	Sessile oak forest
1	Sjemeć Rogatica	Gornja Prača	90	65 89 443 48 43 203	815	Deep acid brown and illimerised	High
2			112	65 90 846 48 42 043	830		High and coopice
3	Panos Višegrad	Sutjeska - Radojna	124	65 96 702 48 42 380	822	Euthric brown and deep acid brown	Coopice
4	Maglić Foča	Slatina	10	65 65 092 48 18 088	710		

The dead larvae and pupae from newly litters were placed in Petri dishes with wet filter paper. They were kept 7 days in the laboratory and then stored in the refrigerator. After the storage in the refrigerator for 3 months, the detailed microscope survey of the dead browntail moth caterpillars was done.

Microscopical examinations of diseased larvae and pupae were carried out using a MOTIC optical Trinocular, model Sextuple BA410E, equipped with a camera MOTICAM 10.0 (10 Mpix, 12.5", CMOS, MOTIC), and for processing the results of measurements of the hyphal bodies, primary conidia and resting spores (life forms) was used program Motic Images Plus 2.0 ML, gauging with the MT-40X.

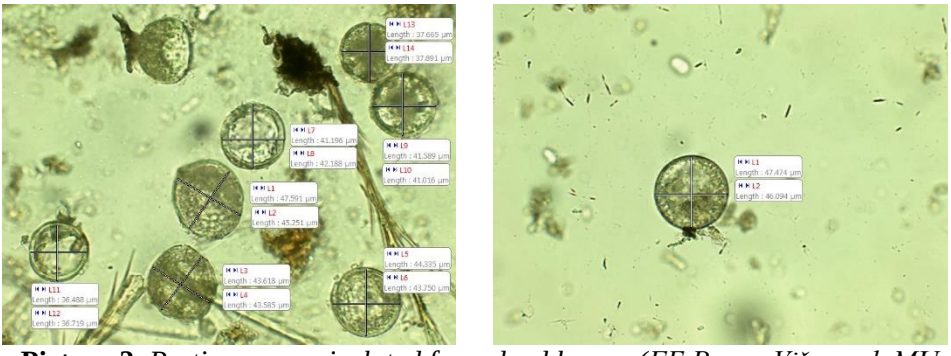
The evaluation of *E. aulicae* infections was recorded as positive when hyphal bodies, primary conidia, or resting spores were detected on the surface of cadavers and puparia or in their tissues. The species identification was based on the size, shape and structural characteristics of different life forms of the fungus.

3. RESULTS AND DISCUSSION

In the spring (May and June) 2015 and 2016 in the selected area in Rogatica (FE Sjemeć), Foča (FE Maglić) and Višegrad (FE Panos) regions (oak high and coppice forest stands in Management units Gornja Prača, Sutjeska Radojna and Slatina), the great increase of the population size of the browntail moth was reported.

In the 40 collected newly litters, there were an average of 3,1 of dead old caterpillars and 4.7 pupae. The detailed microscope survey showed in most of them the presence of the numerous resting spores of the entomopathogenic fungus *E. aulicae*. In addition, the presence of hyphal bodies and primary conidia of this pathogen species was reported, but the number of them was considerably smaller.

The dimension of the resting spores (n=257) are 32.4 – 48.5 µm, a.v. 44.1 µm, primary conidia (n=54) 26.7–38.6 x 21.0-43.1 µm, a.v. 34.1-29.3 µm (Picture 2.). The morphological data correspond to descriptions given by MacLeod & Müller-Kögler (1973), Pilarska *et al.* (2001), Kalkar and Carner (2005), Keller and Petrini (2005) and Tabakovic-Tosic *et al.* (2018). Hyphal bodies were not measured.



Picture 2. *Resting spores isolated from dead larvae (FE Panos Višegrad, MU Sutjeska –Radojna, FC 124)*

4. CONCLUSION

By the field and laboratory studies of the causes of the mortality of the older browntail moth larval instars the presence of hyphal bodies, primary conidia and resting spores of the entomopathogenic fungus *E. aulicae* were confirmed. It has been the first discovery of this kind in Bosnia and Herzegovina.

As entomopathogenic fungus on two development stages of the host, larvae and pupae, presented results indicate that *E. aulicae* is a promising microbial control agent.

The ability of this fungus to grow on artifical media make it worthy of further study for possible use in biological control - the artificial spread of pathogen. This method has advantages because only small amounts of the pathogen and inexpensive equipment for field application are needed.

Acknowledgments

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THE CROWN CONDITION OF BEECH TREES AFTER THE DISASTROUS ICE STRORM ON MT. CRNI VRH

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Abstract: *The Level II Sample Plot where the research presented in the paper was conducted is located on Mt. Crni Vrh, in the Dubašnica management unit – compartment 11 – in the area managed by the Boljevac Forest Estate. Thirty marked beech trees (Fagus moesiaca (Domin, Mally) Czeczott.) had the defoliation assessed and the damage determined by class and agent in the growing period of a three-year-long research period. The investigations presented in this paper were performed following the catastrophic ice storm that devastated this area in the winter of 2014. The aim was to monitor the response of trees to a major natural disaster. The results showed that the investigated beech trees had been recovering relatively quickly although they had remained highly vulnerable to the attack of harmful pests and diseases, primarily to the extremely dangerous "beech bark disease", which occurred in the study stand two years after the damaging ice storm. Since beech is a very sensitive species, its condition after a major disaster needs to be monitored regularly at the affected localities in order to prepare and implement a program of adequate measures of protection and thus prevent the disease from growing to epiphytotic proportions or causing a chain of damaging events which could easily spread to the unaffected surrounding areas.*

Keywords: Sample plot, Beech, Ice Storm, Crown Condition

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СТАЊЕ КРУНА БУКОВИХ СТАБАЛА ПОСЛЕ КАТАСТРОФАЛНОГ ЛЕДОЛОМА НА ЦРНОМ ВРХУ

Извод: *Биоиндикацијска тачка Нивоа II на којој су вршена истраживања приказана у раду, налази се на Црном Врху, у газдинској јединици Дубашница, одељењу 11, на подручју којим газдује ШГ Бољевац, ШУ Бор. На 30 обележених стабала букве (Fagus moesiaca (Domin, Mally) Czeczott.) је у вегетационом периоду током приказаног периода посматрања у трајању од 3 године, вршена оцена дефолијације и детерминисана оштећења по типовима и врстама узрочника. Испитивања приказана у раду су обављена након ледолома катастрофалних размера који је задесио ово подручје у зиму 2014. године, да би се видела реакција стабала после великих природних непогода. Резултати испитивања су показали да се испитивана стабла букве релативно брзо опорављају, али су врло подложна нападу опасних болести и штеточина, што се првенствено односи на изузетно опасну „болест коре букве“, која се јавила у испитиваној састојини две године након штете од ледолома. Обзиром да је буква и као врста природно врло осетљива, након дејства велике непогоде неопходно је редовно праћење стања на угроженим локалитетима, ради припреме и спровођења програма мера адекватне заштите, да не би дошло до штета епифитотичних размера и евентуалног уланчавања штета, које би се лако могле проширити и на околна, незаражена подручја.*

Кључне речи: биоиндикацијска тачка, буква, ледоломи, стање круна

1. INTRODUCTION

The impact of pollution and modified climate factors on the vitality of forests has been evident both in Serbia and its wider region and all over Europe. There has been a growing need for research on this topic both in our country and worldwide. In order to determine forest ecosystem processes, it is necessary to conduct detailed research into the environmental factors that lead to the occurrence of harmful insects and diseases and obtain a deeper insight into the state of forests. The results obtained from this research can be used to draw conclusions regarding the necessary measures of improvement which are established through the forest condition monitoring. The *ICP Forests* is a programme of monitoring the impact of anthropogenic (primarily air pollution) and biotic harmful factors on the state and development of forest ecosystems in Europe. With the cooperation of the Forest Directorate and the Institute of Forestry in Belgrade as the National Focal Center (NFC) of the Republic of Serbia for forest condition monitoring this system of forest monitoring has been integrated into the state forestry environment, so that several institutions with their associates has been participating in the program (*Gagic-Serdar et al., 2018*).

The ice storm that hit the whole of eastern Serbia in late November and early December 2014 caused significant damage to the areas managed by SE Srbijašume, *i.e*. forest estates of Niš, Boljevac, Kruševac, Despotovac and Kučevo. More than 400,000 m^3 of wood was damaged in the state forests alone and the storm affected an area of over 19,000 ha. All the affected surface areas were mapped in GIS technology (*Marković, & Marković*, 2018).

The areas that suffered the consequences of the ice storm in 2014 (about 17,000 ha) are largely located in the altitudinal belt of 600-900 m a.s.l., *i.e.*, in the belt of low mountains. Most of the affected areas have a northern (about 4,000 ha) or a northeastern aspect (about 3,500 ha), and the remaining surface areas are evenly distributed over the other aspect classes. The impact of the terrain slope on the occurrence of ice breaks was not significant (*Marković & Marković, 2018*). This natural disaster had severe and far-reaching consequences on the coniferous and broadleaved forest ecosystems and the environment in general. These consequences included the changes in the soil water regime, erosion, oxygen reduction, reduced amounts of carbon accumulated in biomass. However, the degradation processes that are yet to occur will cause the regressive degradation of forest communities and the depletion of soil that will be inhabited by those tree species that represent the earliest stages in the ontogeny of forest stands.

Considering the size of the forest area affected by the ice storm, as well as its enormous impact on the environment, this natural disaster can be considered catastrophic.

The stands affected by the ice storm are largely beech stands because Serbia is a country in which beech (*Fagus moessaca* (Domin, Mally) Czeczott.), either in pure or mixed stands, accounts for about 60% of wood volume. The beech has a wider horizontal and vertical distribution than any other species in our country, which highlights its great importance for the forest economy in Serbia. Beech stands are found both at low altitudes (at 70m around Negotin) and at up to 1,500m in large mountain massifs. Furthermore, beech has retained its natural structure, as well as its natural range of distribution and natural regeneration capacity. There are not any artificially-established beech stands in Serbia because the only way to restore beech forests is through natural regeneration. The biological properties, ecological requirements, natural range of distribution, multiple-purpose benefits and natural structure of stands make beech the main tree species of Serbian forestry.

Bearing in mind the fact that beech trees are very susceptible to the attack of harmful insects or pathogenic and epyxilic fungi, there is a pressing need to investigate the factors that affect its health state in order to develop a program of measures for its systematic protection.

The paper gives an overview of the health state of 30 beech trees monitored at the Crni Vrh site (where the level II sample plot is located). The health state was defined through the defoliation and occurrence of diseases and pests in the period from 2015 to 2017, following the natural disaster and during the implementation of sanitary cutting, cleaning and removing of broken branches.

2. MATERIAL AND METHODS

2.1. Material

The sample plot where the presented research was conducted is located on Mt. Crni Vrh, in the Dubašnica management unit, compartment 11, managed by the FE Boljevac, FA Bor. The plot is at + 44007'55" (Latitude) and + 21058'38" (Longitude) in an even-aged beech (*Fagus moesiaca)* high stand. The stand is 60 years old. The basic characteristics of the forest ecosystem are as follows: the site is at 1086-1155 m above sea level; the aspect is southern and southwestern; the slope is uniform, steep, with the slope degree of $11\text{-}15^0$; the bedrock is composed of decomposed phyllite and the soil is classified as a fresh, medium-deep, dystric brown soil; dead organic layer is moderately represented with a favourable process of humification; the ground vegetation is sparse and the shrub layer is absent.

Every year, the degree of defoliation is assessed and the damage (entomological, phytopathological, and mechanical) to the marked trees is determined by types and species of agents during the growing period. The assessment also includes the location of the damage (leaves, branches, bark, trunk portion, butt end, root, *etc*.).

2.2. Methods of crown condition assessment

The crown defoliation is evaluated based on the branch die-off and expressed in percentages from 0 to 100 (0% of defoliation defines the trees without dying branches, and 100% the trees with no living branches).

In order to make the results more comprehensive, the following table presents the damage in codes, classified by agent type, agent species, damaged tree part, and damage intensity.

For the assessment to present the real state of the tree health, it was carried out during the growing period (since autumnal leaf discolouration can affect the assessment of defoliation and discolouration and lead to wrong assumptions regarding the tree crown condition). The assessments were carried out on 5 August 2015, 27 July 2016 and 14 September 2017. The basic data regarding the sample plot on Mt. Crni Vrh are given in the PLT tables, Tables 1, 2 and 3 and refer to each year of the research respectively.

Table 1. XX2012. (PLT) *Data regarding the plot selected for the crown condition assessment, Level II, Crni Vrh*

Sequence number	Country Code	Observation plot	Date of assessment	Latitude	Longitude	Altitude	Team identification	Other observations
1	67	4	050815	+44007'55"	+21058'38"	19		

Table 2. XX2012. (PLT) *Data regarding the plot selected for the crown condition assessment, Level II, Crni Vrh*

Sequence number	Country Code	Observation plot	Date of assessment	Latitude	Longitude	Altitude	Team identification	Other observations
1	67	4	200416 270716	+44^{0}07'55"	+21^{0}58'38"	19		

Table 3. XX2012. (PLT) *Data regarding the plot selected for the crown condition assessment, Level II, Crni Vrh*

Sequence number	Country Code	Observation plot	Date of assessment	Latitude	Longitude	Altitude	Team identification	Other observations
1	67	4	140917	+44^{0}07'55"	+21^{0}58'38"	19		

3. RESULTS AND DISCUSSION

The improved methodological approach of the Level II crown condition assessment can be described as systematic monitoring of a set of characteristics of dominant tree crowns on the sample plots. The results of intensive monitoring assessments (*Nevenić et al.*, 2011) conducted for each individual tree whose crown is monitored every year, will after a certain number of replications give answers to different hypothetical assumptions, such as the causes of the serious deterioration of forest vitality (by identifying the causes and applying the expert knowledge in dealing with them).

Intensive monitoring will eliminate the error factor from the evaluation of the current state and the application of standard laboratory methods will provide clear interpretation and detailed explanation of defoliation percentage values.

Intensive crown condition monitoring is focused on the assessments of defoliation and identification of damage. It can further include other parameters, such as tree status, crown shading, crown visibility, fruiting of the visible part of the crown, the presence of secondary shoots, *etc*.

3.1. Results regarding the health condition of individual beech trees, by year

When inspecting the marked trees, the health state of each individual tree was determined by assessing the branch die-off or defoliation from 0 to 100% and the damage caused by the effects of harmful abiotic and biotic factors on the leaves, branches, and trunks. The damage is presented in the codes defined in the legend below Table 4.

3.1.1. The description of the 2015 results

The tree health inspection was conducted on 5August 2015. The inspection included 30 beech trees marked for this purpose on subplot 2. On that occasion, their defoliation was assessed, the intensity of the damage caused by abiotic and biotic agents determined and other observations were made. The basic data regarding the intensive monitoring plot on Mt. Crni Vrh are given in the PLT table (Table 1). Table 4 gives the crown condition parameters and the damage parameters for the sample plot in 2015 and during the entire research period.

Although the inspection revealed that the majority of broken trees or their parts had been removed from the stand and it had been largely cleared, all the trees still showed the signs of the damage caused by ice, mostly in the top parts of the crowns, while the other tree crown parts had increasing defoliation values (5 trees had a defoliation of 80 to 90%, 9 trees 20 - 35%, 8 trees 10 - 15%, and only 9 trees had a defoliation of 0 to 5%.) There was one fallen tree and one stag tree. There were mining insects on the leaves (the foliar damage caused by insects was observed in almost all trees). The presence of the harmful insect known as *Cryptoccocus fagisuga* was observed on the bark of 4 trees.

3.1.2. The description of the 2016 results

The tree health inspection was conducted twice, in the spring and in the summer of 2016 (20 April and 27 July, 2016). The inspection included 30 beech trees marked for this purpose on subplot 2.Their defoliation was assessed, the intensity of the damage caused by abiotic and biotic agents was determined and other observations were made. The basic data regarding the intensive monitoring plot on Mt. Crni Vrh are given in the PLT table (Table 2). Table 4 gives the crown condition parameters and the damage parameters for the sample plot in 2016 and during the entire study period.

It was observed that there had been no newly fallen or dead timber. Of other observations, it is important to note that the beech trees had drastically lower defoliation degree values in the summer inspection than in the inspection conducted in the spring of 2016, and several trees had their leaves again, mainly in whiskers. It proved that the trees had been recovering quickly and noticeably from the damage caused by the ice storm. One tree had a bark burn and a large number of trees still had broken branches and decay that generally develops through wounds.

Given the overall extent of the damage caused by the ice storm, its effects inevitably included the occurrence of the pathogenic fungus *Nectria coccinea* on the broken parts of the investigated trees. Together with *Cryptococcus fagisuga* it is notorious for causing a very serious disease known as the “beech bark disease”.

3.1.3. The description of the 2017 results

The tree health inspection was conducted on 14 September 2017. The assessment included 30 beech trees selected for the annual crown condition monitoring on subplot 2. On that occasion, their defoliation was assessed, the

intensity of the damage caused by abiotic and biotic agents determined and other observations made. The basic data regarding the intensive monitoring plot on Mt. Crni Vrh are given in the PLT table (Table 3). Table 4 gives the crown condition parameters and the damage parameters for the sample plot in 2017 and the previous two years.

It was noted that two more trees had died, but there weren`t any newly fallen trees. The bark burn caused by the effects of an abiotic factor (prolonged exposure to sunlight) was present only in one tree as in the previous year (tree 74), and a larger number of trees still had broken branches and decay that developed through wound sites. Trees 68, 72 and 91 were still standing, but they were completely decayed, and tree 95 had already decayed and fallen in the previous years. The effects of the ice storm that hit this stand could also be seen on trees 78 and 87 which had broken tips as a consequence of this disaster. Furthermore, several trees had the larger branches of their crowns broken during the ice storm (No. 58, 67, 73, 79, and 100). Tree 89 had a very strong defoliation of 85%, as well as the centre rot, and substantial mechanical damage which will probably lead to its death in the following year. Compared to the previous year, it was obvious that the stand can had been restoring gradually from this harmful abiotic agent. This was also proven by the defoliation values which had decreased noticeably and now ranged from 5 to 30%.

The harmful biotic agents present in the stand primarily referred to the presence of the *Cryptococcus fagisuga* Lind. colonies which transmit the spores of *Nectria coccinea* (Pers. ex Fr.) Fries. This fungal pathogen causes the bark canker and eventually kills trees. It is one of the most serious fungi that occur on beech trees, and together with the insect *C. phagisuga* causes the so-called “beech bark disease”. After a tree has been infected by *N. coccinea,* the necrotic zone of the bark is quickly colonized by wood-decaying fungi and xylophagous insects. The degradation of the trees attacked by these secondary organisms is relatively fast.

Other biotic factors that affected the beech trees included the branch decay (Trees 73 and 100) and the center rot (Tree 89). Several trees had the *Diatrype stigma* (Hoffm.) fungus on their trunks, but it didn`t produce any significant effects on the trees.

3.2. The study results regarding the beech tree health state for the entire research period, collectively

Table 4. *Comparative review of the beech tree defoliation and damage after the ice storm (in the period from 2015 to 2017)*

Tree number	2015				2016			
	Defoliation	Scientific name of cause	Location in crown	Extent	Defoliation	Scientific name of cause	Location in crown	Extent
57	10				0	430	3	3
58	5	430	3	3	5	390	3	1
62	15	390	3	1	15			
64	20				15			
65	5				5	390	3	1
66	20	390	3	1	20	290	3	1
67	15	290	3	1	15	290	3	1
68	100	290	3	1	100	Decayed		
69	0				0	290	3	1

Tree number	2015				2016			
	Defoliation	Scientific name of cause	Location in crown	Extent	Defoliation	Scientific name of cause	Location in crown	Extent
71	5	290	3	3	0	430	3	3
72	90	430	3	1	90			
73	10				0			
74	0				0	290	3	1
75	5	290	3	1	0	290	3	1
76	25	290	3	1	0	290	3	1
77	15	290	3	1	40			
78	80				70	290	3	2
79	15	290	3	1	5	290	3	1
87	80	290	3	1	50	390	3	1
88	5	390	3	1	5	290	3	1
89	80	290	3	1	60			
90	30				5	290	3	1
91	90	290	3	1	70			
92	30				10	290	3	1
94	15	290	3	1	15	390	3	1
95	40	390	3	7	fallen			
96	25	430	3	1	10	390	3	1
97	10	390	3	1	30	290	3	1
98	0	290	3	1	10			
100	5				10	290	3	1

Tree number	2017			
	Defoliation	Scientific name of cause	Location in crown	Extent
57	5	432	3	3
58	15			
62	15			
64	15			
65	5			
66	25			
67	20			
68	100	Decayed		
69	5			
71	0			
72	100	Decayed		
73	5	390	3	1
74	5			
75	5			
76	20			
77	20			
78	30			
79	10			
87	20	432	3	1
88	5			
89	85			
90	5			
91	100	Decayed		
92	25			
94	10			
95	fallen			
96	20			
97	20			
98	10			
100	10			

Legend (the codes used in the table)

Damage cause:
290 – biotic, insects
390 – biotic, fungi
430 – abiotic, snow and ice
432 – abiotic, frost cracks

Location in crown
3 – patches

Damage intensity:
1 – damage of 1-10%
2 – damage of 11-20%
3 – damage of 21-40%
7 – damage of 100%

As shown in Table 4, defoliation was reduced during the study period, particularly in the trees with lower defoliation percentages and in the last year of the research, that is, 4 years after the ice storm. The trees with very high defoliation percentages eventually decayed, broke or fell. Some trees that had high percentages of defoliation in the upper crown reduced the defoliation drastically over time, as these dead branches broke and fell off. On the basis of these results, it could be said that the general condition of the study stand had been improving.

Regarding the damage registered on the investigated beech trees, we can note that the damage was drastically reduced in the last year of the research, which means that the trees built up their resistance after they had been affected by the ice storm.

4. CONCLUSIONS

As the most common tree species in Serbia and due to its excellent technical characteristics, the beech is ranked as a species of great significance in the forest economy. However, a wider use of beech wood is limited by its poor durability. The wood is rated as non-resistant and makes suitable grounds for the development of many parasitic and saprophytic organisms, above all parasitic fungi and harmful insects. For instance, some literature sources state that the high (seeds) and coppice beech forests in Serbia host almost 150 species of fungi on their trees, some of which can be found on the cupules, fruit and seedlings, some on the leaves and branch and stem bark, and some cause wood decay and staining.

It is important to emphasize that the beech forest decline has been caused by the interaction of the adverse effects of climate change and the management and biotic factors. One of these adverse factors is naturally the human activity. Unreasonable exploitation of beech forests in Serbia has almost halved the area under forest. The felling of beech forests in the past (especially immediately after the Second World War) was not aimed at forest regeneration, but almost exclusively at wood exploitation. Consequently, beech trees have become non-resistant to the harmful effects of numerous abiotic and biotic factors. Among them, the most serious biotic factors are parasitic fungi and harmful insects. The spread of the dangerous "beech bark disease" caused by the *Cryptococcus fagisuga* insect and the *Nectria coccinea* fungus makes the protection of beech forests even more difficult.

This study shows that despite the fact that the beech is a very sensitive species, if proper care and management measures are carried out, beech trees can recover relatively quickly even from the substantial damage caused by natural disasters such as catastrophic ice storms.

However, one must bear in mind the fact that the physiologically weakened trees are much more susceptible to the attack of dangerous diseases and pests, which in this case refers to the extremely dangerous "beech bark disease" that occurred in the study stand two years after the ice storm. It is therefore necessary to conduct regular monitoring of these localities in the coming period in order to prepare and implement programs of measures of adequate protection for the

prevention of the damage of epiphytic proportions, which could easily spread to the surrounding non-infected areas.

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THE CROWN CONDITION OF BEECH TREES AFTER THE DISASTROUS ICE STRORM ON MT. CRNI VRH

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Summary

As the most common tree species in Serbia and due to its excellent technical characteristics, the beech is ranked as a species of great significance in the forest economy. However, a wider use of beech wood is limited by its poor durability. The wood is rated as non-resistant and makes suitable grounds for the development of many parasitic and saprophytic organisms, above all parasitic fungi and harmful insects. For instance, some literature sources state that the high (seeds) and coppice beech forests in Serbia host almost 150 species of fungi on their trees, some of which can be found on the cupules, fruit and seedlings, some on the leaves and branch and stem bark, and some cause wood decay and staining. It is important to emphasize that the beech forest decline has been caused by the interaction of the adverse effects of climate change and the management and biotic factors. One of these adverse factors is naturally the human activity. Unreasonable exploitation of beech forests in Serbia has almost halved the area under forest. The felling of beech forests in the past (especially immediately after the Second World War) was not aimed at forest regeneration, but almost exclusively at wood exploitation. Consequently, beech trees have become non-resistant to the harmful effects of numerous abiotic and biotic factors. Among them, the most serious biotic factors are parasitic fungi and harmful insects. The spread of the dangerous "beech bark disease" caused by the *Cryptococcus fagisuga* insect and the *Nectria coccinea* fungus makes the protection of beech forests even more difficult. This study shows that despite the fact that the beech is a very sensitive species, if proper care and management measures are carried out, beech trees can recover relatively quickly even from the substantial damage caused by natural disasters such as catastrophic ice storms. However, one must bear in mind the fact that the physiologically weakened trees are much more susceptible to the attack of dangerous diseases and pests, which in this case refers to the extremely dangerous "beech bark disease" that occurred in the study stand two years after the ice storm. It is therefore necessary to conduct regular monitoring of these localities in the coming period in order to prepare and implement programs of measures of adequate protection for the prevention of the damage of epiphytic proportions, which could easily spread to the surrounding non-infected areas.

СТАЊЕ КРУНА БУКОВИХ СТАБАЛА ПОСЛЕ КАТАСТРОФАЛНОГ ЛЕДОЛОМА НА ЦРНОМ ВРХУ

Мирослава МАРКОВИЋ, Снежана РАЈКОВИЋ, Ненад МАРКОВИЋ

Резиме

Буква у шумској привреди има велики економски значај, пре свега као најраспрострањенија врста дрвећа у Србији, захваљујући неким одличним техничким особинама. Међутим, шира употреба буковог дрвета је ограничена њеном краткотрајношћу. Буково дрво је неотпорно и представља одличну подлогу за развој многих паразитних и сапрофитних организама, а међу њима на прво место долазе паразитне гљиве и штетни инсекти. У литератури се рецимо наводи да је у високим (семеним) и изданачким шумама букве у Србији, на стаблима букве констатовано готово 150 врста гљива, од којих се неке јављају на купулама, плодовима и понику, неке на лишћу и кори грана и стабла, а неке су проузроковачи трулежи и обојености дрвета. Важно је нагласити да је узрок појаве сушења у шумама букве последица истовременог негативног утицаја деловања климатских (промена климе), газдинских и биотичких чинилаца. Међу овим факторима посебно место заузима и човек, који је нерационалним искоришћавањем букових шума у Србији, у прошлости, површину под шумама скоро преполовио. Сече букових шума у прошлости (поготово непосредно после II светског рата) нису имале карактер сеча обнављања шума, већ скоро искључиво експлоатациони карактер. Као последица таквог односа према шуми, она је постала јако осетљива на штетно деловање бројних абиотичких и биотичких фактора. Међу биотичким чиниоцима посебно место заузимају паразитне гљиве и штетни инсекти. Појава опасне тзв. "болести коре букве", коју изазива инсект *Cryptococcus fagisuga* и гљива *Nectria coccinea*, што још више отежава проблем заштите букових шума. У раду је показано да иако је природно буква врло осетљива врста, уколико се врше правилне мере неге и газдовања, чак и после великих штета од природних непогода као што су ледоломи катастрофалних размера, стабла се релативно брзо опорављају. Без обзира на то, не сме се заборавити чињеница да су физиолошки ослабљена стабла у много већој мери подложна нападу опасних болести и штеточина, што се у овом случају односи на изузетно опасну наведену „болест коре букве“, која се јавила у испитиваној састојини две године након штете од ледолома. Зато је неопходно редовно праћење стања на оваквим локалитетима и у наступајућем периоду, ради припреме и спровођења програма мера адекватне заштите, да не би дошло до штета епифитотичних размера, које би се лако могле проширити и на околна, незаражена подручја.

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SELECTION OF POTENTIAL AREAS FOR THE ESTABLISHMENT OF FOREST PLANTATIONS FOR ENERGY NEEDS – THE CASE OF LAZAREVAC MUNICIPALITY

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Abstract: *The needs for energy sources in Serbia are constantly increasing. Wood as the most important energy source is not only used for energy purposes, but also for the wood industry, and it is clear that pressure on the resource is increasing. According to FAO methodology, the estimated energy potential of the available biomass derived from forests and wood processing industry in Serbia amounts to 1.53 Mtoe/year (Bražanac-Bosanac et al., 2018). In 2016, the Institute of Forestry in Belgrade carried out a preliminary study on the establishment of forest plantations for energy needs. The municipality of Lazarevac was selected as a pilot project for the establishment of forest plantations for energy purposes. It was estimated that this municipality, given its geographical position and ecological conditions, is absolutely in line with the planned production. In selecting potential areas for the establishment of forest plantations, strict attention was paid to the current use of the available areas. The study area includes the areas that can be determined but are not necessarily required for the needs of such production. Out of a wide range of autochthonous and allochthonous species, the tree species that are most capable of exploiting the potentials of the site and provide high energy values in the given ecological conditions were selected.*

Key words: forest plantations for energy needs, potential vegetation, tree species;

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IZDVAJANJE POTENCIJALNIH POVRŠINA ZA OSNIVANJE ŠUMSKIH ZASADA ZA ENERGETSKE POTREBE NA PRIMERU OPŠTINE LAZAREVAC

Izvod: *Potrebe za energentima u Srbiji se stalno povećavaju. Drvo kao najznačajniji energent ne koristi se samo za energetske potrebe, već i za potrebe drvne industrije, te je jasno da se sve više povećava pritisak na pomenuti resurs. Po metodologiji FAO procenjena energetska vrednost potencijalno raspoložive biomase iz šumarstva i drvno-prerađivačke industrije u Srbiji iznosi ukupno 1,53 Mtoe/godišnje (Brašanac-Bosanac et al., 2018). Institut za šumarstvo Beograd je 2016. godine uradio preliminarnu studiju o osnivanju šumskih zasada za energetske potrebe, a kao idejni pilot projekat za osnivanje šumskih zasada za energetske svrhe izabrana je opšrina Lazarevac. Procenjeno je da ova opština, s obzirom na njen geografski položaj i ekološke uslove apsolutno odgovara planiranoj proizvodnji. Prilikom izdvajanja potencijalnih površina za osnivanje šumskih zasada, strogo je vođeno računa o dosadašnjoj nameni i korišćenju raspoloživih površina. Predmet rada su površine koje je moguće, ali ne i nužno izdvojiti za potrebe ovakve proizvodnje. Iz širokog spektra autohtonih i alohtonih vrsta, izdvojene su vrste drveća koje najbolje koriste potencijal staništa i obezbeđuju visoku energetsku vrednost u datim ekološkim uslovima.*

Ključne reči: šumski zasadi za energetske potrebe, potencijalna vegetacija, vrste drveća

1. INTRODUCTION

In 2016, the Institute of Forestry in Belgrade conducted a preliminary study to allocate potential areas for the establishment of forest plantations for energy needs in Lazarevac municipality. It was estimated that the geographical location and ecological conditions of the municipality are absolutely in line with the planned production. In addition, the municipality in question, as no other in Serbia, is characterized by large complexes of anthropogenic surface areas of deposols caused by surface coal mining. Due to their physical and chemical composition, these soils are often not suitable for agricultural production. Furthermore,the entire area is exposed to severe air and water pollution. The establishment of the plantatiosn of forest tree species for energy needs is highly desirable in these circumstances. In addition, they will contribute to the increase in green areas of Belgrade.

2. RESEARCH AREA

2.1. General natural characteristics of the area

The Municipality of Lazarevac has a very favorable geographical position. It is located 55 km south-southwest from Belgrade. Stubički Vis with an altitude of 393 m is the highest point in the municipality. The city of Lazarevac is at an altitude of 147 m, and the lowest point in the municipality (87 m) is where the Kolubara river passes to a neighboring municipality. The favorable geographical position ensures that the municipality has good traffic communication with Belgrade and central Serbia through the Ibarska highway and the Belgrade-Bar

railway (Rakonjac *et al*., 2011). According to authors (Ducić *et al*., 2005), this area belongs to the continental climate. Air temperature extremes range from -32.6°C to 42.3°C. According to the data of the Belgrade-Košutnjak hydrometeorological station, the mean annual air temperature in this area is 12.3°C, while it is 18.93°C in the growing period. The mean annual rainfall is about 696.1 mm, while in the growing period it amounts to about 395 mm. As a result of surface coal mining and the work of Veliki Crljeni thermal power plant, meso- and microclimate conditions, as well as the air quality, have been significantly changed. According to authors (Rakonjac *et al*., 2011), the terrain of the municipality of Lazarevac is inclined towards the Kolubara River which flows along the western border of the municipality. The northwestern part of the municipality is flatland, and the southeast is hilly.

In the area of Lazarevac municipality, the following units can be distinguished:

The flatland zone, up to 100 m above sea level, covers 15-20% of the territory in the northwest of the municipality (the catchment area of the Kolubara River). The areas that are mainly located near watercourses and are not used for agricultural purposes were selected for the establishment of forest plantations for energy needs. These are mostly abandoned and uncultivated agricultural lands and barrens with or without natural vegetation. These are also the largest complexes envisaged for energy plantations.

The lower Šumadija-hilly zone, from 100 to 200 m above sea level, covers most of the municipality (65% of the territory). In this zone, the areas that are not optimally used for agricultural production are selected for the establishment of forest plantations for energy needs. These are usually barrens, with or without natural vegetation, or abandoned agricultural or forest land.

The higher Šumadija hilly zone, over 200 m, occupies the central portion of the southern part of the municipality (20% of the territory). In this zone, smaller areas of predominantly barren forest lands are selected.

In the immediate vicinity of the town of Lazarevac, artificial Lake Očaga was constructed. More than 10 lakes have been formed in the depressions of unregulated mine spoil banks of open-pit mine site - field `D`. In the territory of the Municipality of Lazarevac, there are numerous small lakes and swamps formed in the old riverbeds of the Kolubara River and its tributaries, known as `oxbow lakes` (`dead` or stagnating water), while some resulted from the exploitation of coal or sand. These lakes can serve as water reservoirs for irrigation in dry seasons (Dražić, 1997). According to the geological map of Serbia and previous research (Miletić, 2004), the area of the municipality was built from different rocks in terms of the geological age and mode of occurrence, as well as in terms of their petrographic and chemical composition. In terms of geology, the oldest rocks include Paleozoic crystalline shales, triad and cretaceous limestone, sandstone and marl. The hilly terrain developed on these rocks. The lower hilly and flatland terrains comprise tertiary and quaternary sediments consisting of sand, clay, sandstone, limestone, loam, gravel, infusion ground and coal.

In the territory of the municipality of Lazarevac, terrestrial soil types are represented by eutric vertisols, eutric cambisols and luvisols, while hydromorphic soil types include fluvisols, gleysols, meadow soils, gleyic chernozems cambisols

gleyc and gleysols molic soil. Besides the natural soil types, large areas of the territory of Lazarevac municipality are covered with anthropogenic soil. Above all, they are represented by deposols that originate from the waste deposited on the open-pit coal mine sites and occupy large areas. Deposols (mine soils) of the area are the soils of poor productivity because they are poor in plant nutrients that are readily available to plants. In addition to deposols, technosols can also be found. These are soils formed by the disposal of the products from industrial and technological processes. These soils include technosols which result from coal combustion in thermal power plants and the sludge dumps that result from by coal washing. These soils occupy very small areas in the municipality (Miletić, 2004).

2.2. The status of forests and forest land

According to the data obtained from the Forest Management Plan (General forest management plan for Podrinje – Kolubara forest area (2004 – 2013)), about 18% of the territory, i.e. 7, 024 ha, are covered in forest, about 800 ha of which are plantations established in the period between 1973 and 1993 during the recultivation of mine spoil banks, and to a lesser extent ash dumps (35 ha). In the selected area there are 3,100 ha of forests, which makes up 5.7% of the total area of the municipality.

These are mostly coppice forests whose composition has been changed compared to their natural potential and fragmented into a large number of small areas. Most of the forests are privately-owned. Hilly terrains are dominated by elm and common maple, whereas in the lowland, Hungarian oak and Turkey oak are the most abundant species. In the forest stands that are found on deposols, the most common are pure black pine plantations (*Pinus nigra*) and those of scots pine (*Pinus silvestris*), followed by mixed plantations of various conifers. Pure plantations consisting of other species of conifers (*Larix europaea*, *Larix japonica*, *Pseudotsuga menziesii*, *Pinus strobus*) occupy small areas. There are occasional plantations of broadleaved tree species (*Quercus robur*, *Quercus petraea*, *Acer pseudoplatanus*, *Acer negundo*, *Alnus glutinosa*, *Fraxinus excelsior* and others).
Apart from Weymouth pine and occasionally black pine plantations, the forests raised on the mine spoil banks are mostly very vital and of good health. The processes of soil restoration, oxygen infiltration, regulation of infiltration and surface runoff, decomposition of organic matter and humus formation have been initiated (Miletić, 2004).

The following tables give an overview of the areas by their land use categories, with particular reference to the structure of forest areas.

Table 1. *Relation of existing and planned areas by category of land use in Lazarevac municipality*

Municipality of Lazarevac	A/km^2	Surface balance	Building land	%	Agricul. land	%	Forest land	%	Other	%
	37.54	existing	3.85	10.26	21.92	58.38	11.34	30.21	0.43	1.15
		planned	3.85	10.26	21.62	57.59	11.34	30.21	0.36	0.96

Source: Regulation on the establishment of the Spatial Plan for the area of special purpose - infrastructure corridor Belgrade-South Adriatic, section Belgrade-Požega, "RS Official Gazette" vol. 37/2006, 31/2010

Table 2. *State forests by basic categories of land use*

Municipality Lazarevac	Total area (ha)	Forests and forest land			Other land			Occupied land
		Total	Natural and artificial forests	Forest land	Total	Infertile land	For other purposes	
	1311,37	1184,40	1102,34	82,06	126,97	46,88	80,09	-

Source: General forest management plan for Podrinje – Kolubara forest area (2004 – 2013)

According to the natural, spatial and functional needs and requirements of the forests in the area, the areas of forests and forest lands are allocated according to their priority functions to the following units:

- **unit `10`**, intended for the production of technical wood, was established on the surface area of 392.94 ha or 36% of the total forest area;
- **unit `12`**, production-protection forests, was established on the surface area of 158.20 ha or 14% of the total forest area;
- **unit `16`**, a large game hunting and breeding center, was established on an area of 356.85 ha or 32% of the total forest area;
- **unit `18`**, intended for the production of other products (lignite production), was established for the needs of coal exploitation on an area of 185 ha or 17% of the total forest area;
- **unit `26`**, intended for soil conservation of degree I;
- **unit `66`**, intended for permanent forest protection and represented by a much smaller area compared to other units.

2.3. Potential vegetation in the municipality of Lazarevac

The potential natural vegetation of Lazarevac municipality comprises the following forest communities:

1. The willow and poplar forest **– *Populeto-Salicetum* Paradis. 1950.** The community of willow and poplar in the area of Lazarevac represent potential natural vegetation on smaller riparian areas of the rivers of Kolubara, Tamnava, Turija and Peštan and their tributaries, where the influence of flooding and ground waters is very pronounced.

2. The monodominant forest of narrow-leaved ash **– *Fraxinetum angustifoliae* Vuk. 1959.** These forests occupy depressions in which water has been stagnationg for a long time.

3. The forest of narrow-leaved ash and spreading elm **– *Fraxino angustifoliae-Ulmetum effusae* Slav. 1952.** These forests occupy considerable foreland areas with a pronounced oscillation of groundwater resulting in the abrupt terrain drainage.

4. Forest of pedunculate oak with narrow-leaved ash **– *Fraxino angustifoliae-Quercetum roboris* B. Jov. et Tom. 1979.** These forests occupy a belt between the hygrophilous willow and poplar forests in the riparian zone and mesophilous pedunculate oak and common hornbeam forests which cannot be reached by flood waters.

5. The forest of pedunculate oak **– *Genisto elatae-Quercetum roboris* Horv. 1938.** The forests of pedunculate oak occupy lower terrains, sufficiently moist due to high groundwater levels, which can be periodically flooded.

6. The forest of pedunculate oak and common hornbeam **– *Carpino betuli-Quercetum roboris* Anić 1959.** Pedunculate oak and common hornbeam forests occur in fragments in the Kolubara basin, being a transition variant between hygrophilous pedunculate oak forests and zonal forests of Hungarian oak and Turkey oak. Groundwater is present at a depth of 2-3m. The community is species-rich.

7. The Hungarian oak and Turkey oak forests **– *Quercetum farnetto-cerris* Rud. 1949.** The community forms potential natural vegetation in the largest part of the municipality. It is a climax community of Serbia. It is found on eutric cambisols, eutric vertisols, luvisols and planosols.

8. Forest of sessile oak and common hornbeam **– *Querco-Carpinetum moesiacum* Rud. 1949**.Sessile oak and common hornbeam forests occur in the area as a variant of extrazonal vegetation, at lower altitudes, in shaded cool valleys, on wet and cold exposures in the zone of climax forests of Hungarian oak and Turkey oak.

According to the phytosociological research (Miletić, 2004) and based on the floristic composition of natural vegetation, the potential natural vegetation of MEC (Mining and Energy Company) `Kolubara` include four different communities: ***Quercetum farnetto-cerris* Rud. 1949, *Carpino-Quercetum robori cerridis* Jov. 1967, *Ulmeto-Quercetum roboris* B. Jov. 65. and *Populeto-Salicetum* Paradis. 1950**.

2.4. The actual vegetation in the municipality of Lazarevac

According to the research done by (Vučković, 1986), in the area of Lazarevac municipality, the actual vegetation consists of the following forest communities:

1. White willow forests – ***Salicetum albae* Issl. 1936.**
2. Forests of common oak – ***Genisto elatae-Quercetum roboris* Horv. 1938.**
3. Forests of common oak and common hornbeam – ***Carpino betuli-Quercetum roboris* Rauš 1971.**
4. Forest of common oak, common hornbeam and Turkey oak with limes – ***Carpino betuli-Quercetum roboris tilietosum tomentosae* Rauš 1969.**
5. Forests of sessile oak and common hornbeam with butcher's broom – ***Querco-Carpinetum aculeatetosum* Jov. 1951.**
6. Forests of sessile oak and common hornbeam with Hungarian oak – ***Querco-Carpinetum quercetosum frarnetto* Gaj.**
7. Submontane beech forests – ***Fagetum submontanum* Jov. 1967.**
8. Forests of Hungarian oak and Turkey oak **– *Quercetum farnetto-cerris* Rud. 1949.**
9. Sessile oak forests – ***Quercetum montanum* Cher. et Jov. 1953.**
10. Forests of sessile oak with moss – ***Quercetum montanum muscetosum* Slav.**

3. MATERIALS AND METHODS

Potential areas for the establishment of forest plantations for energy needs were allocated with close attention to the current purpose and use of the available areas. Forests were not taken into consideration unless they were small fragments of scattered and degraded woodlots that prevented the formation of larger units of energy plantations. The ones that are accessible and enable the formation of larger units of energy plantations were selected. Areas that were not actively used for agricultural purposes were selected, as well. These were abandoned, uncultivated areas and possibly extensively managed plots. Finally, areas of uncultivated mine spoil banks were selected for energy plantations. These were the input elements based on which the criteria for the selection of about 2000 hectares of areas suitable for the establishment of the plantations were defined.

The main criteria based on which suitable areas were selected and classified are the following:

- to avoid a reduction in active agricultural production;
- to introduce some production into the uncultivated and abandoned areas;
- to make abandoned and uncultivated areas suitable to be used for agricultural production again and without major investments;
- to ensure that selected areas are accessible by heavy and easy mechanization and that the mechanization can move on them despite the slope of the terrain and other conditions;
- to ensure that the selected areas have a predefined minimum surface area. Selected areas of less than 1 ha could be taken into consideration only if they are located near the mainland or near a road which makes them readily accessible.

According to the listed criteria, all selected areas can be classified into the following categories: barrens, barrens with natural vegetation, neglected lands, areas with extensive agriculture, scattered and devastated forests and mine spoil banks.

Barrens are areas that are not cultivated and used for any plant production. Within them, the selected areas are located close to roads and watercourses, as well as the areas that could be merged with other suitable surface areas to make larger units and achieve the profitability of the establishment, maintenance and exploitation of energy plantations

Neglected land is represented by areas that were once used for agricultural purposes. However, due to the abandonment of rural households, they have not been used for agricultural production for a long time. They are mostly overgrown with weeds and they do not fully exploit the site potentials.

The areas of extensive agricultural production are similar to the previous ones as they also do not fully exploit the potentials of the site. Such areas were taken into consideration only if the formation of larger units consisting of previously selected areas was required.

As in the case of the previous ones, **devastated forests** were considered only if they consisted of smaller fragments that intersected with the selected and more suitable areas.

Finally, **mine spoil banks** which are result of coal mining were also considered to be suitable areas for energy plantations. These are disturbed natural sites with different bedrocks.

Selection of species for the establishment of energy plantations was done with special attention to the ecology of species and their energy values.

4. RESULTS AND DISCUSSION

4.1. The structure of the areas selected for energy plantations in terms of geological conditions

The selected areas have a highly diverse bedrock. In terms of geology, **mine spoil banks** are most represented in the selected areas. They include soils that are designated as deposols. Based on the previous research and the fieldwork designed and conducted by the Institute of Forestry, it can be concluded that they are suitable for the selected tree species (Dražić, 1997; Miletić, 2004). Mine spoil banks account for about ¼ of the areas selected for forest plantations for energy needs. The species that have had the best performance on the bedrock mentioned are the black alder and the birch.

Following the mine spoil banks, **gravel, sand, alevrolite and pelitolyte** in the riparian area of the alluvial plain are most frequently occurring. This formation occupies about ¼ of the total area. Depending on other ecological conditions of these bedrocks, the following species are selected: narrow-leaved ash and red oak (hardwood species), black alder (medium hardwood species) and poplar and willow (soft hardwood species) species.

The slightly higher parts of the alluvial plain are composed of **marly clay, charcoal clay, diatomaceous soil and sand.** Depending on the type of soil and potential vegetation, energy plantations of predominantly hardwoods (red oak, common hornbeam, black locust) are planned. Soft hardwoods include black alder and poplar trees although on a smaller scale and in specific conditions.

On the elevated terrains, the selected areas are represented by **clay, sand and rarely gravel (Pannonian).** They are suitable for hard hardwoods. The red oak was selected for the lower parts where groundwater still occurs. For the mesophilous conditions of higher terrains, the common hornbeam is selected as a species with the highest energy value. For the southern aspects, the black locust is selected.

Other bedrocks are less frequent in the area and they occur in the mountainous belt of the municipality of Lazarevac.

4.2. The structure of the areas selected for energy plantations in terms of soil conditions

Under the influence of different geological substrates and other pedogenetic factors, different soil types were formed on the selected areas for energy plantations. Depending on the method of moistening the soil profile, semi-terrestrial (in the flatland area of the alluvial plain) and terrestrial soils (in the mountainous part of the area) occur in the entire area of Lazarevac municipality.

The most frequent soil type selected for the establishment of fast-growing energy plantations is **deposol**. Based on previous experience, black alder and birch would be the most suitable species for energy plantations.

Semi-terrestrial soils are more abundantly present than the terrestrial ones and the largest area is occupied by **fluvisols**. The following species are selected for these soil types: narrow-leaved ash, black alder, poplar, willow and red oak. In the alluvial plain, there are **planosols, gleyic planosols and eutric cambisols.** On these types of soil, the following species of trees are most frequently used: poplar, red oak, narrow-leaved ash and black alder.

Among the terrestrial soils in the mountainous zone, **dystric cambisol** is most commonly occurring in the isolated areas. The most frequently used tree species on this type of soil are lime, common hornbeam and aspen. There is also **eutric cambisol**, with the following tree species most frequently used: black locust, common hornbeam, aspen, lime and red oak.

Soils such are **planosols, luvisols and dystric cambisol** occupy smaller areas. They are suitable for the following tree species when establishing plantations for energy needs: common hornbeam, aspen, red oak and black locust.

Other soils such are **eutric vertisols and calcaric cambisols** are very rare in the selected areas.

4.3. The structure of the areas selected for energy plantations based on the potential vegetation

Potential vegetation combined with edaphic conditions is a key environmental factor for the selection of tree species for forest plantations for energy purposes.

In the lowest flatlands, the selected areas are within the sites of potential vegetation of **poplar and willow forests**. Forest plantations of black alder and willow are planned to be established there. There are few such areas.

In the depressions of alluvial plains, these are followed by the areas of potential vegetation of **narrow-leaved ash forests** with a very high level of groundwater. The following species are planned in this area: narrow-leaved ash and black alder. The sites with a lower level of groundwater, though still high, belong to the potential vegetation of **common oak and narrow-leaved ash forests**. The most common species selected for these sites are narrow-leaved ash, common alder, poplar, red oak and willow.

Drier sites of alluvial plains belong to the potential vegetation of pure **common oak forests**. The most frequent species selected for these sites are common alder, red oak, poplar, narrow-leaved ash and common aspen.

Micro-hills are occupied by the sites of **common oak with common hornbeam**. The most common species selected for these sites are red oak, common alder, poplar and common hornbeam.

In the mountainous part of the region, the more frequent one is the site of the climax forests of Hungarian oak and Turkey oak. In the mesophilous ecological conditions, on the sites of potential vegetation of **Hungarian oak and Turkey oak**, plantations of common hornbeam trees are planned to be established, in the most xerophilic ones the black locust, and in the transitional ones the common

aspen and the lime. For the mesophilic sites of **beech**, the intensive common hornbeam plantations are selected.

4.4. The structure of the areas related to the current land use

Within the areas selected for energy plantations, about 1/3 of the total area is barren land. The **barrren land** which has not been used for plant production for a long time has stands of low-value **spontaneous forest vegetation**. If they are located in accessible places or there is a possibility to merge them with other suitable areas, these areas are also selected for the establishment of forest plantations for energy needs. Isolated areas, as well as those that are more difficult to access, are left for afforestation. Barren land and barren land with spontaneous natural vegetation occupy about 58% of the selected area.

The uncultivated and abandoned areas are not optimally used in agricultural production. Therefore they could be temporarily used for the establishment of forest plantations for energy needs due to their short production cycle. However, if necessary, they could be returned to agriculture. Such areas in the municipality of Lazarevac occupy about 7% of the total area.

In the municipality of Lazarevac, areas with **extensive agricultural production** that are allocated for the establishment of forest plantations for energy needs occupy about 6% of the total area. These are predominantly areas of lower fertility classes used as pastures and the ones that produce low agriculture yields.

Devastated forests were mostly avoided. They are selected only exceptionally (2%) for the establishment of forest plantations for energy needs to merge larger complexes.

Physical properties and chemical composition of **mine spoil banks** may be unsuited for agricultural production. Establishment of forest plantations for energy needs is another optimum way of their utilization and recultivation. In the municipality of Lazarevac, about 27% of the total area is represented by these areas. Selecting the appropriate dendroflora species, method of setting up the protection zone and technological procedure for soft landscaping of plateaus and slopes will result in restoration and strengthening of natural components, creation of more favorable microclimatic conditions, protection of land from erosion, protection of the open pit surrounding area from air pollution, and creation of visual barriers and habitats for the return of the old and arrival of the new plant and animal species (Čule *et al*., 2013).

4.5. Tree species selected for the establishment of energy plantations

From a wide range of autochthonous and allochthonous species, it was necessary to select tree species that would optimally use the potentials of the site and provide high energy values in the given ecological conditions. Accordingly, the following criteria were defined:

1. It is necessary to respect the ecology of species and available sites;

2. It is necessary to select species according to their energy values;

3. Priority should be given to autochthonous broadleaved species which will not degrade the sites and can be easily replaced with other species, if there is a need to change the purpose of the area;

4. Selected species should have a meliorative impact on the soil (regulation of the level of groundwater, erosion control, soil structure improvement and enrichment with organic matter and nitrogen).

In conformity with the criteria mentioned, the municipality of Lazarevac was divided into a flatland and a hilly zone:

1. In the flatland zone beside the rivers in the alluvial plains with the highest level of groundwater, at the sites of white willow, black alder and less often of common oak with black alder the following species are proposed: ***Salix viminalis***, ***Alnus glutinosa*** and ***Fraxinus angustifolia***; According to previous experience in the recultivation of deposols in the area planned and carried out by the Institute of Forestry, black alder proved to be very productive. In addition, this species has a very favorable effects on the improvement of anthropogenic sites [3].

2. Regarding the higher terrains, on willow and poplar sites and in small parts of common oak sites, rapid-growing **clones of the Euroamerican poplar** are selected (***Populus euroamericana* cl. I-214**);

3. In the area of common oak sites, **red oak** (***Quercus rubra***) is most commonly selected;

4. In alluvial deposits of higher terrains, on the sites of potential vegetation of common oak and hornbeam, the **common hornbeam** (***Carpinus betulus***) is selected for planting; These sites are still under a certain influence of groundwater on semi-terrestrial soils, thus a significant growth increment of common hornbeam as a species with the highest energy value is expected here.

5. In the pre-hilly zone where common oak is present either individually or in groups, plantations of **red oak** (***Quercus rubra***) are planned to be built; This is a species with high coppice vigor and rapid growth in youth.

6. Common hornbeam (***Carpinus betulus***) is also selected on the sites of potential montane beech vegetation of the hilly zone;

7. The **common hornbeam** is also selected for the mesophilous sites with deeper soil and shaded aspects of the sites of potential vegetation of Hungarian oak and Turkey oak with common hornbeam;

8. For the transitional sites with more favorable ecological conditions and deeper soils of potential vegetation of Hungarian oak and Turkey oak, **silver lime** (***Tilia argentea***) is proposed;

9. The barren lands or abandoned agricultural lands of the hilly zone are planned to be planted in **common aspen** (***Populus tremula***)

10. On the driest sites of potential vegetation of Hungarian oak and Turkey oak forests with southern aspects and shallow and skeletal soils, **black locust** (***Robinia pseudoacacia***) is selected; It was difficult to find an adequate species that suits the low potentials of the site, that is fast-growing, has high coppice vigor and high energy value. In this case, although it is an allochthonous and invasive species, black locust was the best choice.

11. In the hilly zone, another pioneer species showed good results, especially on the mine spoil banks which were formed due to the surface coal mining. It is the **birch** (***Betula verucosa***). It has a very high tolerance to deposols,

high-acidity soils and the presence of coal in the substrate. The species itself spontaneously colonize these sites. It has a rapid growth in youth and a high rate of coppice growth.

5. CONCLUSION

There is a growing need for renewable energy in the whole world. Wood is an important, renewable, natural source of energy. Therefore, the demand for the establishment of fast-growing plantations for energy is growing rapidly.

The municipality of Lazarevac is located near Belgrade. The road network is relatively well-developed. The territory of the municipality is characterized by a low percentage of forest cover (5.7%). Due to its high population, the need for renewable energy sources is increasing.

In selecting areas for establishing forest plantations for energy needs, we focused on the areas that are not optimally used in agricultural production or agriculture is only extensive. These are generally areas of lower fertility. In addition, we selected areas that were connected in larger complexes and located along the existing roads allowing the application of easy and heavy mechanization.

The natural conditions (relief, hydrography, climatic and edaphic conditions) enabled the selection of a wide range of tree species for the needs in question. In proposing species for energy purposes, besides their energy value, special attention was paid to the ecology of species in relation to the ecological conditions in each specific case.

Given that Serbia has no experience in the establishment of forest plantations for energy needs, the plantations in Lazarevac municipality could be used as a test site for further research.

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SELECTION OF POTENTIAL AREAS FOR THE ESTABLISHMENT OF FOREST PLANTATIONS FOR ENERGY NEEDS – THE CASE OF LAZAREVAC MUNICIPALITY

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Summary

In 2016, the Forestry Institute in Belgrade carried out a preliminary study on the establishment of forest plantations for energy needs. As a pilot project for the establishment of forest plantations for energy purposes, the municipality of Lazarevac was selected. In selecting potential areas for the establishment of forest plantations, strict attention was paid to the current use of the available areas. The subject of the work is the area that is possible, but not necessarily, for the needs of such production. From a wide range of autochthonous and allochthonous species, tree species were selected that are the most capable to exploit the potentials of the habitat and provide high energy values in the given ecological conditions. Given that Serbia has no experience in the establishment of forest plantations the plantations in Lazarevac municipality could be used as a test site for further research.

IZDVAJANJE POTENCIJALNIH POVRŠINA ZA OSNIVANJE ŠUMSKIH ZASADA ZA ENERGETSKE POTREBE NA PRIMERU OPŠTINE LAZAREVAC

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Rezime

Institut za šumarstvo Beograd je 2016. godine uradio preliminarnu studiju o osnivanju šumskih zasada za energetske potrebe, a kao idejni pilot projekat za osnivanje šumskih zasada za energetske svrhe izabrana je opšrina Lazarevac. Prilikom izdvajanja potencijalnih površina za osnivanje šumskih zasada, strogo je vođeno računa o dosadašnjoj nameni i korišćenju raspoloživih površina. Predmet rada su površine koje je moguće, ali ne

i nužno izdvojiti za potrebe ovakve proizvodnje. Iz širokog spektra autohtonih i alohtonih vrsta, izdvojene su vrste drveća koje najbolje koriste potencijal staništa i obezbeđuju visoku energetsku vrednost u datim ekološkim uslovima. S obzirom da u Srbiji nemamo dovoljno iskustva sa osnivanjem šumskih zasada za energetske potrebe, osnovani šumski zasadi na području opštine Lazarevac bi u budućnosti mogli poslužiti kao ogledni poligon za dalja istraživanja.

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CLIMATE CHARACTERISTICS OF MOUNTAIN BEECH FORESTS BELT *(Fagetum montanum illyricum* Fuk. et Stef. 1958*)* ON MANJAČA

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Abstract: *This paper describes climate characteristics of mountain beech forests belt on Manjača in the southwestern part of the Republic of Srpska, based on climate data from typical meteorological stations for this region (for the period of ten years 1971-1980). Based on specific temperature and precipitation gradients, average values of the most important climate elements for the studied area are determined by extrapolating. Also, annual and monthly values of climate elements that are important for development of vegetation such as: temperature and precipitation regime, climate-geographical characteristics - thermodrome coefficient by Kerner (KP), drought index by De Martonn (Is), Furnije's coefficient for pluviometric climate aggressiveness (C) are shown. Also, climate classifications by Lang and method of hydric balance by Thornthwaitte.were used for characterization of climate. The aim is determination of climate-geographical factors and characterization of the climate characteristics in belt of mountain beech forests on Manjača, aas well as climate impact on growth and development of forest vegetation in the study area.*

Key words: Manjača, climate elements, climate type.

КАРАКТЕРИСТИКЕ КЛИМЕ У ПОЈАСУ БУКОВИХ ШУМА (*Fagetum montanum illyricum* Fuk. et Stef. 1958) НА МАЊАЧИ

Извод: *У раду су приказане климатске карактеристике шумског појаса планинске букве на Мањачи у југозападном делу Републике Српске, а на основу климатских података десетогодишњег периода мерења (1971-1980), за ово подручје карактеристичних метеоролошких станица. На основу одређених температурних и*

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градијената падавина, екстраполацијом су утврђене просечне вредности најважнијих климатских елемената за истраживано подручје. Такође су приказане годишње и месечне вредности климатских елемената, значајних за развој вегетације: температурни и падавински режим, климатско-географске карактеристике – термодромски коефицијент по Kerner-у (KP), индекс суше по De Martonne-у (Is), Furnije-ов коефицијент за плувиометријску агресивност климе (C). За карактерисање климе коришћена је класификација климе по Lang-у и метода хидричног биланса по Thornthwaitte-у. Циљ рада је утврђивање климатско-географских показатеља и карактерисање обележја климе у појасу букових шума на Мањачи, те утицаја климе на раст и развој шумске вегетације анализираног подручја.

Кључне речи: Мањача, климатски елементи, тип климе.

1. INTRODUCTION

Global climate, biological, geological, and chemical processes and natural ecosystems are interconnected, and changes in any of these environmental components can affect humans and other living organisms (Brašanac-Bosanac, Ćirković-Mitrović, 2013). Climate is one of the major environmental factors. It is closely related to other components of the ecosystem in which it has a clearly defined function and importance (Eremija, 2010). Climate conditions determine the occurrence and survival of vegetation in a given area as well as the interrelationships among the constituents of the ecosystem. Climate is closely related to other components of the forest ecosystem and has a significant impact on the growth and development of trees and stands (Kapović, 2011). Climate affects every aspect of a forest, its growing conditions and productivity in a particular area, as well as its regeneration and use (Govedar, 2011). The regimes of rainfall and air temperature are of particular importance to forest ecosystems whose survival and risk depend on a large number of environmental impacts, including climate (Kapović et al., 2013). Some elements of climate affect the intensity of photosynthesis and respiration and other important processes related to the forest stocking. Furthermore, climate has a great impact on the stability of forest ecosystems, with its fluctuations creating favourable conditions for the occurrence of certain phenomena, such as storms or fires. These phenomena can destabilize forest ecosystems in a very short time and often cause their deterioration. Recent research is increasingly focusing on the impact of climate change on forest ecosystems and their resilience to this phenomenon, which varies with their capacity to adapt. To cope with climate change, plant species will need to adapt to changing conditions or migrate to more suitable sites (F A O, 2013 and 2008). Global warming will lead to the extinction of a great number of plant and animal species, biodiversity loss, changing precipitation regimes, reduced availability of water reserves, changes in the frequency and intensity of climate extremes and many other adverse effects on human health (Kadović, Medarević, 2007). Forest ecosystems will change with the global climate change since physiological tolerance limits of species may be exceeded and the rates of biophysical forest processes change. Increasing temperatures cause biological processes, *i.e.*,

metabolism, respiration, litter decomposition, forest soil mineralization and nitrification to be accelerated, which consequently modifies the biological function of forests (Thompson et al., 2009). The way forests were managed in the past will continue to play a key role in reducing the impact of climate change on forests and the ability of forests to adapt to newly-established climate conditions (Gitay et al., 2001). Due to climate change, Serbia has recently faced frequent and heavy floods, active landslides and erosion, strong wind gusts, frequent and prolonged droughts, with weather extremes affecting both urban and rural areas (Brašanac-Bosanac, 2014).

The study area is located in southwestern Republika Srpska, which is characterized by heterogeneous climate conditions. This area has different climate influences that alternate and combine, which makes it difficult to determine the boundaries between different types of climate (Milosavljević, 1973). From the Sava River in the north to the inland of the Dinarides in the south, the western variant of the Pannonian climate alternates with the humid continental climate and the valley-basin climate, leading to the mountain climate as a variant of the continental climate dominating in the mountains of the southwestern Republika Srpska. The study aimed to determine climate and geographical parameters and characterize the climate in the beech forest belt on Mount Manjača, as well as the impact of climate on the growth and development of the forest vegetation in the study area.

2. STUDY AREA AND METHOD

The study area extends from 44º 28' N to 16º 56' E. It is about 40 km away from Banja Luka. The mountain stretches in a north-south direction, which deviates from the usual direction of the mountains of the Dinaric Alps. Regarding the geomorphology of the area, the largest part of it is a karst plateau with sinkholes. Regarding the orography, it belongs to the lower mountain zone, and its altitude ranges from 800 to 1150 m. It is mainly covered in forest communities of montane beech *(Fagetum montanum illyricum,* Fuk. et Stef., 1958*)*.

Data on average monthly and annual air temperatures and precipitation for the period 1971-1980 were used to determine the climate characteristics of the study area. Data on average air temperatures were obtained from the weather stations of “Banja Luka”, “Kneževo” and “Jajce”, and data on precipitation from “Bočac”, “Trijebovo”, “Ključ”, and “Čađavica”. The insufficient number and unfavorable distribution of weather stations have limited the precise definition of the effects of different currents and their spatial delimitation (Stefanović, 1983).

Based on the determined temperature and precipitation gradients, the average values of temperature and precipitation were extrapolated for the study area. The annual, monthly, and growing season values are presented, as well as the annual amplitude of the most important climate elements – air temperature and precipitation. Geoclimatic indicators were also determined. They included the Thermodrome Coefficient after *Kerner* (KP), *De Martonn* Aridity Index (Is), and *Fournier* Index of Pluviometric Climatic Aggressiveness (C). The *Lang* Climate Classification and the Thornthwaite Water Balance technique were used for the characterization of climate.

3. RESEARCH RESULTS AND DISCUSSION

Air temperature

The mean annual air temperature in the study area is 6.9ºC (Table 1). The growing season is characterized by a mean air temperature of 12.2ºC. High air temperatures occur during the summer season when the mean temperature amounts to 15ºC. The mean maximum air temperature in July is 15.8°C, while the average monthly minimum in January amounts to – 1.6°C. Besides January, temperatures below zero are recorded in another two winter months, which allows the snow cover to persist longer. The mean annual amplitude of air temperature is 17.4ºC. Temperature inversions are common in lower and sunken areas (depressions). The study area has a typical continental type of the temperature regime – July is the warmest month of the year and January the coldest (K o l i ć, 1986a).

Табела 1. *Средње мјесечне вриједности температуре ваздуха и падавина*
Table 1. *Mean monthly air temperature and precipitation values*

Месец Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Год. Year**
Температура (°C) Temperature (°C)	-1,6	-0,6	2,5	5,3	10,9	14,0	15,8	15,1	11,9	7,0	2,9	-0,2	6,9
Падавине (mm) Precipitation (mm)	91	64	61	101	105	102	122	107	109	126	109	90	1187

Precipitation

The annual distribution of precipitation is one of the most important characteristics of the climate of an area. The study area is characterized by high rainfall throughout the year. Combined with the relatively low mean air temperature, it makes the main cause of the humid climate. The annual rainfall average of the study area is 1187 mm. There are two rainfall maxima during the year (Table 1): one in July (122 mm) and another in October (126 mm). The minimum rainfall is 61 mm in March. During the growing season, the area receives an average of 646 mm of precipitation, which is 54.4% of the total annual rainfall. Due to heavy rains in July and August, the area receives 229 mm of precipitation or 19.29% of the total annual rainfall. Combined with the increase in the mean air temperature, it increases the rate of evapotranspiration. It also causes an increase in the relative air humidity and contributes to the humid climate. Such distribution of rainfall is of great importance for the normal growth and development of trees in the study area. The highest rainfall occurs in autumn, with a relative share of 29%. The major rainfall maximum occurs in October, the lower one in July, while the major rainfall minimum occurs in March and the lower one in February. The relative share of precipitation in the colder part of the year is 21%, while it amounts to 28% during the summer months. There are no dry months here due to the even distribution of rainfall. The study area has a continental type of precipitation regime – over 50% of rainfall is in the growing season, although the rainfall maximum occurs in October.

Climate classification after Lang

Lang's bioclimatic classification is presented based on the annual and seasonal values of the rain factor – RF (Table 2). According to the annual value of the Lang Rainfall Factor, the perhumid climate (RF> 160) prevails in the study area, which allows the forest vegetation to be at its physiological optimum. During the growing season, the climate is humid (RF=80–160). During the winter months, the climate is hyperhumid, while it is semi-arid in summer and subhumid humid in autumn.

Табела 2. *Вриједности Lang-овог кишног фактора*
Table 2. *Lang Rain Factor values*

	KF/RF
Година – Year	172.0
Вегетациони период – Growing season	105.9
Пролеће – Spring	57.1
Лето – Summer	29.5
Јесен – Autumn	63.1
Зима – Winter	-

Thornthwaite Water Balance

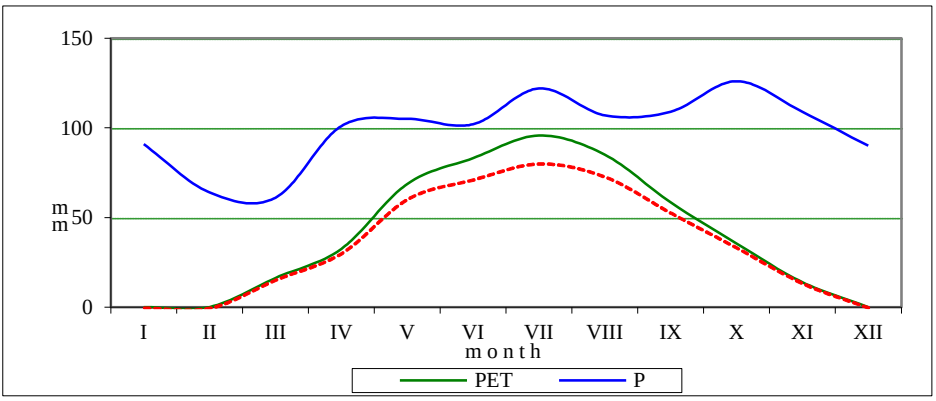
The soil water balance, i.e. the ratio of surplus, deficiency, and reserves of water in the soil, is of particular importance for the survival, growth, and development of plants. Plants have different water requirements, which depend on the characteristics of plant species. The fulfillment of these requirements is determined by environmental conditions, primarily energy and temperature conditions and rainfall totals. This method uses rainfall and air temperature values, which are adjusted depending on the daylight length and the latitude of the station. The results of the Water Balance calculation are shown in Table 3 and Graph 1.

Табела 3. *Основни климатски показатељи за подручје истраживања по Thornthwaite-у*
Table 3. *Main climate indicators for the study area after Thorntwaite*

Месец Month	**T (°C) T (°C)**	**и i**	**(IIET) mm (PET) mm**	**IIET (mm) PET (mm)**	**II (mm) P (mm)**	**CET(mm) AET(mm)**	**M (mm) M (mm)**	**V (mm) V (mm)**
I	-1.6	0.0	0.0	0.0	91	0.0	0.0	91.0
II	-0.6	0.0	0.0	0.0	64	0.0	0.0	64.0
III	2.5	0.4	15.3	16.2	61	15.7	0.4	45.3
IV	5.3	1.0	28.7	32.4	101	30.7	1.8	70.4
V	10.9	3.3	52.3	68.6	105	60.8	7.8	44.3
VI	14.0	4.8	64.4	83.0	102	71.6	11.5	30.5
VII	15.8	5.7	71.2	95.7	122	80.4	15.3	41.6
VIII	15.1	5.3	68.6	85.0	107	73.0	12.1	34.0
IX	11.9	3.7	56.2	58.5	109	52.8	5.7	56.2
X	7.0	1.7	36.1	35.5	126	33.4	2.1	92.6
XI	2.9	0.4	17.3	13.9	109	13.6	0.3	95.4
XII	-0.2	0.0	0.0	0.0	90	0.0	0.0	90.0
God.-Yearly	6.9	26.3	410.1	488.8	1187	432.0	57.0	755.3
IV-IX	12.2	23.8		423.2	646	369.3	54.2	277.0

Potential evapotranspiration, i.e., the amount of water that evaporates under given energy and temperature conditions is greater than the actual evapotranspiration except in the cold, winter period when the PET and AET values are approximately equal. It amounts to 488.8 mm or 41% of the total rainfall.

Apart from the energy-temperature conditions, actual evapotranspiration depends on the amount of precipitation and amounts to 88% of the potential (maximum possible). Graph 1 shows that the amount of moisture that can potentially evaporate is greater than the amount of water that actually evapotranspires. During the year, the rainfall in the study area is higher than the AET, so the soil generally has favorable moisture.



Графикон 1. *Климадијаграм по Thornthwaite-у*
Graph 1. *Thornthwaite Climate Diagram*

There is a deficiency of water in the soil during the summer months, but it is not very pronounced. The highest average value of water deficiency occurs in July. The area is mostly characterized by the constant presence of moisture surplus in the soil. A more pronounced surplus is recorded in the colder part of the year – from November to April, accounting for 38% of the annual rainfall. The ratio of the surplus to deficiency of water in the soil shows that forest trees in the study area have sufficient moisture for their growth and development.

The general climate index was calculated based on the values of the Aridity Index – Ia and the Humidity Index – Ih (Table 4):

Tabela 4. *Indeksi aridnosti, humidnosti i klimatski indeks*
Table 4. *Aridity, Humidity and Climate Indices*

Индекси **Index**	**Година** **Year**	**Вег. период** **Growing season**
Ia	11.65	12.78
Ih	154.54	65.43
Ik	147.55	57.77

According to the values of the annual climate index in the study area, it is dominated by the perhumid climate – A, while the moderately humid – B2 climate prevails during the growing season.

Geoclimatic characteristics

The interelatedness between the geographical location of a site and the elements of climate are called geoclimatic characteristics (K o l i ć, 1988). The values of the most important geoclimatic characteristics are shown in Table 5.

The degree of climate continentality determined by the *Kerner* Thermodromic Coefficient (KP%) expresses the degree of the landmass influence. According to this element, the study area has a humid continental – mountain climate.

The type of runoff determined using the *De Martonne* Aridity Index (Is) shows that there is a pronounced exoreism in the study area, i.e., the water runoff is abundant, which means that the study area is highly forested.

The pluviometric vulnerability determined by the *Fournier* Index of Pluviometric Climatic Aggressiveness (C), i.e., the vulnerability of the area to pluvial erosion (caused by the impact of raindrops) point to moderate vulnerability.

Табела 5. *Климатско-географске карактеристике*
Table 5. *Geoclimatic characteristics*

Континенталност подручја Continentality of the region		**Индекс суше по De Martonn-у De Martonn Aridity Index**		**Плувиометријска угроженост Pluviometric vulnerability**	
КП % KP %	Климатски тип Climate type	ИС IS	Отицање воде Runoff	Ц C	Тип угрожености Vulnerability type
9.8	Блага континентална - планинска Humid continental - mountain	70.2	Обилно Abundant	13.4	Осредња Moderate

Comparative climate indicators

Table 6 compares the research results on the mean precipitation (P), average maximum and minimum air temperature (T_{max} and T_{min}), the amplitude of temperature fluctuation (A) with the results of previous studies (Milosavljević, 1973). The mountain climate prevails in the study area.

Табела 6. *Упоредни климатски показатељи подручја са резултатима Милосављевића (1973)*
Table 6. *Climate indicators of the region compared with the results of Milosavljević (1973)*

Тип климе Climate type	**П (mm) P (mm)**	**Т год (°C) Tyear (°C)**	**$T_{мин}$ (°C) T_{min} (°C)**	**T_{max} (°C) T_{max} (°C)**	**А (°C) A (°C)**
Умерено-континентална Humid continental	700-1950	10,2	-0,3-3,0	> 20,0	20,0
Долинско-котлинска Valley-basin	750-1000	8,0-10,0	-3,0	18,0-20,0	20,0-21,0
Планинска Mountain	1200-1500	< 8,0	< -3,0	< 18,0	18,0-19,0
Подручје истраживања Research area	1187	6,9	-2,6	16,3	18,9

4. CONCLUSIONS

The article presents the climate characteristics in the forests of the montane beech of Illyrian region (*Fagetum montanum illyricum* Fuk. et Stef., 1958) in the Mount Manjača area in southwestern Republika Srpska.

The general characteristics of the temperature and precipitation regime of the analyzed forest belt are as follows: the mean annual air temperature is 6.9ºC and the mean annual precipitation is 1187 mm. There are no dry months during the year because rainfall is evenly distributed (over 50% of precipitation is in the growing season) so that the continental type of temperature and precipitation regime prevails.

Lang`s bioclimatic classification shows that the climate is humid during the growing and hyperhumid in winter. In summer, it is semi-arid and subhumid humid in autumn.

The water balance shows that during the year the potential evapotranspiration is greater than the actual one except in the cold winter period when their values are approximately equal. The lack of water in the soil occurs during the summer months but is not very pronounced. According to general and geoclimatic indicators, it can be concluded that the study area is characterized by a perhumid, humid continental climate – mountain type, with pronounced exoreism, moderate pluviometric vulnerability, which defines it as extremely forested areas with favourable conditions for the growth and development of forest trees.

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CLIMATE CHARACTERISTICS OF THE MONTANE BEECH FOREST BELT *(Fagetum montanum illyricum* Fuk. et Stef. 1958) ON MOUNT MANJAČA

Saša EREMIJA, Ljiljana BRAŠANAC-BOSANAC,
Tatjana ĆIRKOVIĆ-MITROVIĆ, Snežana STAJIĆ

Summary

The article presents the climate characteristics in the forests of the montane beech of Illyrian region (*Fagetum montanum illyricum*, Fuk. et Stef., 1958) in the Mount Manjača area in southwestern Republika Srpska. The general characteristics of the temperature and precipitation regime of the analyzed forest belt are as follows: the mean annual air temperature is 6.9ºC and the mean annual precipitation is 1187 mm. There are no dry months during the year because rainfall is evenly distributed (over 50% of precipitation is in the growing season) so that the continental type of temperature and precipitation regime prevails.

Bioclimatic classification based on Lang's rain factor shows that the climate is humid during the growing and hyperhumid in winter. In summer, it is semi-arid and subhumid humid in autumn.

The water balance shows that the potential evapotranspiration is greater than the actual one except in the cold winter period when their values are approximately equal. The lack of water in the soil occurs during the summer months but is not very pronounced.General and geoclimatic indicators, shows that research area is characterized with perhumid, mild-continental climate - mountainous type, with expressed egzoreism and average pluviometric vulnerability. This is area with favorable conditions for growth and development of beech forests.

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Original scientific paper

FOREST VITALITY (ICP LEVEL I AND SAMPLE PLOT LEVEL II-CRNI VRH AND MOKRA GORA) WITH A SPECIAL EMPHASIS ON ABIOTIC AGENTS IN THE REPUBLIC OF SERBIA IN 2019

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Abstract: The vitality of forests depends on environmental conditions and a great number of abiotic factors, such as climatic characteristics, atmospheric deposition, forest fires, direct atmospheric impacts. Nevertheless, abiotic agents are group of the most important factor threatening the trees sampled and monitored for more than a decade and a half in continuity. Therefore, further analysis can provide different trends of their direct effects and degrees of their out-turn. International program for further and more detailed monitoring of the forest condition in the Republic of Serbia (ICP Forests), which is carried out on both Level I and Level II(Mokra Gora and Crni Vrh) sample plots, will enable scientists to determine the vitality of forests both at the local and at the regional level. Results are vitality and health state of the forest ecosistems with emphasis on abiotic factors.

Key words: abiotic impacts, monitoring, state crown, Serbia

ВИТАЛНОСТ ШУМА (ICP НИВО I И НИВО II -ЦРНИ ВРХ И МОКРА ГОРА) СА ПОСЕБНИМ ОСВРТОМ НА АБИОТИЧКЕ АГЕНСЕ У РЕПУБЛИЦИ СРБИЈИ У 2019. ГОДИНИ

Сажетак: *Виталност шума зависи од услова животне средине и великог броја абиотских фактора, попут климатских карактеристика, атмосферских талога, шумских пожара, директних атмосферских утицаја... (Невенић et al., 2008b). Ипак, абиотски узрочници су најзначајнија група фактора који угрожавају*

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стабла, која се у континуитету прате више од деценије и по. Стога, даљња анализа може пружити различите трендове њихових директних ефеката и различито интерпретиране резултате. Међународни програм за даље и детаљније праћење стања шума у Републици Србији (ICP Forests, ICP за шуме), који се спроводи на огледним парцелама Нивоа I и II, омогућиће научницима да одреде вредност виталности шума како на локалном тако и на регионалном нивоу.

Кључне речи: абиотички утицаји, мониторинг, стање круна, Србија

1. INTRODUCTION

Forests decay is reflected in the impaired vitality of the trees and it is a consequence of the adverse effect of the abiotic and biotic factor originated. Complex of factors effects on the trees as living organisms and complex natural processes within forest biocenoses. Agents classified in one of these two groups may act simultaneously or alternate successively. Groups whose participation is one of those with special high risk for the health of forests are emphasized this time meaning abiotic factors group. Some occur along with biotic and are occurrences of both group chained action causes frequent beech disease, the most numerous species at Sample plot LEVEL 1, and Sample plot LEVEL 2 in locality Mokra Gora and Crni vrh). Identifying processes in forest ecosystems requires detailed research into the environmental factors that can be obtained as an identifier. These are, first of all, climate change, then determining the condition of the canopies that are subject to their impact, the types of these factors and their whole mechanism of action as important agents that must be kept under control in order to have complete insight into all aspects of their action on forest communities. An insight into the condition of the forests in order to reach conclusions about the necessary improvement measures can be established through monitoring the condition of the forests (MANUAL, 2010):. The subject matter of ICP Forests is the monitoring of anthropogenic (primarily air pollution) and all (here) abiotic adverse factors on the condition and development of Europe's forest ecosystems (Google 1). Under the coordination of the Forest Administration and the NFC - the National Focal Point of the Republic of Serbia for forest monitoring at the Institute of Forestry in Belgrade, the forest monitoring system is integrated into the state forestry environment, so that several institutions with their associates participate in the program (Zúbrik et al. 2008).

2. RESEARCH AREA, METHOD AND CRITERIA

Forest condition monitoring is one of the largest forest bio-monitoring systems that is implemented in order to detect changes in forests using key ecological parameters. On the basis of the obtained data, it is possible to determine spatial and temporal trends in the state of forests, i.e., tree species and their crown condition by region. A wider context can include the correlation of the crown condition data with the data obtained from corresponding sample plots as well as external data on natural and human stress factors, which all provide some

indications of the interrelations between the forest vitality and stress factors (Nevenić et al. 2014).

In the period from 2002 to 2019, a total of 130 sample plots arranged in 16 x 16 km and 4 x 4 km grids have been established in the territory of the Republic of Serbia. (Nevenić et al., 2006). In 2019, the condition of forest species was assessed on all 130 sample plots in Serbia.

Institute of Forestry teams conducted field visits of sample plots in the area of forest estates in the presence of experts, forest inspectors, forest engineers and technicians responsible for the particular sample plot localities or areas.

Visual monitoring, conducted according to the ICP Forests Manual, was carried out on the sample plots in the territory of the Republic of Serbia. It included crown condition assessment and determination of damage caused by diseases and pests. According to ICP Forests Manual, crown condition assessments are mandatory on all plots once a year, soil condition assessments every ten years as well as the assessment of the nutritional condition of forest trees – foliar analysis.

A sample plot is determined by its coordinates and its center is marked with a metal rod of a vivid colour. Trees are systematically sampled for the purpose of crown condition assessment. As they are selected in 4-point clusters, it makes a total of 24 trees. In the direction of the 4 cardinal points at a distance of 25 m from the center, six closest trees are selected for the purpose of crown condition monitoring. Tree samples include all tree species with a minimum height of 60 cm. The crown canopy classes after Kraft[2] (dominant, co-dominant, subdominant, suppressed and dying), are used as a criterion for selecting trees, excluding trees with significant mechanical injury. The selected trees are permanently marked with numbers for the future continuous assessments. The trees which are removed due to management measures or for some other reasons are replaced with new ones. If a stand is clear-felled, the central point is kept until the establishment of a new stand (Google 2).

Within the framework of national and transnational research (Level I), the crown condition is assessed by the classes of defoliation, discolouration and combined damage classes. Defoliation is assessed in 5% intervals and it is classified into 5 groups of uneven range (Table 1).

Table 1. *Classes of defoliation according to UN/ECE[3] and EU[4] classification*

Classes of defoliation - dieback	Degree of defoliation	Leaf loss (%)
0	No	0-10
1	Slight	10-25
2	Moderate	25-60
3	Severe	60-100
4	Dead	100

[2] The modified concept of the crown canopy classification, the traditional measurement of variables used in forestry, first applied by Kraft, in Germany, in the nineteenth century, (1884)
[3] United Nations Economic Commission for Europe
[4] European Union

Abiotic factors are also included because, although they are primary agents, they give rise to secondary damage agents and make it easier for insects and fungi to infest once healthy trees. These are the reasons we have been sampling and monitoring trees all these years trying to put all pieces together and get the whole picture.

3. RESULTS ON THE HEALTH CONDITION OF TREES ON LEVEL I TOGETHER WITH LEVEL II (CRNI VRH) AND (MOKRA GORA) SAMPLE PLOTS IN 2019

3.1. MONITORING PLOT ON LEVEL II (CRNI VRH)

During 2019 at LEVEL II, trees were observed on 130 Sample plots of Level one Sample plot LEVEL 2 in localities (Mokra Gora and Crni vrh).

It was found that one tree was completely taken down from the roots and one tree was dried. Among other observations, it is important to note that the defoliation of beech trees during the late summer inspection was drastically lower than during the spring 2019 inspection, with more trees re-leafing, mainly in tufts. icebreakers. One tree is present with bark inflammation, and many tree branches still have branch breaks and rot that develops at the sites of injury. From the phytopathological damage, the presence of the fungus *Nectria coccinea*, which together with the insect *Cryptococcus fagisuga*, causes a dangerous "beech bark disease" in two trees (76 and 87). Also there were found were rot on branches and knots (trees 62, 65, 67, 72, 73, 96 and 100) and central rot on trunks (tree 90).

3.2. MONITORING PLOT ON LEVEL II (MOKRA GORA)

Inspection of health state for Level II Sample plot Mokra Gora is Dedicated with 32 white pine trees in subparcel 2, trees from 82-407.

This year, 2019, during one of the major summer storms, lightning struck in one of trees on Mokra Gora exactly on the plot itself. The fire spread to more than a dozen surrounding trees, but there was no total destruction, ie. only surface (burk) was that fire left a mark on. It was observed that it shortened from a lower angle in terms of terrain to higher positions, and that at a certain height it also stopped spontaneously within the samle plot area. Still, the fire has affected the trees significantly but the extent of the damage has yet to be evaluated.

3.2. SAMPLE PLOTS LEVEL I

Inspection of health state for Level I Sample plot was performrd on 130 sample plots with emphasis on damages of abiotic origin. Those are, among other things, bulge of non-parasitic origin and occur on the bark of beech trunks, on individual trees (Češljar et al. 2014). Frostbites are noticeable, almost the entire length of the trunk. In 2019, precipitation was very high, especially in the first part of the growing season. They were not absent during the rainy summer, and this year, which was extremely and very humid, resulted in the end of normalized drying, but due to the extremely high humidity, this factor was compounded with

fungi, which result in noticeable yellow-chlorotic spots, so the trees ended the season with chlorotic crowns, as if the fall had started earlier in August, even though the leaves remained on the branches.

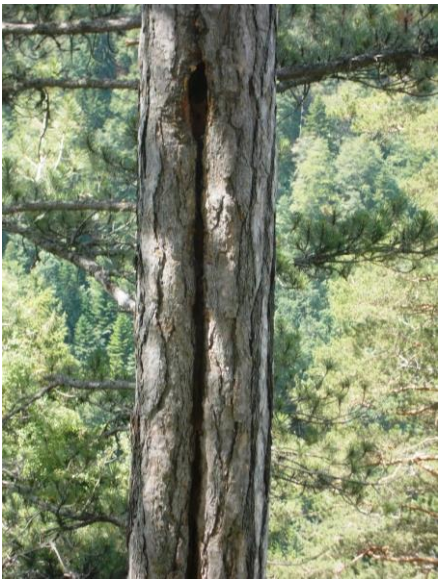
Table 2. *Damage causes on aple plot Level I trees in 2019*

Врсте дрвета/ Tree species	**Инсект/ Insects**	**Гљиве/ Fungi**	**Абиотички агенси/ Abiotic agents**	**Човек/ Human**	**Ватра/ Fire**	**Локално загађење/Local pollution**	**Остале штете/ Other damage**	**Укупно оштећено/ Total damage**
Све врсте/ All species	12,0	7,7	1,2	0,8	0,4	0,0	9,7	31,8
Лишћари/ Broadleaves	13,4	8,5	1,3	0,9	0,5	0,0	8,7	33,3
Четинари Conifers	1,4	1,7	0,0	0,0	0,0	0,0	16,8	19,9
Буква/ Beech	27,7	11,6	2,4	2,2	0,6	0,0	11,9	56,4
Китњак/ Sessile oak	4,5	5,0	0,5	0,0	0,0	0,0	9,0	19,0
Цер/ Turkey oak	10,9	6,7	2,0	0,7	0,6	0,0	6,7	27,6
Јела/ Fir	0,0	2,9	0,0	0,0	0,0	0,0	7,4	10,3
Смрча/ Norway spruce	3,5	0,0	0,0	0,0	0,0	0,0	37,8	41,3
Црни бор/ Austrian pine	0	0	0	0	0	0	0	0

Table 3. *Abiotic Damage causes, host plant tree species and sample plots with those*

Damage / Tree species / Sample plot / Cause	**Abiotic agents ice ruptures,**	**Frost/ and bark cracks**	Drought /**sample plot number**	**Man-made** mechanical damage from pullout force (bark stripped off, breakage, various injuries) **/ sample plot number**	**Forest fires / sample plot number**	**Other causes / sample plot number**
Beech	32	Several causes combined / 9, 13, 50, 52, 55, 58, 85, 91, 98, 99, 87, 407, 412	412, 413	Mechanical injury / 4, 50; severe mechanical injury / 51, 69, 90	96	
Hornbeam		55				
Turkey oak	29, 34, 36; 39		Several causes combined / 6,70,92			Non parasitic Bulge /30 38
Hungarian oak	2, 17 ,20 29, 39 and 88	Frost ribs / 17, 20	17, 20			60

Damage / Tree species / Sample plot / Cause	**Abiotic agents ice ruptures,**	**Frost/ and bark cracks**	Drought /**sample plot number**	**Man-made** mechanical damage from pullout force (bark stripped off, breakage, various injuries) **/ sample plot number**	**Forest fires / sample plot number**	**Other causes / sample plot number**
Sessile oak	75, 77	107	Severe drought / 78			
Fir		418	Severe drought / 428, 429	Mechanical pullout injury / 401,402		
Spruce	73,74	/ 419		Mechanical pullout injury / 406		
Austrian pine	419	65				
Black locust	428					
Scots pine	45, 59	53				



Слика 1. Figure 1. *Black pine tree frostbite, SP 53 (Orig.)*

Слика 2. Figure 2. *Late frost damage, beech SP 32 (Orig.)*

4. DISCUSSION

Abiotic damages recorded included bulges of other than parasitic origin in the bark of individual beech trees (Gagić-Serdar et al. 2018). Frost cracks were clearly visible along the entire trunks. In 2019 there was hufe amount of

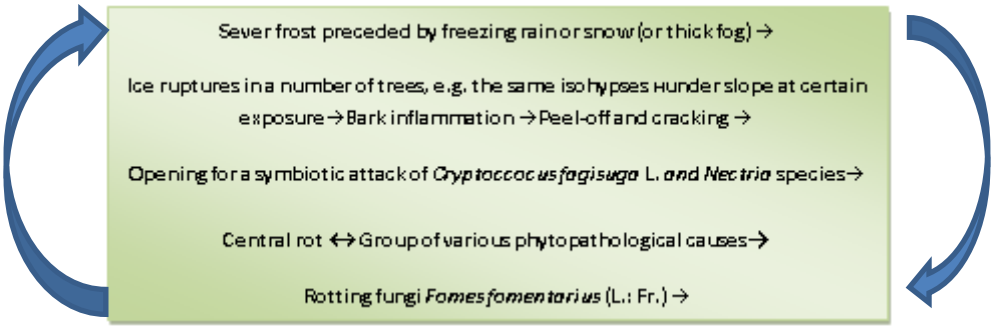
precipitation from the beginning of summer and in this rather wet year trees do not displayed yellow chlorotic crowns prematurely, as if the autumn drying commence doesn't apaer, although the leaves remained on branches.

Beech trees at sample plot 7 showed damage and injury from tree cutting and pull-out. In this plot entire quadrants were missing, while some trees had injuries of unknown origin and about ten trees had bark inflammation (Chira, D., F. Chira, 1998). Mechanical damages caused by birds were detected in spruce trees at sample plot 420. Some Turkey oak trees suffered bark damage during tree marking. Man-made mechanical damages were identified in in about ten oak trees per sample plot, resulting from tree cutting and pull out. Such injuries pose a risk of entry of numerous hazardous insects and fungi, which can cause severe diseases. The share of such trees in the total number of trees assessed is 0.62%.

Bulges of non-parasitic origin were detected in beech tree bark at sample plots 30 and 96. Frost cracks stretched along the entire beech tree trunks. In one fir tree a lightning scar stretched along the entire trunk. Mechanical damages to sessile oak tree peaks were recorded in 4% of trees. Such damages occurred during tree cutting and pull-out. Frost cracks and other mechanical damages were present in Hungarian oak trees as well at 3 sample plots.

In a number of fir trees abundant sap secretion was observed and, according to the historical experience, all such trees are likely to dry the following year. A large-scale presence of lichen *Usnea barbata,* reflecting a healthy habitat, was perceived. There were also completely dry and broken trees fully covered with lichen (sample plots 415 and 416).

It is important to underline that in 2019 specific old symptoms of an intense and widely spread phenomenon – ice ruptures – were clearly recognized and frequently observed in high, primarily beech forests (Marković et al. 2014). Such quantitatively and qualitatively severe injuries of trees occurred during dormancy in winter 2014/2015, in periods of bitter frost preceded by precipitation or merely high humidity at certain altitudes of Homolje Mountain Range (Marković & Marković, 2018). Geographically, eastern parts of the country were most affected (sample plots in Eastern Serbia, exceptionally sample plot 70 – Lukovo, sample plot 412 Tisovac and and sample plot 413 Jasenova glava). Continuous and mandatory performed sanitation must commence with sanitation tree cutting and further growth measures for a number of reasons. The injured trees are an easy prey for secondary pests and diseases. It is necessary to prevent them, i.e., to eliminate favorable conditions for incidence of possible pest calamities. Wherever an opening appeared, it is necessary to protect the exposed layers (risk of bark inflammation) and put an end as soon as possible to complex yet possible scenarios of cycles of linked and chained damages (an exemplary pattern of a beech stand decay after initial ice rupture as an abiotic factor is presented in Graph 1):



Graph 1. *Example of the pattern of beech stand decay after the initial effect of a harmful agent (ice rupture) as an abiotic factor*

In 2019 forest fires broke out (0.24% trees affected) at several sample plots (e.g. sample plot 96), which resulted in total absence of assimilation organs in trees. Thereafter, the fire bed is occupied by pioneer vegetation, and more successful in succession are either invasive (blackberry) or economically and productively low graded species (birch, aspen, etc.). Still blazing forest fire in Stara Planina will have far-reaching consequences, but now it's too early for any forecasts or damage assessmant. What is certain is that the contribution on the fire occurrence was the climate factor, and an unusually long and warm period without precipitation precipitation In October of the current year. This year there was a spontaneous fire caused by lightning strikes on the very samle field of Mokra Gora. The fire has affected dozens of trees and the extent of the damage has yet to be assessed (Pictures 3 and 4).

Слика 3. *Forest fire on Sample plot Mokra Gora, 2019 (Orig.)*

Слика 4. *Damged trees from fire caused by lighthing on Sample plot Mokra Gora, 2019 (Orig.)*

Abiotic factors included frost shake on the bark of Hungarian oak trees, which were present on a small scale, while the damage to the leaves was very pronounced. Mechanical damage to oak trees was registered in more than 25% of

the studied trees and they were caused by human factor, i.e. during tree felling and hauling (Marković et al. 2012). Češljar These injuries pose a potential danger and make trees prone to many harmful insects, disease-causing fungi, as well as wood-destroying organisms (Vajda, 1974).

4. CONCLUSION

During 2019, monitoring of the abiotic parameter was carried out at the existing sample plots of Level I and Level II, with the continuously and annually carried out frequency.

At Sample plot Level II Crni Vrh the percentage of trees not affected by defoliation, trees affected by low defoliation and dead trees compared to the previous year was the same.

From the phytopathological damages, the presence of fungus *Nectria coccinea* was found in two trees. Also observed were rot on branches and nodes (on 7 trees) and central trunk rot (on 1 tree). Although not abiotic these symptoms are an indirect consequence of ice-breaks as a significant factor from the abiotic group.

Defoliation in 2019 at the Sample plot of Level II in Mokra Gora for trees affected by fire may have been the result of a fire extinguished by chance. In general, in 2019, as in the previous year, the damage caused by abiotic factors is the least affected trees on Sample plot Level II Mokra Gora.

The Input entry of new data into the GIS system of NFC Serbia is done every year, which will be a very valuable archive for future scientific research. The more time passes, the better and easier it will be to gain an insight into the state of forests in the experimental fields, the aforementioned influence of abiotic factors and a more accurate approach to the perennial analyzes of the vitality of the forests of the Republic of Serbia.

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FOREST VITALITY (ICP LEVEL I AND SAMPLE PLOT LEVEL II-CRNI VRH AND MOKRA GORA) WITH A SPECIAL EMPHASIS ON ABIOTIC AGENTS IN THE REPUBLIC OF SERBIA IN 2019

Renata GAGIĆ-SERDAR, Tomislav STEFANOVIĆ, Ilija ĐORĐEVIĆ, Goran ČEŠLJAR, Natalija MOMIROVIĆ

Summary

The estimation of the crown condition, through data values for defoliation and chlorosis, and the establishment of damage contributes to the performance of definitive conclusions about the adverse effect of complex abiotic factors. This paper are focused on abiotic, those chainedwith them, their nature and it's violation of the vitality of forests in 2019 Serbia.

Direct impact of these factors, conditions trees state and can be taken as a result of forest communities health, reversebly. Primarily because of the short time period processed. Problem concerning the interpretation of results and their occasional fluctuations, highlights the importance of continuous monitoring of parametars as well as additional evaluation of various abiotic and environmental data et the end.

ВИТАЛНОСТ ШУМА (ICP НИВО I И НИВО II -ЦРНИ ВРХ И МОКРА ГОРА) СА ПОСЕБНИМ ОСВРТОМ НА АБИОТИЧКЕ АГЕНСЕ У РЕПУБЛИЦИ СРБИЈИ У 2019. ГОДИНИ

Рената ГАГИЋ-СЕРДАР, Томислав СТЕФАНОВИЋ, Илија ЂОРЂЕВИЋ, Горан ЧЕШЉАР, Наталија МОМИРОВИЋ

Резиме

Процена стања круна, кроз вредности података за дефолијацију и хлорозу, и процену оштећења доприноси извођењу коначних закључака о штетном утицају сложених, овде, абиотских фактора. Овај рад је фокусиран на абиотичке, као и оне везане за њих, њихову природу и нарушавање виталности шума из разлога деловања истих у 2019. години у Србији.

Директан утицај ових фактора, утиче на здравствено стање стабала на БИТ, оба Нивоа и може се тумачити као резултат општег стања шумских заједница, и обратно њихово деловање на те факторе. Првенствено због кратког временског периода који се обрађује, 2019. година. Проблем који се односи на интерпретацију резултата и њихове повремене флуктуације, наглашава важност континуираног праћења параметара, као и додатну процену различитих абиотичких чинилаца, података о животној средини и тако циклично.

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POTENTIALS OF THE EVALUATION OF THE WOOD QUALITY IN LIVING TREES BY USING SEMI- AND NON-DESTRUCTIVE METHODS IN ORDER TO REDUCE WOOD-PROCESSING COSTS

Ivana ŽIVANOVIĆ[1], Zoran PODUŠKA[1], Ljubinko RAKONJAC[1], Filip JOVANOVIĆ[1]

Abstract: *Being a natural, ecological and renewable resource, wood is increasingly replacing artificial and toxic materials in the manufacture of various types of packaging and other products; thus, its proper and economically justified use has become necessary. The best utilization of wood raw materials has been sought both in practice and theory, which led to the development of a number of non-destructive and semi-destructive methods for the wood quality assessments in various stages of wood exploitation. In this paper, two instruments for the inspection of the internal condition of standing trees were analyzed. The resistograph was designed for the detection of internal defects. In addition to assessing the condition of living trees of different species, the instrument is used to assess the wood density in various materials. The observed resistance during drilling is proportional to the change in the wood density or the relative mass of the element analyzed. The results of drilling in different spots or directions, through the cross-section and along the element, can be used to map the properties of the element. The fractometer is a device designed to measure the strength and other mechanical properties of on a core sample extracted by using an increment borer from a certain part of the tree or branch examined. The fractometer can determine the maximum fracture force and bending and pressure strength of wood. It is also possible to identify the stage of decay. Due to its heterogeneous structure and anisotropy, the wood compressive and bending strengths differ between different anatomical directions even within a single species. The results of previous research in the literature indicate that there is a significant positive correlation between the radial bending strength and the longitudinal compressive strength of wood. This*

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actualizes the need for the use of different tree species in construction, depending on the load that the wood element will be exposed to. These devices provide high precision and quality in measurement and can achieve a good correlation between the measured values and the mechanical properties of wood. This way, science and practice could be provided by significant data on the properties and quality of wood, while its consumption is minimized.

Keywords: fractometer, resistograph, wood quality determination and evaluation, wood consumption, wood-processing costs

MOGUĆNOSTI PROCENE KVALITETA DRVETA ŽIVIH STABALA POLUDESTRUKTIVNIM I NEDESTRUKTIVNIM METODAMA U CILJU SMANJENJA TROŠKOVA PRERADE

Izvod: *Drvo, kao prirodni, ekološki i obnovljiv resurs, sve više zamenjuje veštačke i toksične materijale u izradi različitih vrsta ambalaže i drugih proizvoda, te je njegovo pravilno i ekonomski opravdano korišćenje postalo nužno. U praksi i u teoriji se teži što boljem iskorišćenju drvne sirovine, stoga je razvijen veliki broj nedestruktivnih i poludestruktivnih metoda analize kvaliteta drveta u raznim fazama eksploatacije. U radu su analizirana dva uređaja za procenu stanja dubećih stabala na licu mesta – rezistograf i fraktometar. Rezistograf je razvijen sa ciljem detekcije unutrašnjih defekata u drvetu. Osim za procenu stanja živih stabala različitih vrsta drveća, ovaj instrument se koristi za procenu gustine drveta u različitim drvnim materijalima (kompoziti, razne konstrukcije). Posmatrani otpor u toku bušenja proporcionalan je promeni gustine drveta ili relativne mase elementa koji se ispituje. Rezultati bušenja na više mesta u različitim pravcima, kroz poprečni presek i duž elementa, mogu se složiti i organizovati u mapu stanja elementa. Fraktometar je uređaj za merenje čvrstoće i ostalih mehaničkih osobina drveta na izvrtku uzetom Preslerovim svrdlom sa određenog dela stabla ili grane koja se ispituje. Fraktometrom se mogu odrediti vrednosti sile loma i čvrstoće pri savijanju i(li) pritisku. Takođe, moguće je identifikovati fazu štete prouzrokovane truljenjem. Zbog heterogene strukture i anizotropnosti drveta, čvrstoće na pritisak i savijanje se razlikuju za istu vrstu u različitim anatomskim pravcima. Rezultati dosadašnjih istraživanja u literaturi ukazuju na značajnu i pozitivnu korelaciju između radijalne čvrstoće na savijanje i uzdužne pritisne čvrstoće drveta. Ovo aktuelizuje potrebu za korišćenjem različitih vrsta drveća u građevinarstvu u odnosu na opterećenje kojem će element od drveta biti izložen. Ovi uređaji pružaju veliku preciznost i kvalitet pri merenju i mogu postići dobru korelaciju između merenih vrednosti i mehaničkih svojstava drveta. Na taj način nauka i praksa mogu dobiti značajne podatke o svojstvima i kvalitetu drveta, a utrošak materijala se minimalizuje.*

Ključne reči: fraktometar, rezistograf, ispitivanje i procena kvaliteta drveta, iskorišćavanje drveta, troškovi prerade drveta

1. INTRODUCTION

Forests are a very valuable national resource. They represent habitats of wild animals and plants, and they also serve as a renewable source of raw materials for wood and wood fiber products.

Forests may be able to produce sufficient wood but production costs will rise and so too will the cost of wood products (Rajković and Tabaković-Tošić, 2007). Natural genetic engineering has created wide variation in the structure of wood, causing numerous difficulties in the wood processing industry, i.e. in the use of wood as a material. Wood is sometimes difficult to process into quality products due to the large range of its mechanical and chemical properties. Due to its organic origin and renewability, wood is one of the most sought-after natural materials. Its rapid exploitation stemmed from the high demand and development of new products has led to the lack of good-quality raw wood materials.

Development of the wood processing industry is causing growing demand for high-quality wood raw materials (Marković *et al.*, 2015). Therefore, attention must be paid to the rational use of this material. In each technological process, it is necessary to determine the quality of wood assortments, because it significantly influences further processing and use of wood. Wood properties are mainly determined by its structure, biological and organic origin, but also by the conditions in which the wood is used and exploited. Being a natural, ecological and renewable resource, wood is increasingly replacing artificial and toxic materials in the manufacture of various types of packaging and other products; thus, its proper and economically justified use has become necessary. As practice and theory strive to make the best use of wood raw materials, a large number of non-destructive and semi-destructive methods for analyzing the quality of wood in various phases of its exploitation have been developed.

Most methods determine properties of wood in an indirect way; therefore, suitable devices have been constructed to determine the characteristics of the material analyzed based on the drilling resistance, sound propagation or velocity, radiation absorption, etc. Using statistical methods, the measured parameters are transformed into the required properties of wood. Finally, the accuracy of the method used is checked, by establishing a correlation between the properties of wood, determined by the non-destructive method and those measured experimentally (Todorović, 2014).

Non-destructive methods can determine properties of wood in situ, without destruction. This way, science and practice are provided by significant data on the properties and quality of wood, while its consumption is minimized (Todorović, 2014). In developed countries, most of these methods are standardized and applied successfully in both science and practice. There are mechanical methods, acoustic methods and methods of radiation.

In this paper, two devices for the assessment of wood quality in standing trees were analyzed – the resistograph and the fractometer, as tools for the evaluation of the effects of decay on wood.

The resistograph was patented in 1990 (Rinntech, Heidelberg, Germany[2]). It is a device that measures drilling resistance on site, determining certain properties of wood. The resistograph was developed as an easy to use and precise measuring system for detecting internal defects in wood. The energy consumption of the device is measured electronically. The results are immediately stored in the

[2] www.rinntech.com

internal memory of the device (Rinn *et al.*, 1996). Besides the assessment of wood quality in standing trees of different species, the instrument is also used for the determination of the density of wood in various wood materials, such as wood composites and various types of timber products. Drills vary in price, applicability, weight, drilling depth, and particularly in technical characteristics, such as precision and resolution (Kasal and Tannert, 2011).

The fractometer (Lat. frango, frangere = to break) is a device for measuring the strength and other mechanical properties of wood on a core sample extracted by using an increment borer from a certain part of the tree or branch being examined. Two versions of the device have been developed, Fractometer 1 which measures the maximum force and fracture angle in the bending load and Fractometer 2 which, in addition, measures the properties of compressed wood. Depending on the device used, the fracture strength and bending strength and/or compression can be determined. Moreover, it is possible to identify the stage of decay (2017).

Reference books on wood properties have very limited importance in assessing individual trees. A tree that is examined is usually not the best representative of the species and deviates from the average values of the mechanical properties in comparison to the surrounding trees in the habitat, and is often damaged by fungi or insects. If the symptoms of internal defects are detected, it is necessary to examine the tree in more detail, especially in public areas. A tree can collapse due to its poor mechanical properties. However, a tree can also break easily if its strength is reduced due to the destruction of its structure by fungus activity. In tree safety assessment, using the Visual Tree Assessment (VTA) method, tree characteristics are first visually checked. VTA helps in making the difference between trees where there is a potential risk of collapse and those that are really dangerous to the environment. VTA provides information on the physical characteristics of a tree and its mechanical properties and indicates the correct use of measuring instruments.

2. MATERIAL AND METHODS

The analytic-synthetic method was used as a basic method in the paper. Prior to the analytical procedure, it was necessary to collect, evaluate, select, systematize and update information about the two devices studied. The evaluation of data was based on simple, practical, but also some complex indicators. It was necessary to make a full review of the results obtained in numerous papers.

The collected literature sources, related to the potentials for applying the resistograph and the fractometer in forest evaluation have been carefully studied and classified in several groups:

1. Literature related to the historical development of the devices studied;
2. Literature related to the theoretical definitions, purpose and practical applications of the devices;
3. Literature comprising comparative tests with other non-destructive methods for quality evaluation of living trees;
4. Literature comprising the result of the same methods applied to different tree species.

3. RESULTS AND DISCUSSION

A number of studies deal with the problem of determining the characteristics of wood using the resistograph. In addition, numerous papers have compared this method with various other non-destructive and semi-destructive methods. The results of the most notable studies are presented in Table 1.

Resistance drilling has been used to inspect trees and timber since 1987 (Rinn, 2013). Rinn *et al.* (1996) have compared the tree-ring density obtained by using the drilling resistance method with X-rays densiometry in several different species. The results show that the resistance from the drilled profiles correlates to the density of dry wood (r^2>0.8). Changes in the density within and between tree rings and the density variations caused by decay were discovered using the resistance profile.

Table 1. *The most notable wood property investigations conducted using semi- and non-destructive methods*

Nº	Method used	Tree species	Correlation (r^2)	Property analyzed	Reference
1.	Drilling resistance, X-rays densiometry	Several	>0.80	Dry wood density	Rinn *et al.* (1996)
2.	Resistograph, Micro-densitometry	Several	0.93–0.97	Quality, wood density	Chantre and Rozenberg (1997)
3.	Resistograph	*Eucalyptus globulus*, *Ulmus glabra*	Strong	Density	Costello and Quarles (1999)
4.	Resistograph	*Pinus taeda*	0.29–0.65	Wood density	Isik and Li (2003)
5.	Resistograph	*Pinus echinata*	0.23–0.47	Wood density, drilling resistance	Gwaze and Stevenson (2008)
6.	Fractometer	25 tropical species	Strong	Radial bending strength, radial bending angle, longitudinal compressive strength	Tang *et al.* 2005
7.	Fractometer, Static testing	*Agathis* sp., *Pinus merkusii*, *Acacia mangium*, *Swietenia* sp., *Tectona grandis*	Strong	Compressive strength, basic density	Matsumoto *et al.* (2010)

Chantre and Rozenberg (1997) made recordings using the resistograph and micro-densitometry on the same trees. The results of comparing the two types of profiles showed excellent correlations (from 0.93 to 0.97). They concluded that the resistograph provides better correlations for the evaluation of the whole trunk parameters and that a single value can be summarized. It also provides an evaluation of wood quality.

Costello and Quarles (1999) compared decayed and sound wood assessments made using the resistograph and the portable drill with laboratory measurements of wood density. They made field evaluations of sixteen trees of *Eucalyptus globulus* Labill. and five trees of *Ulmus glabra* Huds., cut, sectioned along the resistograph, drilled in test paths and measured for density. Density measurements and resistograph measurements show strong relations of soundwood depth in 85.5% of all cases for *Eucalyptus globulus* and in 100% of all cases for

Ulmus glabra. Portable drill measurements provided a close connection with the density measurements in 73% of the cases for *Eucalyptus globulus* and 81% for *Ulmus glabra*. Drill evaluations were noticeably diverse among operators. The resistograph provided a higher level of uniformity and accuracy than the portable drill. Both methods showed that the knowledge of mechanical patterns of wood properties is critical for evaluation.

Isik and Li (2003) used the resistograph as a tool for quick assessment of wood density of living trees in progeny trials. They examined 1477 trees from fourteen full-sib loblolly pine tree families. The resistograph amplitude had weak (0.29) to moderate (0.65) phenotypic correlations with wood density on an individual-tree basis. They gave an opinion that the resistograph is more reliable for measuring the relative wood density of living trees than other instruments.

The resistograph was also used by Gantz (2002) to estimate genetic parameters of wood in two softwood and two hardwood species and compare them to x-ray densitometry. The conclusion was that the resistograph provides good results in genetic tests for wood density.

Gwaze and Stevenson (2008) searched for high correlations between wood density and drill resistance obtained by the resistograph. At the individual tree level, the linear relationship between wood density and drill resistance (amplitude) was weak and positive (r^2=0.23), but at the family mean level the relationship was stronger (r^2=0.47).

Kahl *et al.* (2009) did quick, quantitative, field estimation and made a comparison with conventional methods of wood density for logs of Norway spruce in four different decay stages. They noticed the predicting model of wood density but that predictor explained 65% of the differences in wood density. The relationship between the drill resistance and gravimetric wood density depended on decay status.

The first presentation of fractometar examination was given by Mattheck *et al.* (1995) as a new method that included visual tree assessment on a biomechanical basis, as well as fractometer examination. Numerous field studies suggested that radial strength decreases in the same way as longitudinal strength because of decay action. The authors pointed out that "all the equipment, including the Fractometer, is only able to measure and quantify what one has already seen before. Most important of all is the experience of the arborist, and this will never change in the future since it cannot be substituted by any kind of measuring device.'' (*Mattheck et al.*, 1995).

Schwarze *et al.* (1995) tested two devices, ''Metriguard'' (stress wave timers for detecting decay) and the fractometer, for the measurements of the loss of strength. Metriguard failed to detect the first fungal stages, but it detected decays of white and brown rot in further stages. The fractometer indicated a great loss of strength for all stages of fungal attack [for *Ustulina deusta* (Hoffm.) Lind., even in an early stage of decay].

Zipse *et al.* (1998) investigated the effects of wind on the mechanical properties of 14 wind exposed living trees of *Fagus sylvatica* L. using a fractometar. They concluded that the wind exposed trees develop wood which is stronger and allows larger stresses before a failure.

Matheny *et al.* (1999) evaluated the fracture moment and the fracture angle of core samples from the lower trunk of 25 tree species using the fractometer. They found that the results varied with species, core segment, and location of the tree. Some of these differences might be related to the examination of different species within a genus. Also, there was some major variation in fractometer results due to location, so they suggested that habitat factors could be the cause of such differences. They concluded that when using the fractometer, researchers must pay special attention to the samples taken from individual trees rather than tables of standardized results. In evaluating the strength loss associated with decay, fractometer results must be compared to the values from clear samples of the same tree.

On the other hand, Gruber and Hagermann (2000) explored the bending solidity of 24 (1 m long) stem samples of *Fagus sylvatica*, *Populus* spp., *Picea abies* (L.) H. Karst. and *Pseudotsuga menziesii* (Mirb.) Franco, using DIN 52-186 and the fractometry method. They did not find any correlation between the DIN bending solidity and the fractometer measurements. Still, their suggestion is that fractometry method can be highly recommended for evaluating tree strength.

Lin *et al.* (2003) analyzed radial changes of living trees in *Taiwania cryptomerioides* Hay. using the fractometer. The differences in crushing strength in the transverse direction increased from the pith to the bark. The analysis of variance and correlation showed that the value of the radial difference in crushing strength was lower than the tree-to-tree variation.

Another study (Tang *et al.*, 2005) was done by evaluating the wood strength properties of 25 tree species in Hong Kong using Fractometer II. Radial bending strength was tested on 2656 samples and longitudinal compressive strength and fracture angle on 4779 samples. Meaningful and positive correlations between radial bending strength and longitudinal compressive strength were established, showing a strong connection between radial and longitudinal mechanical strengths. Hierarchical clustering and multidimensional scaling analysis revealed a clear grouping of tree species into different types of wood properties.

Chiu *et al.* (2006) used the fractometer to measure the crushing strength, aiming to mark the line between juvenile and mature wood. They used segmented regression and variance component analysis for this purpose and discovered that the crushing strength of core wood increases with the tree age. Differences between trees were more significant than within tree variations and the line between juvenile and mature wood at the age of 18–20 was found at an approximate distance of 10.8–13.2 cm from the pith.

Matsumoto *et al.* (2008) examined two Japanese softwoods. *Cryptomeria japonica* (L.f.) D. Don and *Pinus densiflora* Siebold & Zucc. were tested by measuring radial changes of bending and compression strength of core samples using the fractometer. They also tested small clear specimens of juvenile wood for static bending properties and static compression strength parallel to grain at juvenile stage. However, they did not find a meaningful relationship between the bending strength of core samples and static bending strength of small clear specimens. A significant positive correlation was found between the compression strength obtained with the fractometer and the static test. They concluded that

wood properties, mostly the compression strength of wood, can be assessed by the compression strength of core samples measured with the fractometer.

Matsumoto *et al.* (2010) did another experiment with living trees. They examined wood properties of five Indonesian species using the fractometer. They concluded that the compressive strength measured with the fractometer could be applied for living tree properties and they noticed a high coefficient of determination between this compressive strength and density. Therefore, they concluded that the fractometer is a good tool for the determination of wood properties *in situ*.

Ganesan and Hamid (2010) did research on 25 urban tree species in Singapore. They used the fractometer to assess the radial bending strength, longitudinal compression strength and fracture angle and made some tables of standard values for the tested species. They found that the readings for the fracture moment and fracture angles can be obtained with confidence. Speaking of the longitudinal compressive strength, they had difficulty in determining the first spot of failure when wood fibers are kinked.

Due to its heterogeneous structure and anisotropy, the wood compressive and bending strengths differ between different anatomical directions even within a single species. The results of previous research in the literature indicate that there is a significant positive correlation between the radial bending strength and the longitudinal compressive strength of wood. This actualizes the need for the use of different tree species in construction, depending on the load that the wood element will be exposed to. These devices provide high precision and quality in measurement and can achieve a good correlation between the measured values and the mechanical properties of wood.

4. CONCLUSIONS

The purpose of this paper was to show the significance of two apparatuses (the resistograph and the fractometer) as tools for the evaluation of the effects of decay on wood. The strength of wood determines the stability and safety of a tree. The devices in question are suggested for measuring the strength properties of wood directly. Studies discussed in this paper have shown that the transverse strength decreases in the same way as the axial strength, as a result of wood decay. Basic comprehension of the method used and the knowledge of technical properties of the devices employed is required for the proper selection of a suitable device. Besides the resolution and precision of the profile, when the use of the resistograph is considered, there are many other details to be considered before a final decision is made what device to choose and how to use it.

Studies discussed in the paper revealed high correlations between the measured properties and the actual wood quality. That means that the quality of wood can be estimated *in situ*, and the devices in question can help us make the right decision. These estimates make wood processing much less expensive because trees can be selected according to the quality tests before they are cut. This way, science and practice could be provided by significant data on the properties and quality of wood, while its consumption is minimized.

Finally, it must be pointed out that all the devices used, including the resistograph and the fractometer, are only measuring and quantifying tools of what has already been seen by man. Therefore, the most important of all is the practical experience of the researcher. It will not change in the future because the human expertise cannot be replaced by any measuring tools.

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POTENTIALS OF THE EVALUATION OF THE WOOD QUALITY IN LIVING TREES BY USING SEMI- AND NON-DESTRUCTIVE METHODS IN ORDER TO REDUCE WOOD-PROCESSING COSTS

Ivana ŽIVANOVIĆ, Zoran PODUŠKA, Ljubinko RAKONJAC, Filip JOVANOVIĆ

Summary

Optimizing the wood production is one of the major tasks for producers. Wood properties are mainly determined by its structure, biological and organic origin, but also by the conditions in which the wood is used and exploited. As practice and theory strive to make the best use of wood raw materials, a large number of non-destructive and semi-destructive methods for analyzing the quality of wood in various phases of its exploitation have been developed. Most methods determine properties of wood in an indirect way; therefore, suitable devices have been constructed to determine the characteristics of the material analyzed based on the drilling resistance, sound propagation or velocity, radiation absorption, etc. Using statistical methods, the measured parameters are transformed into the required properties of wood. In addition, the accuracy of the method used is checked, by establishing a correlation between the properties of wood, determined by the non-destructive method and those measured experimentally.

The analytic-synthetic method was used as a basic method in the paper. Prior to the analytical procedure, it was necessary to collect, evaluate, select, systematize and update information about the two devices studied. The evaluation of data was based on simple, practical, but also some complex indicators. It was necessary to make a full review of the results obtained in numerous papers.

Studies discussed in the paper revealed high correlations between the measured properties and the actual wood quality. That means that the quality of wood can be estimated in situ, and the devices in question can help us make the right decision. These estimates make wood processing much less expensive because trees can be selected according to the quality tests before they are cut.

Based on the results presented in the analyzed studies, in can be concluded that devices used, including the resistograph and the fractometer, are only measuring and quantifying tools of what has already been seen by man. Therefore, the most important of all is the practical experience of the researcher. It will not change in the future because the human expertise cannot be replaced by any measuring tools.

MOGUĆNOSTI PROCENE KVALITETA DRVETA ŽIVIH STABALA POLUDESTRUKTIVNIM I NEDESTRUKTIVNIM METODAMA U CILJU SMANJENJA TROŠKOVA PRERADE

Ivana ŽIVANOVIĆ, Zoran PODUŠKA, Ljubinko RAKONJAC, Filip JOVANOVIĆ

Rezime

Optimizacija drvne industrije je jedan od glavnih zadataka proizvođača. Svojstva drveta su uglavnom rezultat njegove strukture, budući da je drvo biološkog i organskog porekla, ali su njegova svojstva takođe posledica uslova u kojima se ono koristi i eksploatiše. Usled nastojanja u praksi i nauci da se postigne najbolja moguća upotreba

drvnih materijala, razvijene su brojne poludestruktivne i nedestruktivne metode za ispitivanje kvaliteta drveta u raznim fazama njegove eksploatacije. Većina metoda utvrđuje svojstva drveta na indirektan način, tako da su konstruisani odgovarajući aparati za utvrđivanje karakteristika ispitivanog materijala, koji se zasnivaju na otporu na bušenje, širenju i brzini zvuka, apsorpciji radijacije, itd. Primenom statističkih metoda, merene vrednosti parametara pretvaraju se u odgovarajuće osobine drveta. Pri tome, tačnost primenjene metode se proverava izračunavanjem korelacija između osobina drveta koje su određene nedestruktivnim metodama i onih dobijenih eksperimentalnim putem.

Osnovni metod ovog rada bio je analitičko-sintetički metod. Pre samog analitičkog postupka, bilo je neophodno prikupiti, razvrstati, proučiti, sistematizovati i dopuniti dostupne informacije o uređajima koji su analizirani – rezistografu i fraktometru. Procena prikupljenih podataka zasnivala se na jednostavnim i praktičnim, ali i složenim pokazateljima kvaliteta drveta. Bilo je nužno načiniti iscrpan pregled rezultata koji su predstavljeni u brojnim naučnim radovima.

Istraživanja o kojima je raspravljano u ovom radu ukazala su na postojanje značajnih zavisnosti između merenih svojstava i stvarnih pokazatelja kvaliteta drveta. To znači da se kvalitet drveta može proceniti *in situ* i da spomenuti uređaji mogu biti od koristi pri donošenju pravih odluka u proizvodnji. Zahvaljujući ovim procenama, obrada drveta je znatno jeftinija, s obzirom da se stabla mogu odabrati shodno ispitivanjima njihovog kvaliteta i pre nego što su ona posečena.

Na osnovu analiziranih literaturnih izvora, može se zaključiti da uređaji koji se koriste, uključujući rezistograf i fraktometar, predstavljaju samo pomagala za merenje i kvantifikaciju onoga što je čovek već uočio. Stoga, praktično iskustvo istraživača je nezamenljivo, što se u budućnosti neće promeniti, jer se stručnost istraživača ne može zameniti nikakvim uređajima za ispitivanje.

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THE REGIONAL CLIMATE MODEL (REG-IN) FOR FORECASTING THE ADAPTIVITY OF FOREST ECOSYSTEMS IN BELGRADE

Tatjana RATKNIĆ[1], Mihailo RATKNIĆ[1], Lazar VUKADINOVIĆ[2]

Abstract: *Regional climate modelling with regional climate models has become a part of modern research with a wide range of applications. This article examines the latest segments in the study of regional climate modeling used to assess the adaptivity and survival of particular forest species in changing conditions. It presents the results of the regional climate model (acronym REG-IN) used to predict the adaptive capacity of forest ecosystems in Belgrade. Compared to the SXG and E-P models, the REG-IN model exhibits certain deviations due to the specific environmental conditions of the area. These data have made it possible to predict the future rate of survival of individual forest ecosystems.*

Keywords: regional model, forest ecosystems, adaptation, survival, REG-IN

REGIONALNI KLIMATSKI MODEL (REG-IN) U FUNKCIJI PREDVIDJANJA ADAPTIVNIH MOGUĆNOSTI ŠUMSKIH EKOSISTEMA NA PODRUČJU BEOGRADA

Izvod: *Regionalno modeliranje klime sa regionalnim klimatskim modelima postao je deo savremenog istraživanja i omogućava upotrebu u širokom spektru primene. U ovom radu preispituju se najnoviji segmenti u istraživanju regionalnog klimatskog modelovanja u funkciji adaptacije i opstanka pojedinih šumskih vrsta u novonastalim uslovima. Prikazani su rezultati regionalnog klimatskog modela (akronim REG-IN) u funkciji predvidjanja adaptivnih mogućnosti šumskih ekosistema na području Beograda. U poredjenju sa modelima SXG i E-P, model REG-IN pokazuje izvesna odstupanja koja su uslovljena specifičnim ekološkim uslovima područja. Ovi podaci su omogućili da se predviti stepen opstanka pojedinih šumskih ekosistema u budućnosti.*

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Ključne reči: regionalni model, šumski ekosistemi, adaptacija, opstanak, REG-IN

1. INTRODUCTION

Climate change significantly contributes to the introduction of new approaches in forestry. These approaches emerge from the study of the effects of global and regional climatic changes (studies of different climate scenarios, changes in the concentration of greenhouse gases, ozone layer state, changes in the intensity of ultraviolet radiation, etc.).

The results of these studies should serve to determine:

- the response of forest ecosystems to climate change;
- the impact of climate change on biodiversity;
- the degree of impact and response of species to climate change;
- the importance of global climate change and the possibility of new species and subspecies to emerge under changing climate conditions;
- the occurrence of weed and invasive species, insects, plant diseases, etc.

Human activity has destroyed a large number of habitats. These habitats have often been fragmented or damaged by long-term pollution from various sources.

Global climate models can form a good basis for climate projections. However, their spatial resolution is so low that they cannot provide an accurate simulation of climate in the areas with pronounced and complex orographic features. In these circumstances, downscaling must be used. Downscaling refers to any method used to create higher-resolution simulations from the data obtained from global climate models (Giorgi & Mearns 1999).

Some of these methods are “dynamical”, which means that they use regional climate models to simulate future climate.

Other methods of downscaling are “statistical”. They allow for the production of high-resolution projections. Statistical models are computationally cheap and quick to run, but they don’t necessarily represent the physical dynamics of the local climate (Reich KD et al., 2018).

Representing the local physical dynamics is important because it can have a major impact on the local changes caused by global warming.

2. MATERIAL AND METHODS

Mean, minimum, and maximum temperature and precipitation data for the period 1871 to 2018 were used to construct the climate models. This article will present the data of the climate model for air temperatures.

The reference period (1871 - 1900) was taken as a parameter for assessing the survival of forest ecosystems. Potential and actual vegetation of the Belgrade area today was formed by climate conditions that prevailed in this period.

We developed a statistical model that mimics a dynamic model.

The resulting climate models were compared with the SINTEX-G (SXG) Global Model and the EBU-POP Regional Model presented in "Change in climate indices for Serbia to the SRES-A1B and SRES-A2 scenarios" (Krzić et al., 2011). SX-G is a global atmospheric-ocean general circulation model developed at CMCC/ INGV (Centro Euro-Mediterraneo per and Cambiamenti Climatici/Istituto Nazionale di Geofisica e Vulcanologia) in Bologna, Italy (Gualdi et al., 2003a, 2003b; Guilyardi et al 2003).

Model results (REG-IN) are shown for A1B and A2 scenarios. Regarding the concentration of greenhouse gases, the A1B scenario can be characterized as "moderate" and the A2 scenario as "high". At the end of the twenty-first century, one of the greenhouse gases CO2 will reach the values around 690 ppm according to the A1B scenario and around 850 ppm according to the A2 scenario. This is 2 to 2.2 times the current value of 385 ppm.

The article presents data for the following three future periods: 2021-2050, 2051-2080, and 2081-2100.

To monitor climate change through existing models, the data for the reference period of 1961-1990 is also provided. This is the period most researchers take as a reference period when comparing their models.

The results are presented in tables and graphs.

3. RESEARCH RESULTS

Projections of the EURO-CORDEX initiative suggest that European land areas will warm faster on average than global land areas, in the range of 1 – 4.5°C under the RCP4.5 scenario, and in the range of 2.5 – 5.5° C under the RCP8.5 by the end of the century (Jacob et al., 2014), while the number of heatwaves will be increasing in the same period (projected to occur as often as every two years in the second half of the 21st century) under the RCP8.5 scenario (EEA, 2016a). With the increase in mean annual temperature, rainfall is projected to increase by up to 25% in central and northern Europe, while a significant decrease is expected in southern Europe. By the end of the century, extreme daily rainfall will decrease by up to 25% in some parts of southern Europe, while it will increase by the same value in central and eastern Europe (Jacob et al., 2014).

The existing climate change projections for Serbia predict a trend of increasing temperatures for the A1B and A2 scenarios for the three study periods (2011-2040, 2041-2070, and 2071-2100) (MEP, 2015). The following temperature changes are expected for the study periods:

1. 2011-2040 – a temperature increase of 0.5-0.9°C for the A1B and 0.3-0.7°C for the A2 scenario;

2. 2041-2070 – a temperature increase of 1.8-2.2° C for the A1B and 1.6-2.0°C for the A2 scenario;

3. 2071-2100 – a temperature increase of 3.6-4.0°C for the A1B and 3.2-3.6°C for the A2 scenario.

The most pronounced warming, which exceeds 4.0°C by the end of the century, is expected for the summer and autumn seasons (MEP, 2015).

Summer warming in the Balkans and western Turkey will be 5-6°C for 2071-2100 according to the A2 scenario (Gao & Giorgi (2008). ICTP-RegCM3 for 2071-2100 and the A2 scenario project an increase of 7°C in the Balkan countries including Serbia (Önol & Semazzi (2009).

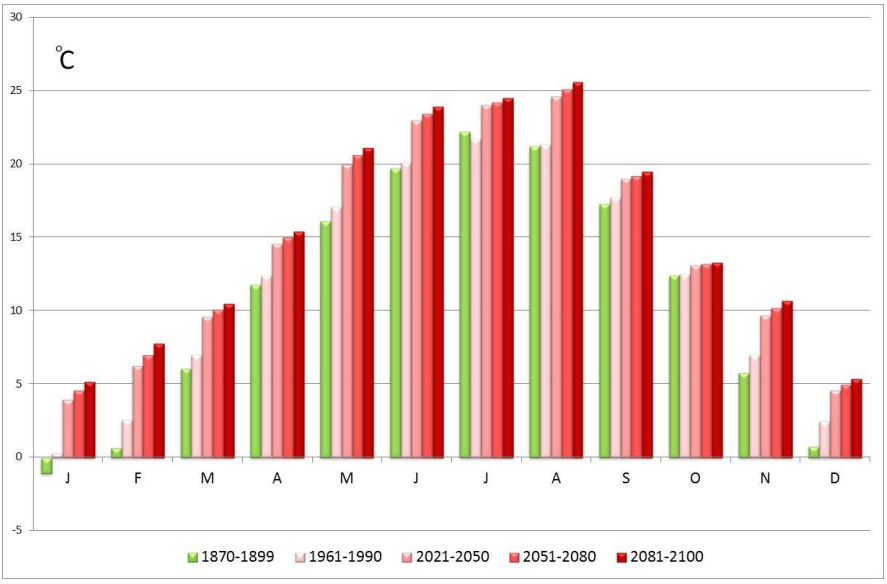
Table 1 provides mean air temperatures by month for the reference periods (1871-1900 and 1961-1990) and the model values obtained for the three projected periods (2021-2050; 2051-2080; 2081-2100). These values are also shown in Graph 1.

Table 1 shows the mean air temperature values for all the study periods. Table 2 provides a comparison of the seasonal mean air temperature by study period with the global and regional models. The following four seasons are distinguished:

1. December, January, February (DJF),
2. March, April, May (MAM),
3. June, July, August (JJA) and
4. September, October, November (SON).

Table 1. *Mean air temperature by study period*

Periods	Months												
	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
1871-1900	-1.1	0.7	6.1	11.8	16.1	19.7	22.2	21.2	17.3	12.4	5.8	0.8	11.1
1961-1990	0.3	2.6	7.0	12.4	17.1	20.1	21.7	21.3	17.7	12.5	7.0	2.5	11.9
2021-2050	4.0	6.3	9.6	14.6	20.0	23.0	24.0	24.6	19.0	13.1	9.7	4.6	14.4
2051-2080	4.6	7.0	10.1	15.0	20.6	23.4	24.2	25.1	19.2	13.2	10.2	5.0	14.8
2081-2100	5.2	7.8	10.5	15.4	21.1	23.9	24.5	25.6	19.5	13.3	10.7	5.4	15.2



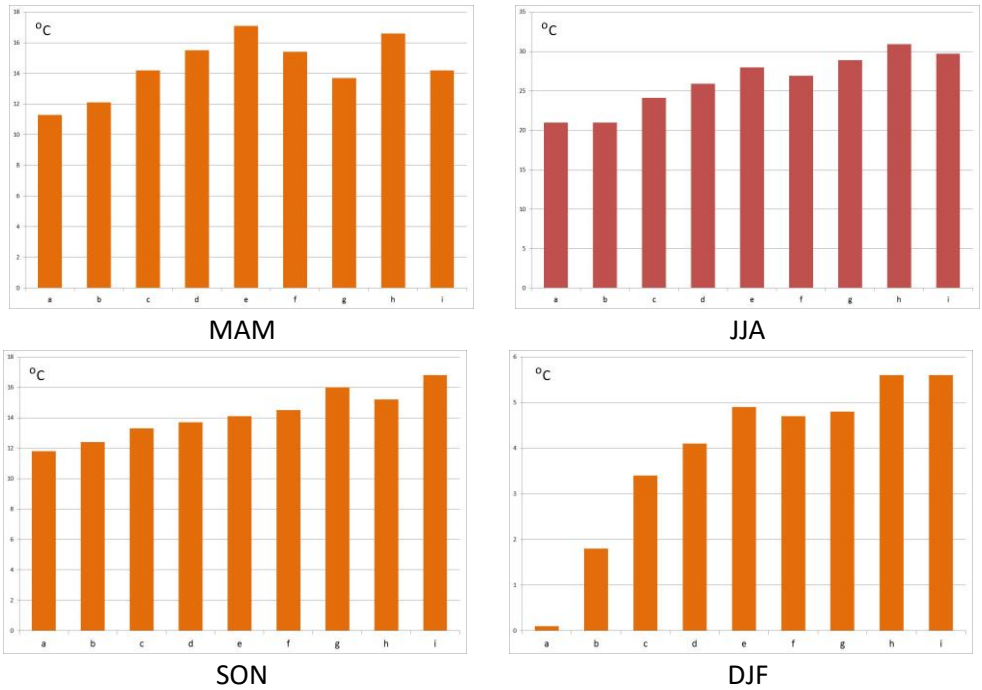
Graph 1. *Mean air temperature by month, reference period, and projected period*

Table 2. *Seasonal air temperatures by study period with the global and regional models*

Seasons	Periods								
	1871-1900	1961-1990	2021-2050	2051-2080	2081-2100	2071-2100	2071-2100	2071-2100	2071-2100
	RP	RF-2	REG-IN model			A1B (E-P)	A1B	A2 (E-P)	A2 (SXG)
Designation	a	b	c	d	e	f	g	h	i
MAM	11.3	12.1	14.2	15.5	17.1	15.4	13.7	16.6	14.2
JJA	21.0	21.0	24.1	25.9	28.0	26.9	28.9	30.9	29.7
SON	11.8	12.4	13.3	13.7	14.1	14.5	16.0	15.2	16.8
DJF	0.1	1.8	3.4	4.1	4.9	4.7	4.8	5.6	5.6

Legend: RF – reference period a-1871-1900; RF-2 Reference period 2 b-1961-1990; Reg-IN model c-2021-2050; d-2051-2080; e-2081-2100; (A1B E-P) f-2071-2100; (A1B SXG) g-2071-2100; (A2 E-P) h-2071-2100; (A2 SXG) i- 2071-2100;

Compared to the reference period, changes in mean air temperature for the December-January-February (DJF) season range from +3.30C (2021-2050) to +4.00C (2081-2100) according to the REG-IN model. Compared to the E-P and SXG models, mean air temperatures have approximately the same values and differ by 0.1 to 0.2^{0}C compared to the A1B scenario, while compared to the A2 scenario the values are lower by 0.7^{0}C (Table 2, Graph 2).



Graph 2. *Seasonal air temperatures by study period with the global and regional models*

According to the REG-IN model, the mean air temperatures for the March-April-May (MAM) season range from +3.1°C (2021-2050) to +5.8°C (2081-2100)

compared to the reference period. Compared to the A1B scenario, the REG-IN model temperature data are higher by 1.7°C (E-P) and 3.4°C (SXG) respectively. Compared to the A2 scenario, the values are higher by 1.1°C (E-P) and + 2.9°C (SXG) respectively (Table 2, Graph 2).

Regarding the June-July-August (JJA) season in the REG-IN model, the deviation of the mean air temperature from the reference period ranges from +3.1°C (2021-2050) to +7.0°C (2081-2100). Compared to the A1B scenario, the REG-IN model temperature data are higher by 1.1°C (E-P) and lower by 0.9°C (SXG). Compared to the A2 scenario, the values are lower by 1.9°C (E-P) and 1.7°C (SXG), respectively (Table 2, Graph 2).

For the September-October-November (SON) season, according to the REG-IN model, the deviation of the mean air temperature from the reference period ranges from +1.9°C (2021-2050) to +2.3°C (2081-2100). Compared to the A1B scenario, the REG-IN model temperature data are lower by 0.4°C (E-P) and 1.9°C (SXG) respectively. Compared to the A2 scenario, the values are lower by 1.1°C (E-P) and 2.7°C (SXG), respectively (Table 2, Graph 2).

Table 3. *Mean maximum air temperature by study period*

Periods	Months												
	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
1871-1900	2.1	5.2	11.2	17.0	21.6	25.0	27.9	27.4	23.3	17.5	9.7	4.1	16.0
1961-1990	3.4	6.2	11.7	17.5	22.4	25.3	27.2	27.2	23.7	18.1	11.0	5.5	16.6
2021-2050	6.1	9.5	14.0	19.3	24.1	27.6	29.7	30.1	24.3	19.1	12.8	6.3	18.4
2051-2080	7.5	11.7	15.5	20.3	24.8	28.5	30.9	31.4	24.4	19.8	13.7	6.7	19.2
2081-2100	9.1	14.4	17.3	21.5	25.5	29.7	32.3	33.1	24.5	20.7	14.7	7.0	20.2

Table 4. *Comparison of the mean maximum air temperature by study period with regional models*

Seasons	Periods						
	1871-1900	1961-1990	2021-2050	2051-2080	2081-2100	2071-2100	2071-2100
	RP	RF-2	REG-IN model			A1B	A2
MAM	16.6	17.2	19.1	20.0	21.2	19.5	20.8
JJA	26.7	26.6	29.1	30.2	31.5	35.3	36.7
SON	16.8	17.6	18.3	18.5	18.6	19.1	19.8
DJF	3.8	5.1	7.0	8.1	9.3	7.3	7.9

Changes in the mean maximum air temperature for the December-January-February (DJF) season, according to the REG-IN model, deviate from to the reference period by +3.2°C (2021-2050) and +4.3°C (2081-2100). Compared to the E-P Model and the A1B scenario, the mean maximum air temperature values are higher by 2.2°C, and 1.2°C compared to the A2 scenario (Table 4).

According to REG-IN model for the March-April-May (MAM) season, the mean maximum air temperatures are +2.5°C (2021-2050), and +3.4°C (2051-2080) to +4.6°C (2081-2100) compared to the reference period. Compared to the A1B scenario, the REG-IN model temperature values are higher by 1.7°C (E-P) and compared to the A2 scenario, they are higher by 0.4^0C (E-P). (Table 4).

According to the REG-IN model for the June-July-August (JJA) season, the mean maximum air temperatures are +2.4°C (2021-2050), +3.5°C (2051-2080)

and +4.8°C (2081-2100) compared to the reference period. Compared to the A1B scenario, the REG-IN model temperature values are lower by 3.8°C (E-P) and compared to the A2 scenario by 5.2°C (E-P), (Tabela 4).

According to the REG-IN Model for the September-October-November (SON) season, the mean maximum air temperatures are +2.5°C (2021-2050) and +2.7°C (2051-2080) to +2.8°C (2081-2100) compared to the reference period. Compared to the A1B scenario, the REG-IN Model temperature values are lower by 0.5°C (E-P) and 1.2°C (E-P) compared to the A2 scenario. (Table 4).

Table 5. *Mean minimum air temperature by study period*

Periods	Months												
	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
1871-1900	-2.3	-5.3	-3.0	1.7	6.7	10.8	14.3	16.1	15.3	12.1	7.9	2.0	6.4
1961-1990	-2.3	-0.3	3.2	7.8	12.1	15.0	16.3	16.1	13.0	8.4	4.0	-0.1	7.8
2021-2050	-0.8	1.9	6.1	10.5	14.8	17.8	18.7	18.1	13.3	8.3	3.7	-0.1	9.4
2051-2080	-0.6	3.1	8.1	12.4	16.7	19.3	19.8	18.6	12.8	7.3	2.7	-0.8	10.0
2081-2100	-0.5	4.3	10.1	14.4	18.6	20.9	20.8	19.0	12.3	6.4	1.8	-1.4	10.6

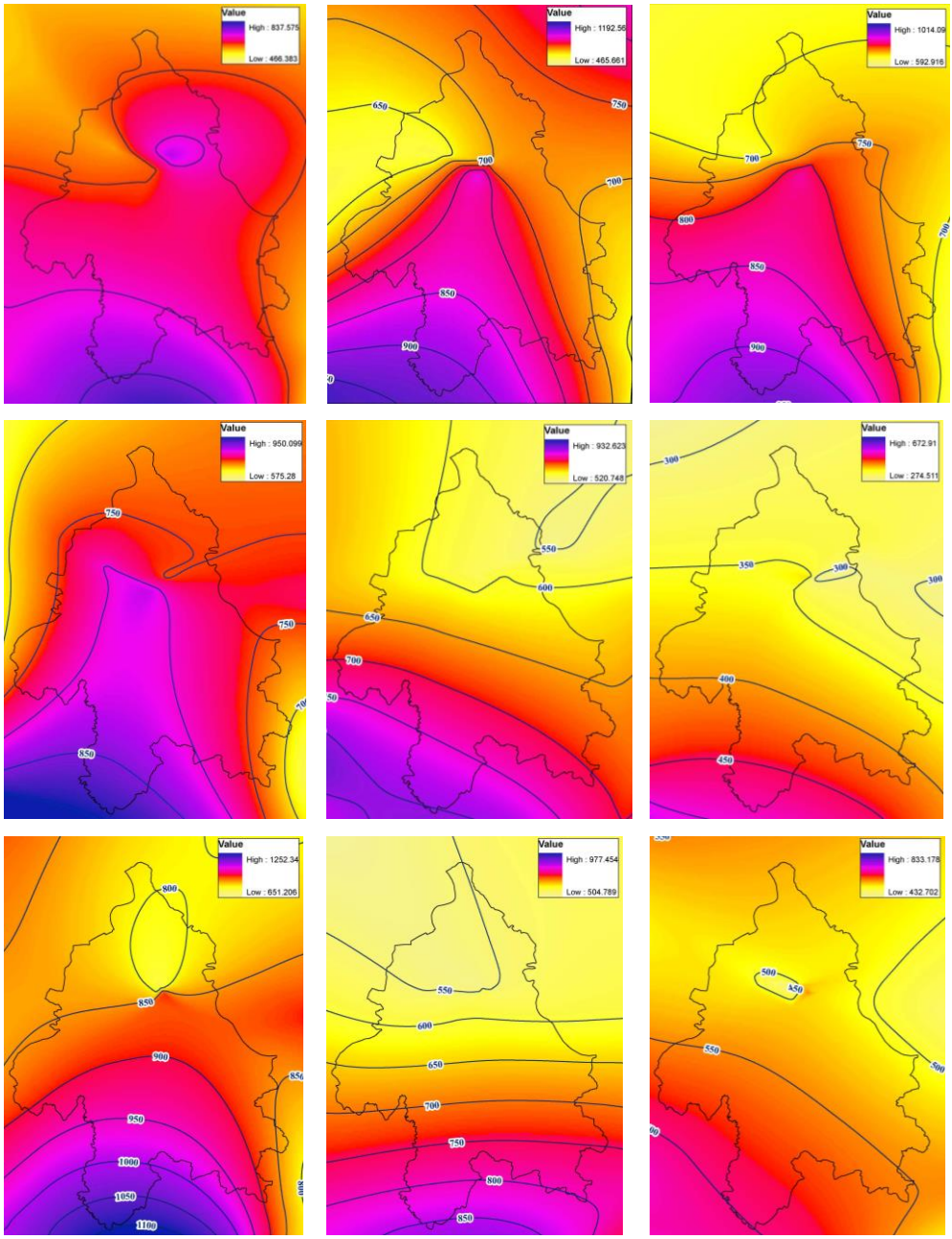
Table 6. *Mean minimum and mean maximum air temperatures*

Periods	Mean minimum air temperature				Mean maximum air temperature			
	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF
1871-1900	6.4	15.2	7.3	-3.5	16.6	26.7	16.8	3.8
1961-1990	7.7	15.8	8.5	-0.9	17.2	26.6	17.6	5.1
2021-2050	9.8	19.1	9.9	0.8	19.1	29.1	18.3	7.0
2051-2080	11.1	21.0	10.6	1.5	20.0	30.2	18.5	8.1
2081-2100	12.6	23.3	11.3	2.1	21.2	31.5	18.6	9.3

Changes in the mean minimum air temperature for the December-January-February (DJF) season, according to the REG-IN model, are +4.3°C (2021-2050), +5.0°C (2051-2080) and + 5.6°C (2081-2100) compared to the reference period. Compared to the E-P Model and the A1B scenario, the mean minimum air temperatures are lower by 0.5°C and by 1.6°C compared to the A2 Scenario (Table 7).

Table 7. *Comparison of the mean minimum air temperature by study period with regional models*

Seasons	Periods						
	1871-1900	1961-1900	2021-2050	2051-2080	2081-2100	2071-2100	2071-2100
	RP	RF-2	REG-IN model			A1B	A2
MAM	6.4	7.7	9.8	11.1	12.6	12.3	13.4
JJA	15.2	15.8	19.1	21.0	23.3	25.4	26.6
SON	7.3	8.5	9.9	10.6	11.3	11.9	11.9
DJF	-3.5	-0.9	0.8	1.5	2.1	2.6	3.7

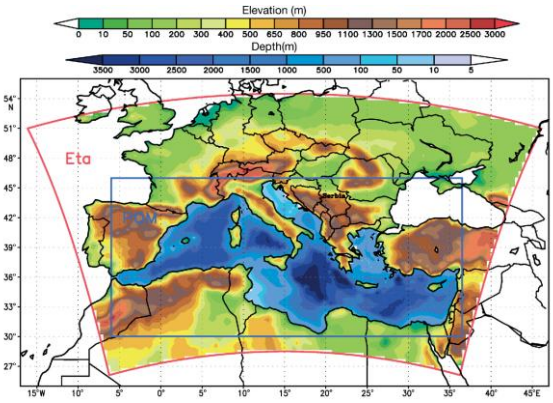


Picture 1. *Simulation of the REG-IN Model*

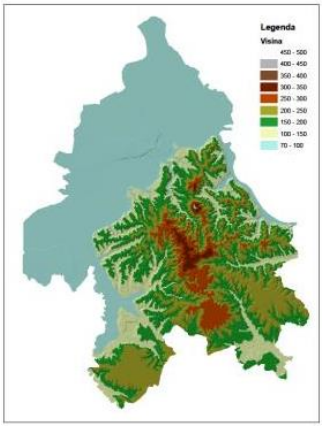
According to the REG-IN model for the March-April-May (MAM) season, the mean minimum air temperature range from +3.4°C (2021-2050) and +4.7°C (2051-2080) to +6.2°C (2081-2100) compared to the reference period. The temeperature values obtained in the REG-IN model are higher by 0.3°C than the values obtained in the A1B scenario (E-P) and lower by 0.8°C than the A2 scenario values (E-P) (Table 6).

According to the REG-IN model for the June-July-August (JJA) season, the mean minimum air temperature range from +3.9°C (2021-2050) and +5.8°C (2051-2080) to +8.1°C (2081-2100) compared to the reference period. The temeperature values obtained in the REG-IN Model are lower by 2.1°C than in the A1B scenario (E-P) and 3.3°C compared to the A2 scenario (E-P), (Table 6).

According to the REG-IN Model for the September-October-November (SON) season, the mean minimum air temperature range from + 2.6^{0}C (2021-2050) and +3.3^{0}C (2051-2080) to +4.0^{0}C (2081-2100) compared to the reference period. The temeperature values obtained in the REG-IN Model are lower by 0.6^{0}C than in the A1B scenario (E-P) and by 0.6^{0}C compared to the A2 scenario (E-P), (Table 6).



Picture 2. *Model domains. Area bounded by outer line is the Eta Model domain; the inner rectangle represents the domain boundary of the Princeton Ocean Model (POM) (Krzić et al., 2011)*



Picture 3. *Area bounded by outer line is the REG-IN Model domain*

4. FORECASTS OF ADAPTIVE OPPORTUNITIES OF FOREST ECOSYSTEMS IN BELGRADE

Based on the environmental characteristics of each site and the main species, the survival of all forest and shrub sites found in the Belgrade area was projected.

The model includes all the specific site features: location, size of the mountain massif, bedrock, climate, altitude, aspect, microclimate, potential forest community expansion (limited by orographic conditions), etc. This produced a realistic projection of environmental conditions. The term “habitat loss” refers to a

drastic change in environmental habitat conditions in which a forest community exists today.

G – FORESTS, FOREST HABITATS AND RELATED WOODLAND AREAS

G1 – BROADLEAVED DECIDUOUS FORESTS		Period		
G1.1 – Riverine forests of willow (Salix), alder (Alnus), and birch (Betula)		2019-2049	2050-2080	2080-2100
G1.1141	Continental willow (*Salix*) galleries on recent alluvial deposits	b	A	A
G1.1142	Continental willow (*Salix*) galleries on gley soils	b	A	A
G1.115	Willow and poplar floodplain forests	A	A	A
G1.116	White poplar (*Populus alba*) floodplain forests	A	A	A
G1.117	Black poplar (*Populus nigra*) floodplain forests	A	A	A
G1.119	Mixed floodplain forests of black poplar (*Populus nigra*) white poplar (*Populus alba*)	A	A	A
G1.2 - Ash-alder (Fraxinus)-(Alnus) and oak (Quercus)-elm (Ulmus)-ash (Fraxinus) riverine forests				
G1.2231	Mixed forests of narrow-leafed ash (*Fraxinus angustifolia*) and pedunculate oak (*Quercus robus*) along large rivers	a,b	a,b	A
G1.2233	Mixed forests of field ash (*Fraxinus angustifolia*), pedunculate oak (*Quercus robur*) and hornbeam (*Carpinus betulus*) along large rivers	a,b	A	A
G1.2234	Hygrophilic forests of pedunculate oak (*Quercus robur)* and common hornbeam (*Carpinus betulus*)	a,b	A	A
G1.4 – Broadleaved swamp forests that don`t grow on acid peat				
G1.42	Oak (*Quercus*) swamp forests	A	A	A
G1.44	Narrow-leafed ash (*Fraxinus angustifolia*) swamp forests	A	A	A
G1.6 - Beech (Fagus) forests				
G1.6911	Moesian monodominant submontane beech forests	A	A	A
G1.6913	Moesian submontane beech forest with linden trees (*Tilia* spp,)	A	A	A
G1.6914	Moesian submontane beech forests with sessile oak trees (*Quercus petraea)*	A	A	A
G1.7 – Thermophilous deciduous forests				
G1.7611	Typical forests of Hungarian oak and Turkey oak	h	h	h
G1.7612	Forests of Hungarian oak and Turkey oak with butcher`s broom (*Ruscus aculeatus)*	h	h	h
G1.763	Moesian Oak of Virgil (*Quercus virgiliana*) forests	f,h	f,h	f,h
G1.7A12	Pannonian Oak of Virgil (*Quercus virgiliana*) forests	h	h	h
G1.7A14	Pannonian forests of pedunculate oak (*Quercus robur*) on loess	b	b	b

G1.7A15	Pannonian forests of sessile oak (*Quercus petraea*) and Turkey oak (*Quercus cerris*)	A	A	A
G1.8 – Acidophilous oak-dominated forests (Quercus)				
G1.871	Moesian acidophilic sessile oak (*Quercus petraea*) forests	A	A	A
G1.A – Moeso-eutrophic forests of (Quercus), (Carpinus), (Fraxinus), (Acer), (Tilia), (Ulmus) and related woodland				
G1.A1B1	Pannonian sessileoak-hornbeam (*Quercus petraea*) - (*Carpinus betulus*) forests	A	A	A
G1.A1C1	Moesian sessileoak-hornbeam (*Quercus petraea*) - (*Carpinus betulus*) forests	A	A	A
G1.A24	Non-riverine ash (*Fraxinus excelsior*) forests with linden trees (*Tilia* spp,)	f,b	A	A

The table labels in the columns are: a - reduction of groundwater level; b - reduction of the area of distribution; h - area expansion; f - occurs on a limestone bedrock; A - habitat loss

5. CONCLUSIONS

Climate models indicate that adaptive measures and climate change mitigation are necessary. It is still possible to avoid the worst-case scenarios provided that appropriate mitigation measures are applied. On the other hand, some climate changes are of such a character that we have to adapt to them. This means that reducing greenhouse gas emissions and adapting to climate change are not mutually exclusive but must be applied together (Reich et al., 2018).

The climate model-based analysis provides an opportunity to develop strategies to address the effects of climate change in the Belgrade area. Additional research is needed at this stage of model development to reduce errors of regional climate modeling (Giorgi et al, 2009). It is proposed to introduce an "ensemble-based approach" to modeling which provides information on climate change in the form of a probability density function.

The actual and potential vegetation in the Belgrade area will develop in conditions of increased temperature compared to the present circumstances. This trend of changes also indicates an increase in summer temperature extremes in the city area, which makes the conditions for the development of vegetation even more difficult.

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THE REGIONAL CLIMATE MODEL (REG-IN) FOR FORECASTING THE ADAPTIVITY OF FOREST ECOSYSTEMS IN BELGRADE

Tatjana RATKNIĆ, Mihailo RATKNIĆ, Lazar VUKADINOVIĆ

Summary

Regional climate modelling with regional climate models has become a part of modern research with a wide range of applications. This article examines the latest segments in the study of regional climate modeling used to assess the adaptivity and survival of particular forest species in changing conditions. It presents the results of the regional climate model (acronym REG-IN) used to predict the adaptive capacity of forest ecosystems in Belgrade. Compared to the SXG and E-P models, the REG-IN model exhibits certain deviations due to the specific environmental conditions of the area. These data have made it possible to predict the future rate of survival of individual forest ecosystems.

REGIONALNI KLIMATSKI MODEL (REG-IN) U FUNKCIJI PREDVIDJANJA ADAPTIVNIH MOGUĆNOSTI ŠUMSKIH EKOSISTEMA NA PODRUČJU BEOGRADA

Tatjana RATKNIĆ, Mihailo RATKNIĆ, Lazar VUKADINOVIĆ

Rezime

Regionalno modeliranje klime sa regionalnim klimatskim modelima postao je deo savremenog istraživanja i omogućava upotrebu u širokom spektru primene. U ovom radu preispituju se najnoviji segmenti u istraživanju regionalnog klimatskog modelovanja u funkciji adaptacije i opstanka pojedinih šumskih vrsta u novonastalim uslovima. Prikazani su rezultati regionalnog klimatskog modela (akronim REG-IN) u funkciji predvidjanja adaptivnih mogućnosti šumskih ekosistema na području Beograda. U poredjenju sa modelima SXG i E-P, model REG-IN pokazuje izvesna odstupanja koja su uslovljena specifičnim ekološkim uslovima područja. Ovi podaci su omogućili da se predviti stepen opstanka pojedinih šumskih ekosistema u budućnosti.

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GEOLOGICAL SUBSTRATE OF THE TERRITORY OF NOVI PAZAR AS AN INDICATOR OF PRESERVED ENVIRONMENT

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Abstract: *We strive to live in a healthy environment and to keep the entire food chain unpolluted and free of all unwanted contaminants. The care for humans cannot be considered partially if at the same time we do not succeed in a fight for unpolluted environment for flora and fauna. Likewise, we need to be well aware of environmental conditions and benefits they provide us with for better quality and healthier living in a particular area. Certainly, each territory has its own characteristics caused by environmental conditions. In geological terms, the territory of Novi Pazar is special in its characteristics since in this area Vardar zone faces Dinaric zone, where both have an impact on the quality of the environment. Knowing the property of parent material that by its dissolution it gives elements which reach lithosphere, hydrosphere and atmosphere and through the food chain they circulate from plants, animals to humans, it is necessary to intensify the study of the properties of geological substrate as an indicator of preserved and healthy environment.*

Key words: Novi Pazar, geological substrate, environment

GEOLOŠKA PODLOGA PODRUČJA NOVOG PAZARA KAO INDIKATOR OČUVANE ŽIVOTNE SREDINE

Izvod: *Trudimo se da živimo u zdravoj životnoj sredini i da ceo lanac u ishrani bude nezagađen i oslobođen svih neželjenih primesa. Briga za čoveka ne može se parcijalno posmatrati, ako se istovremeno ne izborimo da imamo nezagađenu sredinu za biljni i životinjski svet. Isto tako moramo dobro poznavati ekološke uslove i prednosti koje nam oni pružaju za kvalitetniji i zdraviji život na određenom prostoru. Naravno da svako područje ima svoje karakteristike uslovljene ekološkim uslovima. Područje Novog Pazara u*

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geološkom smislu je karakteristično, jer se na ovom prostoru susreću Vardarska i Dinarska zona, gde jedna i druga imaju uticaj na kvalitet životne sredine. Poznavajući svojstva matičnog supstrata, da svojim rastvaranjem daje elemente koji dospevaju u litosveru, hidrosferu i atmosferu i da kroz lanac ishrane, oni kruže od biljaka, životinja do čoveka, neophodno je intenzivirati proučavanja svojstava geološke podloge kao indikatora očuvane i zdrave životne sredine.

Ključne reči: Novi Pazar, geološka podloga, životna sredina

1. INTRODUCTION

The global concept of sustainable management of natural resources has an important environmental and social economic dimension, and it is developed as a result of growing awareness of the impact of activities of humans on the environment. According to Komatina (1999), geological substrate is of great importance to the whole flora and fauna, and it is reflected depending on the composition of parent material.

Natural regeneration of forest areas, as well as the choice of methods of natural regeneration, depend most on ecological (habitat) conditions, among which heterogeneity of geological base is very often a decisive factor (Čokeša et al, 2006).

The researched territory is characterized by the diversity of parent material, which reflects the presence of a large number of different types of rocks. The geological substrate of the territory of Novi Pazar is special in its characteristics since in this area Vardar zone faces Dinaric zone.

In the territory of Novi Pazar, there are, as everywhere, small sins against the nature. In the first place there is a very often occurrence of forest fires, or a poor decision to form Golo Brdo city dump on the spring of the Josanica river in a Common Spruce stand at the altitude of 1300 meters. After a certain period of time, all this affects negatively the geological substrate and other environmental factors.

2. MATERIAL AND METHODS

The researched territory is situated in southwestern Serbia, in stellate valley of the Josanica, the Raska, the Dezevska, the Trnavska and the Ljudska rivers at the altitude of 496 meters, surrounded by high mountains Golija, Rogozna, Turjak, Crni Vrh, and Pester plateau.

For this paper, data from literature related to the territory of Novi Pazar and wider area of Pester and Kopaonik are used. Data on the composition of geological substrate are taken from Basic Geological Map 1:100.000 – sheets Sjenica (Mojsilovic et al., 1979) and Novi Pazar (Urosevic et al., 1970), as well as the data from General Forest Management Plan for the forest area "Gornji Ibar".

To study the content of documents, content analysis was applied as a kind of partial analysis (Milosavljević, Radosavljević, 2008). Some authors (Bulmer, 1977; Neuman, 2014) classify content analysis into a group of nonreactive methods since it does not involve direct elicitation of data from the research subjects. The

respondents are not aware of the research, unlike questionnaires, interviews, and experiments, which are reactive methods (Neuman, 2014).

3. RESULTS AND DISCUSSION

The geological substrate is the basis for formation of soil, where the plant cover is formed. By their decomposition, all the elements from the substrate reach soil and water and then through the food chain they reach plants, animals and humans. The researched territory is represented by two geological sheets (Figure 1).

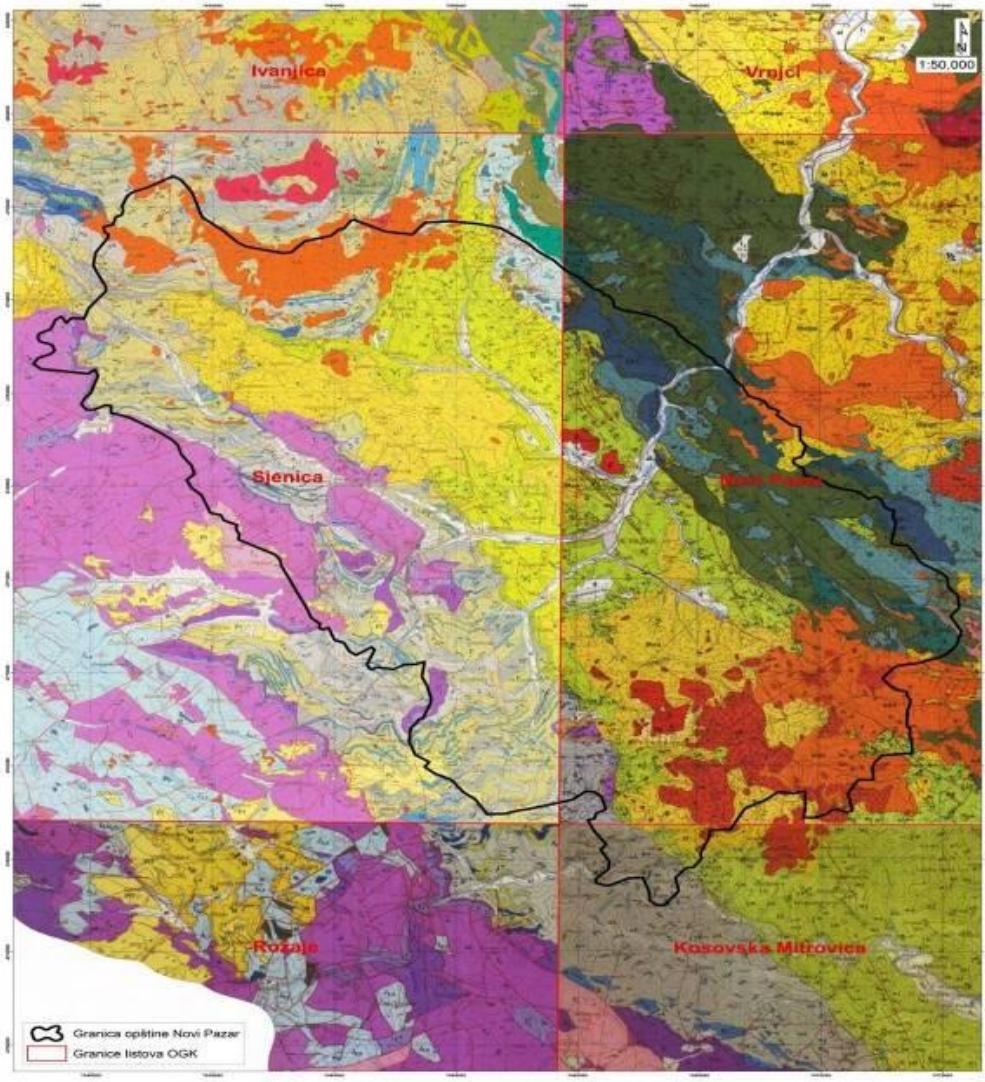

Figure 1. *Geological map of the researched territory according to the Basic Geological Map 1:100.000, Sheet Sjenica (Mojsilović et al.,1979) and Novi Pazar (Urosević et al.,1970).*

3.1 Geological Characteristics of the Sheet Sjenica

"Sheet Sjenica" covers an area of 1,506 km^2 and extends in southwestern Serbia, between 43“00 and 43“20 of latitude and 20“00 and 20“30 of longitude. Javor and Golija are in the north, Jadovnik and Giljeva in the west, southern border of the sheet is Pester-Tutin-Stari Kolasin, and eastern border reaches Novi Pazar and extends toward Golija. It is a mountainous region with an average altitude of over 1000 m. Relief is rugged with significant differences in height. Sjenicko polje, Kostam polje and Pestersko polje stand out morphologically.

In this researched territory the following mapped units are singled out (Mojsilović et al.,1979):

- Low-grade metamorphic rocks of Paleozoic age discovered on the southern slopes of Golija and in the area of the Ljudska Reka river, as well as between Novi Pazar and Tutin. On the southern slopes of Golija, rocks have a very high crystallinity, which is a consequence of thermometamorphic action of quartz-latite and granodiorite masses.
- Quartz conglomerates and breccia form a narrow zone on the southern slopes of Golija and around Muhovo. They appear in the form of thick deposits. Their color is gray, rarely grayish brown. Sericite quartzite appears in the same area in the form of thinner layers.
- Phyllites extend in the area of Golija mountain, the Ljudska Reka and south from old Ras. Their color is gray, grayish brown and rarely almost black.
- Wide zone north and east from Muhovo, in the upper part of the Dezevska Reka river, in the Ljudska Reka river valley, then south of the village Gorandje and around Vrbasice, is made of sandstone, slate and phyllites.
- Sandstone is discovered around the village Gorandje, the Raska river valley, around Muhovo and in the area of Hodzevo.
- Plagiogranite is found in a small and narrow area in the village Orlje.
- Quartz clastites are found on location around Sopocani and Siljak, with a maximum depth of up to 120 m.
- Oolitic limestone occurs to a lesser extent in Hodzevo and in the area towards Crkvine, with a maximum thickness of about 100 m.
- Clayey and sandy limestones, stand out at the peripheries of Pestersko polje and Kostam polje in the valley of the Josanica, along the Novi Pazar –Tutin road and at Hodzevo.
- Spilite-keratophyre association, diabases are predominant among these rocks, then spilite, gabbro and keratophyre, while porphyrite is significantly rarer. Diabase breccias are found only in Golija.
- Porphyrite is found only on a few locations in sediments of diabase-hornstein formation, namely on Golija and Bekova. Iron and manganese coatings give brownish red and ochre color. Metamorphosed diabase-hornstein formation has been distinguished around Bekova and in Petrovo polje.
- Pre-flysch marl spreads in the valley of the Raska river around the village of Jablanica and on southeastern slopes of Golija.

- Lower flysch horizon has been developed in the area of the Deževska river, then the Saronjska Reka river, between Novi Pazar and Sudsko Selo and north of Rajcinovica Banja.
- Sandstone horizon, developed in the Glavoc area, Musina Livada, Kalem village, northwest of Vojnice and in Boturovina. The thickness of these layers is about 300 meters.
- Pyroclastics are found in the area of Golija, the Ljudska Reka river, the Raska river, around the town of Novi Pazar and near Vojnice village.
- Terrace sediments are singled out on the map along the Raška and the Dezevska Reka rivers. Terraces into which the Raška river has cut its stream bed extend from Sopocani to Pazarište on both sides of the Raska river. Their maximum width is about 200 m and depth is 10 to 15 m. Terraces of gravel, sand and sandy clay, 5 to 10 m thick, have been formed along the Dezevska river.
- Diluvium and rock creeps are found in the valley of the river Ljudska Reka and in the Dezevska Reka. Their thickness varies from 20 to 30 m.
- Proluvium is found on Pešter, then next to the Sebecevska Reka and the Ljudska Reka rivers, and its thickness is 20 to 30 m.
- Alluvium is found along the Raška, the Ljudska and the Deževska rivers and its thickness is up to 30 m.

3.2. Geological Characteristics of the Sheet Novi Pazar

"Sheet Novi Pazar" includes an area in the southwestern part of Serbia, between 20º30'' and 21º East longitude and 43º and 43º20'' North latitude. This territory is characterized by mountainous and high mountainous area with strong dissection and fine texture of relief. It includes central and southern parts of Kopaonik, Rogozna with Crni Vrh and southeastern parts of Golija. An overview of the territory of Rogozna and southeastern parts of Golija is presented in the paper:

- Significant area in the sheet Novi Pazar, namely the part from Novopazarska Banja to Odojevice, is rich in serpentinite.
- Quartzite also appears in the area of Golija and Rogozna mountains.
- Crystalline limestone occurs in the area of the Josanicka Reka. Its depth is 20 to 30 m.
- Metamorphosed diabase is found on Cukara, where it forms smaller concordant lenses in phyllites.
- Conglomerates and conglomerate breccia are found in a larger area on the western slopes of Rogozna in the area of the villages Znusa and Belanjska. The thickness of a series does not exceed 50 m.
- Marly limestone is noted in the Znuska Reka, Postenje and Blazevo. Its depth varies from 100 to 250 m.
- Dacito-andesite and quartz-latite are noted in Lopuznje, Sanac and Javor.
- Quartz-latite and latite are noted around Cepeljski Krš, on Crni Vrh, in the village Bare and on Javor.

- Basaltic andesite and trachybasalt are noted in the western part of Rogozna, Musov Vrh and Koznik.
- Alluvial formations are noted along river valleys of the river Raska, the Dezevska, the Josanica, the Trnavska.

If we analyze the territory of Novi Pazar, it can be concluded that significant majority of the area of its territory, in terms of geological substrate, is made of limestone and serpentinite, i.e. in the Sheet Sjenica limestone is predominant, while in the Sheet Novi Pazar the predominant substrate is serpentinite. These two geological formations affect differently the preservation of the environment by their decomposition. In the researched territory the environmental benefits which are a prerequisite for having unpolluted soil, clean and potable water, possibility for engaging in agriculture and forestry, development of spa tourism, as well as development of hunting, sports and health tourism must be reaped. (Hadrović, 2015).

5. CONCLUSIONS

The geological environment represents a very important component of the environment, its foundation. The degradation of rocks and minerals enables release of certain elements which then pass into lithosphere, hydrosphere and atmosphere and through the food chain that includes plants, animals and humans, these substances directly affect the health of plants, animals and humans.

The territory of Novi Pazar by its natural conditions represents one the most beautiful regions in Serbia. Surrounded on all sides by mountain ranges, with two spas with thermal mineral water and rich flora and fauna, it represents the right place for relaxation and development of all types of tourism. The geological substrate plays an important role in the above together with other environmental factors.

The geological composition of this territory dominated by limestone and serpentinite is conditioned by favorable geomorphological environment, abundance of thermal mineral water and high-quality potable water, which has favorable effect on quality and preservation of the environment.

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GEOLOGICAL SUBSTRATE OF THE TERRITORY OF NOVI PAZAR AS AN INDICATOR OF PRESERVED ENVIRONMENT

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Summary

The geological environment represents a very important component of the environment. The degradation of rocks masses enables release of certain elements which then pass into lithosphere, hydrosphere and atmosphere and through the food chain that includes plants, animals and humans, these substances directly affect the health of plants, animals and humans. Geological background and lands that it generated, as a set of environmental factors affect the divergence of plant forms and vegetation units. In addition to the chemical composition of the geological substrate, physical structures and quantitative relationship of individual elements and their salts in the substrate have a significant impact on vegetations that develop on that substrate, which is particularly well be seen when comparing the vegetation generated on different bedrocks and soils, as well as by comparative comparison of the chemical content of their representatives. The geological composition of territory Novi Pazar, dominated by limestone and serpentinite is conditioned by favorable geomorphological environment, abundance of thermal mineral water and high-quality potable water, which has favorable effect on quality and preservation of the environment.

GEOLOŠKA PODLOGA PODRUČJA NOVOG PAZARA KAO INDIKATOR OČUVANE ŽIVOTNE SREDINE

Sabahudin HADROVIĆ, Ljubinko RAKONJAC, Aleksandar LUČIĆ, Saša EREMIJA

Rezime

Geološka sredina predstavlja veoma važan sastavni deo životne sredine. Degradacijom stenskih masa, oslobađaju se pojedini elementi, koji potom prelaze u litosferu, hidrosferu, biosferu i putem lanca ishrane u kojem učestvuju biljke, životinje i čovek, direktno utiču na zdravlje biljaka, životinja i čoveka. Geološka podloga i na njoj nastala zemljišta, kao skup ekoloških faktora utiču na divergenciju biljnih oblika i

vegetacijskih jedinica. Pored hemijskog sastava geološke podloge, na vegetaciju koja se na njoj razvija, značajan uticaj imaju fizička struktura i kvantitativan odnos pojedinih elemenata i njihovih soli u podlozi, što se naročito lepo može videti pri komparaciji vegetacija nastalim na različitim geološkim podlogama i zemljištima, kao i komparativnim upoređivanjem hemijskog sadržaja njihovih predstavnika. Geološki sastav područja Novi Pazar, gde dominiraju krečnjak i serpentinit, uslovljen je povoljnim geomorfološkim ambijentom, bogatstvom termomineralnih voda i voda visokog kvaliteta za piće, što se povoljno odražava na kvalitet i očuvanost životne sredine.

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APPLICATION OF SMALL UNAMANNED AERIAL SYSTEMS IN LOGISTICS AND PLANNING

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Abstract: *The application of modern technologies makes it easy to collect, process, present, and apply data for logistics in hard to reach areas. Proper delivery of equipment, personnel, and materials directly affects the quality of work. The need for precise and real information about the condition of the terrain and the conditions of the environment has always existed since this knowledge enables proper planning, forecasting and task performing in the field. Improvement in the digital industry enables fast and easy transfer of unchanged digital data from the field to the information processing centers, which consequently improves decision making and planning processes. New workflows made proper logistics even more important because it increased the precision of field work and better anticipation of previously unforeseen circumstances. Work on hard to reach areas, with large slopes, non-existent and/or non-persistent infrastructure, and different degree of vegetation coverage requires precise planning and organization of works, in order to minimize the number of unforeseen situations and make the most expeditious workflows. This paper presents the practical application of small unmanned aerial systems for collecting a large amount of data in a short time, the processing of the data, and the production of relevant information for decision making. There are two most important aspects of this paper. First one is fast, easy, safe and precise collection of large amounts of data which is an alternative to the traditional methods. The second is computer data processing, which enables a fast and automatic transformation of raw data into relevant information in digital formats that are suitable for further processing and easily accessible to decision makers. This work shows that it is possible to record quickly and in detail a large area, and obtain real, current, accurate and high-fidelity information about each*

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point of terrain, with high precision and reliability.

Keywords: unmanned aerial systems, Agisoft Metashape, logistics, terrain mapping, terrain modeling

PRIMENA MALIH BESPILOTNIH SISTEMA U LOGISTICI I PLANIRANJU

Izvod: *Primena modernih tehnologija omogućava lako prikupljanje, obradu, prezentovanje i primenu podataka u logistici u teško pristupačnim terenima. Adekvatno dostavljanje opreme, ljudstva i materijala direktno utiče na kvalitet radova. Potreba za preciznim i realnim informacijama u vezi sa uslovima terena i okoline je oduvek postojala, jer ovo znanje omogućava pravilno planiranje, predviđanje i izvođenje zadataka na terenu. Napredak u digitalnoj industriji omogućava brz i lak prenos neizmenjenih podataka sa terena do centara za obradu podataka, što dalje unapređuje proces donošenja odluka i planiranje. Nove procedure rada su doprinele značaju logistike jer je povećana preciznost izvođenja radova kao i predviđanje do sada nepredvidivih okolnosti. Velika preciznost planiranja je neophodna kada se radi na nepristupačnim terenima sa velikim nagibima i nepostojanom infrastrukturom i sa različitom pokrivenošću vegetacijom. Time se smanjuje broj nepredviđenih situacija na minimum i ubrzava proces rada. U radu je prikazana praktična primena malih bespilotnih letelica za brzo prikupljanje velike količine podataka, zatim obradu podataka, i stvaranje relevantnih informacija potrebnih za donošenje odluka. Ovaj rad ima dva bitna aspekta. Prvi je brzo, lako, bezbedno, i precizno prikupljanje velike količine podataka u poređenju sa tradicionalnim metodama. Drugi aspekt je kompjuterska obrada podataka koja omogućava brzu i automatsku transformaciju sirovih podataka u relevantne informacije, koje su pogodne za dalju obradu i lako dostupne profesionalcima odgovornim za donošenje odluka. Ovaj rad prikazuje da je moguće brzo i detaljno snimiti veliku površinu, i dobiti tačne i veoma pouzdane informacije o svakom delu terena sa visokom preciznošću.*

Ključne reči*:* Mali bespilotni sistemi, agisoft metashape, logistika, prikupljanje podataka

1. INTRODUCTION

Any kind of field work requires careful preparation and efficient workflow and organization. Transportation, delivering and support for personnel and equipment are the first elements to be considered in terms of fieldwork and operations. Since the purpose of logistics is planning and managing of the flow of the equipment and people, the accurate information about the environment and essentials for successful operations and task execution are needed. With a sufficient amount of precise information, we can plan, predict, and foresee the best and the most efficient workflow. Acquiring the information would be the first issue to address especially when entire work has to be done in remote areas. These hard-to-reach areas are especially affected with lack of actual and real-time information which is needed for the decision-making process and proper workflow planning and scheduling. If logistics suffer from GIGO (Garbage in – Garbage out) syndrome, it cannot be expected for the workflow to fulfill high standards of execution.

In order to cover large areas in a fast manner, we opted for aerial

photography as it was still the most widely used form of aerial imaging (Campbell and Wynne, 2011) and the cost-effective form of remote sensing (2015). Ever since World War I reconnaissance, aerial photography has been improving and delivering more information through the processes of photogrammetry and feature extraction. Images are very versatile and they carry a lot of valuable spatial and temporal information about our environment (Campbell and Wynne, 2011). The additional reasons for choosing small Unmanned Aerial Systems were the high versatility of drones and high level of detail which was possible to get from onboard visual sensor.

The especially important aspect of logistics is the "greenness". The logistic is a heart of transportation of manpower and equipment. If the costs of transportation are being cut, and better utilization of vehicles and distribution has been implemented, we can talk about green logistics (Rodrigue *et al.*, 2017).

In addition to the reduced costs, the utilization of the small Unmanned aerial vehicle is a silent and non-invasive way to gather data, without disturbing the environment. Also, airborne vehicles can cover a large area and focus resources on the current situations (2004).

Unmanned aerial vehicle (UAV) or more commonly known as a drone is remotely operated aircraft without a pilot on board. The ease of use and fast deployment have moved drones from military use into civilian in the past few decades. Moreover, the use of small UAVs has been widely exploited in engineering and scientific use. The whole set of equipment – aerial vehicle/platform, a video sensor, and ground control station is represented by the term small Unmanned Aerial System (sUAS). Since the most of the civilian applications include drones that weigh less than 50 kg (very often just a few kilograms) these are considered as a small sUAS. Basic classification of sUAS is on fixed-wing (they resemble an airplane) and multicopter (with 3 or more propellers). Each of the classes has certain advantages and purposes, but those comparations are beyond the scope of this paper, and they are not discussed here.

The aim of this paper is to present and examine the possibilities and opportunities of the application of sUAS and feature extraction software for the purpose of the increase of the amount and improving the precision of the information needed in logistics. The multicopters UAS was found to be the most suitable one for this study.

In this paper, it was examined what kind of information can be produced from the data collected in the field. These raw data will be processed through the various algorithms in order to produce information which will be further used for planning and decision making. This information would affect both human stakeholders (decision makers, employees, investors, end-users, etc.) and natural environment as the non-human stakeholder. The main idea is to give opportunity to decision makers to make the right decisions based on the information unspoiled and unchanged by subjective judgment of the person collecting the data; and at the same time to give more space to manipulate and experiment with different approaches to processing of the data in order to get the most useful information, and thus the more optimized workflow.

2. MATHERIAL AND METHODS

In order to examine the possibility of sUAS and associated technologies, the study area that would be very demanding for traditional methods of terrain analyses work was selected. Also, this area would be a good representative of terrain which demands good and precise information prior to the start of field work.

The area chosen for this study is situated in Bosnia and Herzegovina, Republika Srpska entity, 4 km southwest from the town of Nevesinje, and it covers 1.6 km^2 (Picture 1). The actual coordinates of the terrain are 43.219497, 18.0509090 SE, and 43.238675, 18.0709605 NW, in WGS84 (EPSG: 4326) projection. This area is dominated with typical karst relief. It consists of several hills, high and low vegetation, dirt roads, and several fenced agricultural fields (tillage and pastures).

Picture 1. *Study area*

The equipment used for this was DJI Phantom 4. This sUAS weighs only 1.4 kg and has the ability to sustain wind up to 80 km/h. The aircraft has a GPS/GLONASS navigational system for accurate positioning and it also allows its onboard CMOS sensor to capture 20 Mpix geotagged still images. In order to capture all images in nadir setting the sensor/camera was mounted on 3-axis gimbal. Easy deployment and small visual and audio footprint made this aircraft ideal for the purpose of aerial photography. This electrically powered UAS can cover up to 25 ha in a single flight, with every flight lasting about 25 minutes.

The flight routes were designed before the launch and those were performed through an onboard computer in auto-pilot mode. The flight software of

choice was Drone Deploy. The field coverage was performed with 80% of the front, and 80% of the side overlap between the neighboring images. The chosen altitude was 100 m above ground level from the take-off point. This allowed high detail on every image, plus it proved to be a safe altitude when considering the variety of terrain elevation and vegetation height.

All images were processed in professional photogrammetry software Agisoft Metashape. The hardware used for this purpose consists of i7 8700k 4.9 GHz CPU, RTX 2070 GPU, 64GB RAM and both solid-state and rotary hard drives for processing and storage.

The second part of processing took place in Trimble eCognition Developer, and ArcMap software which allows application of various algorithms, classification and feature extraction. The software provided more information on the area of interest, in addition to the models, features, and exports from Agisoft Metashape.

The first product in Agisoft was Dense Point Cloud. Each point in the cloud had its X, Y, and Z coordinates. From point cloud, the Digital Elevation Model (DEM) and Digital Surface Model (DSM) were created. The information from the DEM combined with the source digital images produced the orthomosaic with spatial information of the terrain.

Accuracy check and improvement and transformation of coordinate system projection were achieved through the use of Ground Control Points. These high accuracy points were measured with high-precision GPS RTK surveying equipment before the flight and those were used during the processing to increase the precision of the terrain model, which consequently improved the accuracy of the DEM, DSM, and orthomosaic.

Agisoft Metashape was used for identification, drawing, and measurement of profiles, slopes, cross-sections, and terrain features.

From the 3D terrain model, DEM, DSM and orthomosaic it was possible to extract further features and profiles and export .tiff files for additional processing and feature extraction in Trimble eCognition and ArcMap software.

3. RESULTS AND DISCUSSION

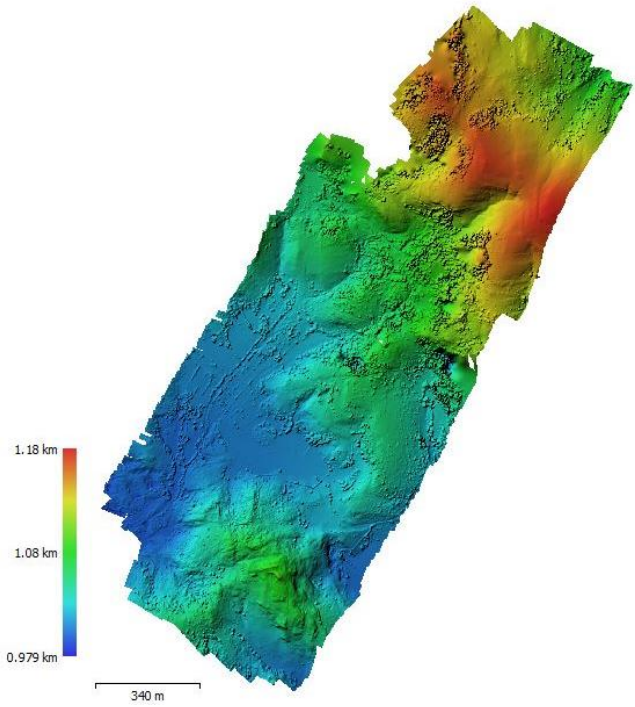
With use of sUASs, it is possible to acquire high-detailed information, with unmatched versatility and timing (Stark *et al.*, 2013). In this study, the total covered area was 160 ha, in just over 3 hours of total flight time, between 10 AM and 2 PM. The number of acquired images was 1,587. All images were in RGB .jpeg format.

All images were used to create a single terrain model in the photogrammetry software AgisoftMetashape. The initial processing took 2.5 hours. During this initial processing, dense point cloud (Picture 4), digital elevation model (Picture 2), digital surface model and orthomosaic (Picture 3) were produced.

The processing in Agisoft Metashape resulted in the creation of a dense point cloud with 147.2 M of points. The density of the point cloud allowed a precise spatial definition of fine terrain features which in turn resulted in the production of fine-detail DEM.

Distinguishing between features like vegetation, flat surfaces and bare

surfaces, different levels of inclinations were easy due to the highly detailed point cloud and consequently DEM.



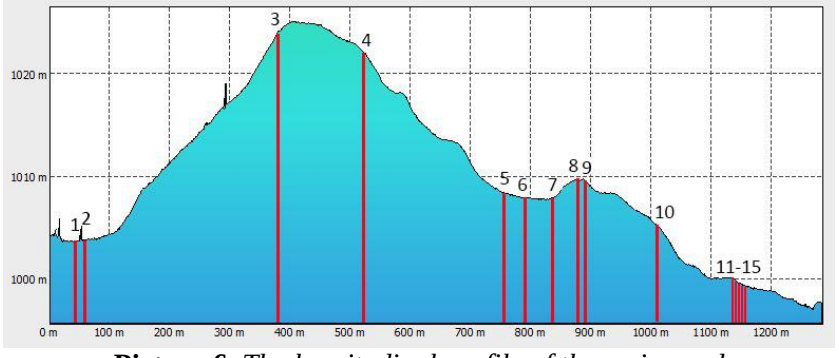
Picture 2. *Digital Elevation Model with an elevation scale*

Picture 3. *Orthomosaic*

Picture 4. *Main road and terrain view in Dense Point Cloud*

Picture 5. *Main road – gravel road with position of profiles*

The use of UAV primarily results in optimization of logistic processes, with the aim of reducing inventory costs, significantly shortening the process, reducing use of human resources (Škrinjar *et al.*, 2018). This statement is confirmed with findings in this paper, but in addition to optimization of logistics process, possible advantages of use of sUAS in planning, work site monitoring and maintenance are also examined.



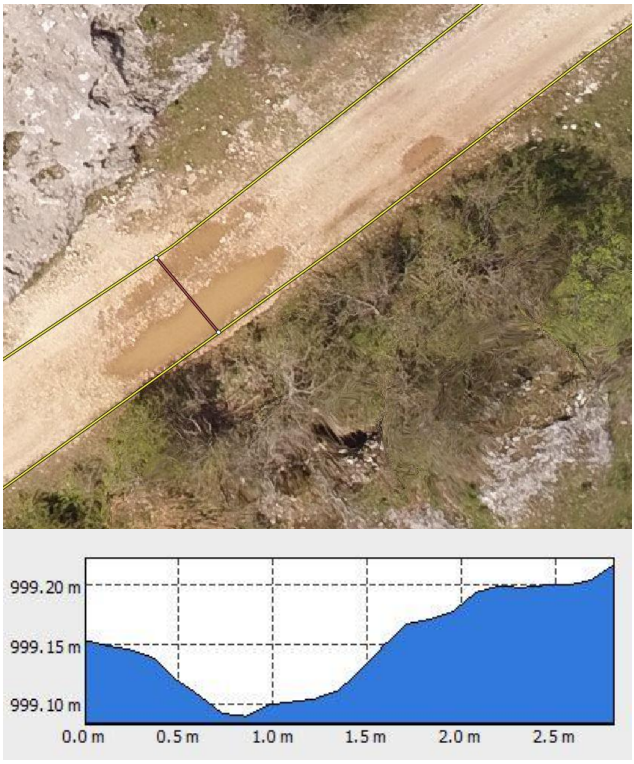
Picture 6. *The longitudinal profile of the main road*

The first thing examined was the main road which goes through the study area and as such is the main road for delivering personnel and equipment. The length of the road in this study area is 1,285 m. It was also interesting to look into the state of the road. The most critical points of the road were identified (Picture 5).

Table 1. *Properties of the profiles*

Profile	Distance (m)	Elevation (m)	Total width (m)	Damage width (m)	Percentage of damage
1	53.32	1004.00	3.58	1.10	30
2	60.89	1004.15	4.92	2.10	43
3	391.36	1025.00	3.01	1.05	35
4	521.21	1020.00	6.88	N/A	0
5	777.82	1007.90	4.88	2.95	60
6	799.84	1007.85	4.55	2.08	62
7	853.16	1009.65	5.13	1.52	30
8	889.32	1008.45	4.75	3.04	64
9	900.22	1008.40	5.37	2.70	50
10	1085.44	1000.10	4.28	1.44	37
11	1140.18	999.10	2.80	2.14	76
12	1148.71	999.08	3.13	0.98	31
13	1152.04	999.05	3.30	0.73	22
14	1159.21	999.02	3.48	0.93	27
15	1166.73	998.85	3.60	1.70	47

Fifteen profiles in total were identified on the main road, and that road was identified to be unpaved and covered with gravel and local materials from the surrounding decomposed rocks and stones. This type of road is not suitable for all vehicles, therefore this information about the type and health of the road should be considered when planning the field workflow.



Picture 7. *The minimum width of the road and its cross-section profile*

Picture 8. *The maximum width of the road and its cross-section profile*

Picture 6 shows the frequent changes of the slope, which in combination of the curvature of the road requires special attention during the transportation planning.

Extracted features were positions and profiles of the maximum/minimum widths and damages of the road. The properties of each selected profile of interest are presented in Table 1.

From Table 1 it can be seen that Profile 11 has minimum width of 2.8 m and it has been identified at the distance of 1140.18 m from the beginning of the road in the study area. It is also where the road is the most damaged (76%), which is clearly presented in Picture 7.

The profile with maximum width of 6.88 m is Profile 5 at the distance of 777.82 m, and it has no visible damage (Picture 8).

Elevation changes in different parts of the terrain are well presented in the cross-section of the entire area (Picture 9). The main road, which is the most suitable for personnel and equipment delivery, is in the lowest part of the area. On both sides of the main road, the terrain rises abruptly, which can affect the further delivery of material, equipment, and human resources to the point of work.

In order to provide the information about the future work areas at different elevations, the thematic map of areas is shown in Picture 10.

The largest areas are found at the elevation between 1000 m and 1030 m above sea level. This area has the most potential for storing material, equipment

and personnel, while the work is performed at higher elevation.

Many field works require precise knowledge about the aspect of the terrain for the efficient and the most successful workflow. Here is presented the thematic map of the terrain aspect of the entire study area (Picture 11).

Picture 9. *Cross-section of the entire study area*

In Table 2 it is presented how much of the area every aspect occupies in percentage. The most dominant aspect is south-west.

The linear features of study area were extracted for better analysis of the terrain and in order to mark potential dirt road (Picture 12).

Picture 12 shows potential dirt road which utilizes the terrain features and current land use in the most appropriate manner and it is in accordance with them. This dirt road could prove to be the best way of delivery of materials, personnel, and equipment at the higher elevation of the study area.

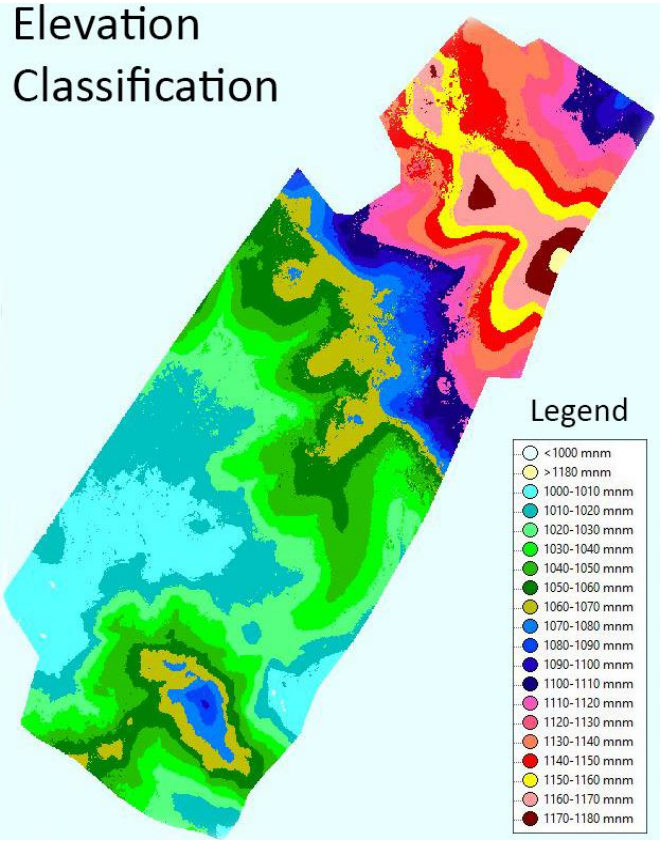
Identification of existing and potential features in forested and hard to

reach areas are of extreme importance in field work and environmental protection through biological monitoring and erosion protection.

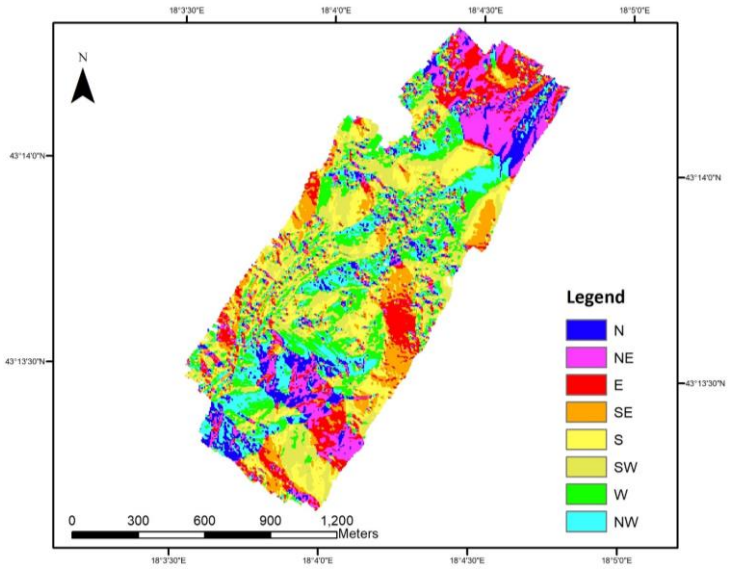
Biological monitoring is defined as a system of collecting, assesing, and forecasting the changes in the environment caused by anthropogenic factors (Ratknić *et al.*, 2013). One method of creation of soil erosion assesment maps is through collection and analyses, and comparison of existing land use maps and projects (Braunović *et al.*, 2015). Through identification of landscape features very precise measurements and more accurate assesments of human impacts are also possible.

Table 2. *Aspect*

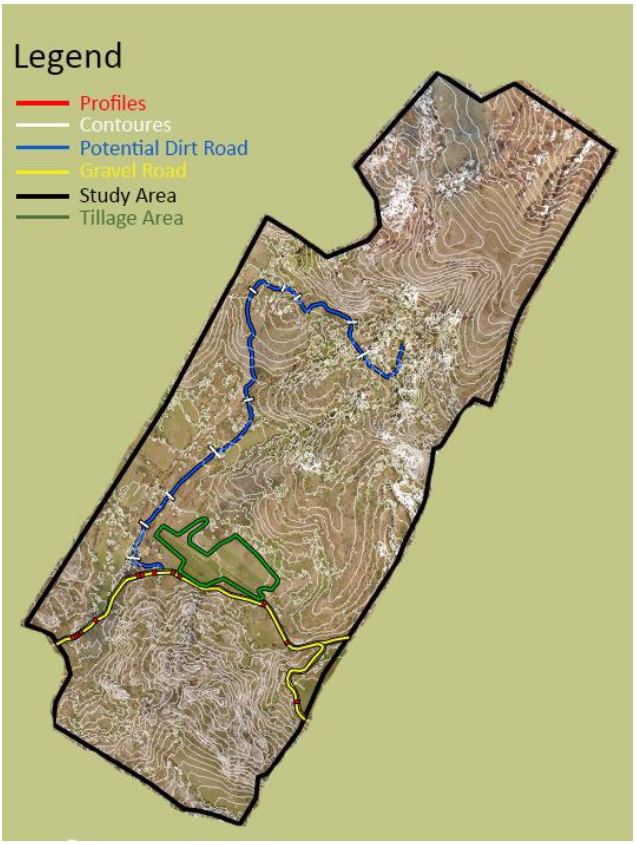
Aspect	%
N	9
NE	11
E	10
SE	11
SE	14
SW	17
W	15
NW	12
Total	100



Picture 10. *Classification of the terrain elevations (10 m)*



Picture 11. *Terrain aspect of the study area*



Picture 12. *Extracted linear features of the study area*

4. CONCLUSION

Deployment of sUAS has numerous characteristics which make it suitable for mapping of hard-to-reach areas:

- it can be equipped with various imaging sensors;
- it is fast and easy to deploy;
- it exposes both user and the environment to the minimal risk;
- it can cover large areas in short time;
- its use comes at much lower prices than using traditional methods.

Using sUAS have decreased the possibility of human error to the minimum, so we can plan the work with original knowledge of the environment and get more information that can affect the workflow, and the outcome of the operations.

The raw data from the field can be easily stored in the digital form, and be revisited at any given time. This is especially important during the performance measurements and evaluation. In addition, it provides valuable asset for repeated processing of data, if any new technology would occur and compare the results of the current and future technologies.

Presented results and information can be used to improve the planning of the efficient workflow (cut costs and save time). However, these are just some of the information available from the use of sUAS. The amount and the sort of information ultimately depends on the types of the field work and the environment. There is also great potential in monitoring of the entire workflow and the qualitative and quantitative measurements of the performed work.

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APPLICATION OF SMALL UNAMANNED AERIAL SYSTEMS IN LOGISTICS AND PLANNING

Nenad ŠURJANAC, Natalija MOMIROVIĆ, Marija MILOSAVLJEVIĆ, Sonja BRAUNOVIĆ, Milan KABILJO

Summary

Gathering the right amount of accurate data and information is crucial for proper and precise planning. Acquiring the field information of large and remote areas is time-consuming. Due to the requirements of time and adequate personnel, the data gathering process is subjected to the various external and internal influences.

The application of small unmanned aerial systems significantly reduces the time needed for field data gathering. All acquired data are in digital format which makes them very suitable for automatic processing, information extraction, and sharing.

The quality and amount of extracted information allow much of the work and decision making to be done from the office without the need for multiple construction site revisiting.

This paper showed how quickly we can acquire raw data on 150 ha remote study area, and turn them into information needed for decision making. After spending a single day in a field, all available information regarding the identification of landscape, landcover, and existing and potential road profiles were extracted in the office. This approach saved time and provided information which is easy to read, share, process, and revisit if needed.

In this paper, it is represented how small unmanned aerial system, as a new technology for data gathering, is time effective and consequently cost-effective and represents a paradigm shift in the planning and monitoring of fieldwork.

Future application of systems like the one used in this paper will contribute to the acquiring of high-quality information which will further contribute to the management of projects.

PRIMENA MALIH BESPILOTNIH SISTEMA U LOGISTICI I PLANIRANJU

Nenad ŠURJANAC, Natalija MOMIROVIĆ, Marija MILOSAVLJEVIĆ, Sonja BRAUNOVIĆ, Milan KABILJO

Rezime

Prikupljanje odgovarajuće količine podataka i informacija je ključno za precizno planiranje radova. Snimanje i sakupljanje podataka o velikim površinama, direktno na terenu, u nepristupačnim i udaljenim područjima zahteva mnogo vremena. Ako se uzmu u obzir zahtevi u vremenu i obučenom ljudstvu, moraju se uračunati i unutrašnji i spoljašnji faktori koji mogu uticati na kvalitet i količinu podataka koji se prikupljaju.

Primena malih bespilotnih sistema značajno smanjuje vreme potrebno za prikupljanje podataka. Svi sakupljeni podaci su u digitalnoj formi, što ih čini veoma pogodnim za automatsku obradu, dobijanje informacija, kao i deljenje i prosleđivanje.

Količina i kvalitet dobijenih informacija omogućavaju da sav posao i donošenje

odluka prilikom planiranja budu završeni u kancelariji, bez potrebe za naknadnim terenskim radom.

Ovaj rad prikazao je koliko se brzo mogu prikupiti podaci o području velikom 150 ha i obraditi u korisne informacije. Sve informacije o pejzažu, topografiji, zemljišnom pokrivaču, poprečnim i podužnim presecima postojećih i potencijalnih puteva su dobijene u kancelariji. Ovaj pristup je uštedeo vreme i pružio informacije koje su lako čitljive, deljive i koje su dostupne za dodatnu obradu i naknadnu reviziju.

Ovim radom je demonstrirano da mali bespilotni sistemi, koji predstavljaju novu tehnologiju za prikupljaje podataka, štede vreme i novac i predstavljaju promenu načina na koji se donose odluke u planiranju i praćenju radova na terenu. Buduća upotreba ovakvih sistema će doprineti dobijanju kvalitetnih informacija koji će dalje doprineti upravljanju projektima.

A GUIDE FOR WRITING RESEARCH PAPER

SUSTAINABLE FORESTRY is a scientific journal in which are published research papers of forestry scientific disciplines, environmental protection, wood processing, landscape architecture and horticulture and environmental engineering (Erosion Control).

PAPER TITLE IN ENGLISH 11 points, bold

PAPER TITLE should be written with capital letters (**bold**), Font Size 11, centered on the page. Title should be 11 Enter keystrokes below the top margin, and the writing should be started in the fifth row.

11

Name AND FAMILY NAME[1] 11 points, italic

Name and the family name of the authors should be written in capital letters (normal), Font Size 11 points italic, centered on the page, with single line spacing below the paper title. With mark 1, in superscript (with command Insert Footnote), above the name of the last author is marked a Footnote in which are indicated title, name and family name, occupation and institution in which some of authors are employed.

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Abstract: *The abstract is written in English, Font size 10 points, italic, Justify, with three spaces below the name of the paper author. In abstract are given basic aim of research, materials and methods, more important results and conclusion (maximum 500 characters).*

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Key words: in English 10 points, normal, minimum 3, maximum 6 words. Below the abstract, Font Size 10 points, normal.

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PAPER TITLE IN SERBIAN 11 points, bold

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Abstract: *Text of the abstract in Serbian, 10 points, italic*

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Key words: in Serbian 10 points, normal

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The journal **SUSTAINABLE FORESTRY**, which is published at least once a year, publishes original scientific papers, review papers and short communications. The paper should be, in whole, written in English, and Abstract and Summary should be written in English and Serbian. The paper length, including tables, graphs, schemes, pictures and photographs can have maximum 6

[1] Footnote (Insert Footnote):

1Title, name and family name with addresses of all authors.

Author for correspondence: Name and family name, address, phone, e-mail.

* If the paper is a part of a research within a project in acknowledgement are indicated: name of the project, registration number and the full name of the institution that finances the project.

typewritten pages, A4 format (Portrait), with normal line spacing (Single Space). Margins: Top 1.5cm, Left 1.5cm, Bottom 1.5cm, Right 1.5cm, Gutter 0.5 cm. The text of the manuscript should be typed using Times New Roman font, 11 points. Justify align (Format → Paragraph → Indents and Spacing → Special → First Line 0.0). Without pagination (the system of numbering pages). LAYOUT: header 0.5 cm, footer 0.5 cm. PAPER: width 16,5 cm, height: 24 cm. In every new line the size of a Tab is 1.27 cm.

1. INTRODUCTION (**bold**), centered on the page, Font Size 11 points, Text normal, Justify, with single line spacing below the title.

The introduction should be a short review of explanation about reasons that led to the research of specific scientific issue. The introduction contains reference data of published papers that are relevant for the analyzed issue.

2. CHAPTER TITLE 11 points, bold

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The paper should be typed by the guide for writing research paper, in *Word* format, Roman alphabet, using exclusively the *Times New Roman* Font. Successive blank spaces are not to be used for text alignment; instead, ruler alignment control tool and Toolbars are suggested. Only one space follows after any punctuation mark. If special signs (symbols) are used in the text, use the *Symbol* Font.

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2.1 Subchapter title 11 points, bold

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Subchapter text, 11 points, normal

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Table 1. 11 points, bold *Table title,* 11 points, italic

	Font size in Tables is 8		

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Continuation of the text, 11 points, normal

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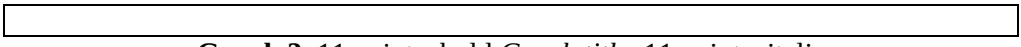

Graph 3. 11 points, bold *Graph title,* 11 points, italic

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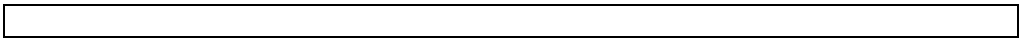

Picture 2. 11 points, bold *Picture title,* 11 points, italic

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Continuation of the text, 11 points, normal

MATERIAL AND METHODS (**bold**), centered on the page, Font Size 11. Text normal, Font Size 11, Justify, with single line spacing below the title.

Within this chapter there can be subtitles of first and second line. In the description of material it should be given enough information to allow another researchers to repeat the experiment at a different location. It is necessary to provide information on the material,

subject of the study that precisely defines its origin, physical characteristics etc. If a device or instrument is used to obtain experimental results should be specified: name of the device or instrument, model, manufacturer's name and country of origin. If a scientifically recognized method is used it has to be cited in the References, without the explanation of the steps of the used method. If changes were made in a scientifically recognized method should be provided the original literature references that will support –justify those changes.

RESULTS (**bold**), centered on the page, Font Size 11. Text normal, Font Size 11, Justify, with single line spacing below the title.

Within this chapter there can be subtitles of first and second line. The paper results should be presented in the form of text, tables, pictures (diagrams) and, rarely, photographs. From the results should be clear whether the hypotheses have been confirmed or disproved and whether the aim and tasks have been achieved. It should not be avoided the presentation of the negative results or disproving the hypotheses.

DISCUSSION (**bold**), centered on the page, Font Size 11. Tekst normal, Font Size 11, Justify, with single line spacing below the title.

Discussion should not be the simple repeating of obtained results. The results should be discussed by comparing them with the research results of other authors with compulsory citing of literature sources. It is very important to give discussion of the results and the opinion of the authors. Interpretation of perceived ambiguities and illogicalities should be correctly stated.

CONCLUSION (**bold**), centered on the page, Font Size 11. Tekst normal, Font Size 11, Justify, with single line spacing below the title.

Conclusions of the paper should be carefully carried out and shown clearly to the reader. Conclusions can be significantly connected with the result discussion, but in them should be given freer and wider interpretation of the paper subject and results. The special quality is the defining of suggestions for future work and identifying the issues need to be resolved.

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Summary 10 points, bold

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Summary text in English 10 points

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Summary 10 points, bold

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Summary text in Serbian 10 points

Papers and all enclosures (photos, schemes, pictures and graphs) should be sent to the Editorial Board of the journal in three printed copies and on CD and e-mail.

In this text is given a detailed structured instruction for writing papers. Papers that do not meet the propositions of this guide will not be forwarded for review and will be returned to the author.

Categorization of papers (suggested by the author – determined by Editorial board taking into account the opinion of the reviewer):

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1. Review paper (paper that contains original, detailed and critical review of the research issue or field in which the author made a contribution, visible on the basis of auto-citations);
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3. Preliminary communication (Original scientific paper of full format, but small-scale or preliminary character).
4. Other known forms: scientific review, case study and others, if Editorial board finds that such paper contributes to the improvement of scientific thought.

Professional articles

1. Professional paper (annex in which are offered the experiences for improving professional practice, but which are not necessarily based on scientific method).

This guide, as well as an example of correctly printed paper in the journal Sustainable Forestry, can be found on the web-site of Institute of Forestry **(*http:// www.forest.org.rs*).**

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