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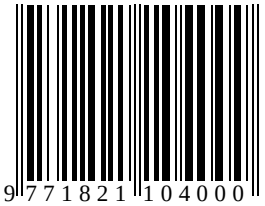

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# *CORYLUS* L., ITS DIVERSITY, GEOGRAPHICAL DISTRIBUTION AND MORPHO-ANATOMICAL CHARACTERISTICS WITH SPECIAL REFERENCE TO THE SYSTEMATIC CLASSIFICATION AND PHYLOGENICS OF TURKISH HAZEL (*CORYLUS COLURNA* L.)

*Vlado ČOKEŠA[1], Branka PAVLOVIĆ[1], Snežana STAJIĆ[1], Zoran PODUŠKA[1], Đorđe JOVIĆ[1]*

**Abstract:** *Botanists have not yet reached an agreement regarding the number of species and lower taxa within the Corylus L. genus (hazel). According to different literature sources worldwide, 14, 16,18, or 20 species have been described within the genus. There are many synonyms in the scientific literature for the same species, which creates additional confusion in determining the total number of species within the genus. According to the WCSP (World Checklist of Selected Plant Families), (http://apps.kew.org/wcsp/synonomy.do?name_id=47827), 16 species have been recognized worldwide. According to this valid classification based on morpho-anatomical characteristics, all hazels are divided into two sections, and each section into two subsections. The paper presents the main differences between these groups and subgroups, as well as their distribution in the world. Special attention is given to the range of distribution, morpho-anatomical characteristics, systematic classification, and relatedness of Corylus colurna L. to other species.*

**Keywords:** Genus *Corylus L.* – classification and distribution of species, *Corylus colurna* L. – morpho-anatomical characteristics and phylogeny**.**

[1]Mr Vlado Čokeša, MSc Branka Pavlović, dr Snežana Stajić, dr Zoran Poduška, dr Đorđe Jović, Institute of Forestry, Belgrade, 3 Kneza Višeslava, Serbia

**ROD *CORYLUS* L., DIVERZITET, GEOGRAFSKA SPECIJACIJA I MORFO-ANATOMSKE KARAKTERISTIKE SA POSEBNIM OSVRTOM NA SISTEMATSKO MESTO I FILOGENIJU MEČJE LESKE (*CORYLUS COLURNA* L.)**

**Izvod:** *U pogledu broja vrsta i nižih taksona, u okviru roda Corylus L. (leske), među botaničarima ne postoji saglasnost. Na osnovu različitih literaturnih izvora u okviru roda, u svetu je opisano 14, 16, 18, odnosno 20 vrsta. U naučnoj literaturi za iste vrste postoji mnogo sinonima, što stvara dodatnu zabunu u definisanju ukupnog broja vrsta u okviru roda. Prema WCSP listi (World Checklist of Selected Plant Families), (http://apps.kew.org/wcsp/synonomy.do?name_id=47827), u svetu je danas priznato 16 vrsta. Prema ovoj važećoj klasifikaciji, na osnovu morfo-anatomskih karakteristika, sve leske su podeljene u 2 sekcije i u okviru svake sekcije, 2 podsekcije. U radu su date osnovne razlike između ovih grupa i podgrupa, kao i njihovo rasprostranjenje u svetu. Poseban osvrt je dat na rasprostranjenje, morfo-anatomskih karakteristika, sistematsko mesto i srodničke veze sa drugim vrstama vrste Corylus colurna L.*

**Ključne reči:** Rod *Corylus* L. – klasifikacija i rasprostranjenje vrsta, *Corylus colurna* L. - morfo-anatomske karakteristike i filogenija.

## 1. INTRODUCTION

*Corylus* L. (hazel) is a genus of deciduous trees and large shrubs that grow, in the temperate zone of the northern hemisphere. Some authors classify it in the birch family, *Betulaceae*, (Chen et al., 1999; Rushforth, 1999; Huxley, 1992), though some place the hazels (along with hornbeams and related species) into a distinct family, *Corylaceae*: *Tribus Coryleae Meissn. 1842. Gen.: 846; Carpineae Döll. 1845. Zur Erkl. Laubkn. Ament; Podfam. Corylaeae Eichl. 1876. Syllab.:19.*, (Flora of Serbia II, Stevanović, 2012; Bean et al., 1976; Erdogan et al., 2002). There is no agreement among botanists on the number of species of the *Corylus* L. genus. According to the first group of authors, this genus has 14 species, the second and third groups state16, or 18 respectively, while the fourth group of authors states that this genus numbers as many as 20 taxa at the species level. A plethora of synonyms given to each species further increases the discrepancy in the number of species within this genus.

Moreover, in some cases, subspecies and varieties are described as species. To resolve all doubts, the whole genus is classified according to morpho-anatomical characteristics into sections and subsections. Besides the basic name taken from WCSP (World Checklist of Selected Plant Families), (http://apps.kew.org/wcsp/synynomy.do?name_id=47827), the synonyms for all species are listed. Where there are subspecies and varieties, their names are provided.

## 2. RESEARCH MATERIAL, METHOD AND AIM

The paper deals with the taxonomy of *Corylus* L. (hazel), i.e., provides the systematization of all species and lower taxonomic units within this genus. Therefore, the paper aims to group the accepted species within the genus systematically on the basis of their morpho-anatomical characteristics. The division into groups and subgroups (sections and subsections) was made on the basis of their habitus (whether it is a tall tree with one shoot or a lower shrub with several shoots) and the visual appearance of the fruit dome (involucrum leaves). Accordingly, all the accepted species are grouped as follows:

**I.** – Shrub with several stems, shoots up to 12 m high. Fruit (hazelnut) surrounded by soft, leafy involucrum:
**Ia.** – Involucrum short, approximately the same length as the fruit (hazelnut) – (6 accepted species);
**Ib.** – Involucrum long, twice as long as the fruit (hazelnut) or even longer, forming a "beak" – (4 accepted species).
**II.** – Tree with one stem, 20–35 m in height. Fruit (hazelnut) surrounded by a rigid, prickly involucrum:
**IIa**. – Involucrum moderately prickly and with glandular hairs – (5 accepted species);
**IIb.** – Involucrum with dense spines, resembling a chestnut bur – (1 accepted species).

All taxa within the above classification are given synonyms and their geographical distribution. Special attention is paid to the phylogeny of *Corylus colurna* L., i.e., its relationships with other species from its subsection and their ranges. Based on the collected available literature data, lower category taxa are listed for each species if they are described.

## 3. RESULTS

### 3.1. Systematics and taxonomy of Corylus L.

**Fam. *Corylaceae***

Tribus Coryleae Meissn. 1842. Gen.: 846; Carpineae Döll. 1845. Zur Erkl. Laubkn. Ament; Podfam. Corylaeae Eichl. 1876. Syllab.:19.

According to *Flora of Serbia II* (Stevanović, (ed.) 2012), these are deciduous trees or shrubs distributed exclusively in the temperate zone of the northern hemisphere.
**Leaves** – simple, alternate, generally serrated.
**Flowers** – unisexual, small, anemophilous. Male flowers – individually arranged in loose hanging catkins, with 3 to 12 or more anthers, grown on cover scales. Each flower has two bracteoles united in a bract, without a flower sheath. Female flowers – dichasia grouped in small catkins or special inflorescences in the form of buds, two in a dichasium, each with one bract and two bracteoles. The flower sheath is small,

irregularly lobed, and more or less fused with the pistil. The ovary is unilocular or bilocular, with one ovule. There are two stigmas.
**The fruit** is a syncarpous nut regularly with a sheath. The pericarp is more or less woody.
The family includes the genera Carpinus, Ostrya, Corylus, and Ostryopsis.

**Rod: *Corylus* L. – hazels**

1737. Gen. Pl.ed. 1:293, n0 730; 1754. ed. 5:433, n0 953.
Name: derives from the greek word "kerys" meaning helmet, which refers to the green shell that encloses the fruit.

According to *Flora of Serbia II* (Stevanović, (ed.) 2012), it is a deciduous shrub, less often a tree.
**Shoots** –slender and flexible.
**Buds** – oval to round, often slightly flattened, with several scales. The stipules fall off early.
**Leaves** – simple, alternating, mostly symmetrical, large, with double-serrated margins.
**Male flowers** – in hanging, cylindrical catkins that appear during the summer, preceding flowering, 2 to 4 on a common stalk. In the spring, during flowering, they elongate and become loose.
**Female flowers** – in twos, in small bud-like inflorescences from which reddish stigmas protrude in the spring during flowering.
**Fruit** – syncarpous nut (hazelnut), enclosed in a short or long tubular shell, composed of two leaves, which is open in the upper part and more or less serrated.

According to various sources, the genus includes 14-18 (20) species distributed in Europe, Asia, and North America. However, according to the WCSP, a total of 16 species have been officially accepted. The genus center is in East and Southeast Asia.

The shape and structure of the shell, as well as the habitus (whether it is a tree or a shrub with shoots) are important in species delimination, (Rushforth, 1999). Species can also be determined on the basis of pollen, under magnification (600 times), by characteristic exospores with three noticeable pores (Hubert, 1874). There is no agreement among botanists on the number of species that belong to the *Corylus* L genus., because some botanist consider certain species to be subspecies and vice versa. Double-naming is common and creates additional problems, since the plethora of synonyms magnifies the number of species. The determined species in East Asia are highly disputable. WCSP and *Flora of China* differ in the taxa that are accepted as species. Within this region, only those species that are on the "The Plant list" (a Working list of all plant species – version 1) and the list of scientific names and synonyms accepted by the Royal Botanic Garden – WCSP, are given in the list of species, (Rushforth, 1999; Wu, et al., 1999; Flora of China 4; Flora of North America 3). In accordance with the above methodology, the species are grouped as follows:

**I –** Shrub with several stems, shoots up to 12 m high. Fruit (hazelnut) surrounded by soft, leafy involucrum:

**Ia** – Involucrum short, approximately the same length as the fruit (hazelnut**)**

- ***Corylus americana*** Walter – American hazel
  Synonyms:
  *Corylus americana* var. *altior* Farw.;
  *Corylus americana* var. *calyculata* (Dippel) H.J.P.Winkl.;
  *Corylus americana* f. *calyculata* (Dippel) Schelle;
  *Corylus americana* var. *indehiscens* Palmer & Steyerm.;
  *Corylus americana* f. *missouriensis* (A.DC.) Fernald;
  *Corylus calyculata* Dippel;
  *Corylus humilis* Willd.
  Literature: Govaerts, R. (2003).
- ***Corylus avellana*** L. – common hazel
  Synonyms:
  *Corylus sylvestris* Salisb.
  Accepted Infraspecifics:
  ***Corylus avellana* var. *avellana*** L.
  ***Corylus avellana* var. *pontica*** (K.Koch) H.J.P.Winkl.,
  Synonyms: *Corylus imeretica* Kem.-Nath.
  Literature: Dimopoulos et al., (2013).
- ***Corylus yunnanensis*** (Franch.) A.Camus – Yunnan hazel,
  Literature: Wu, et al. (1999). Flora of China 4:
- ***Corylus wulingensis*** Q.X.Liu & C.M.Zhang – Asian hazel,
  Literature: Govaerts, R. (2003).
- ***Corylus heterophylla*** Fisch. ex Trautv. – Asian hazel
  Accepted Infraspecifics:
  ***Corylus heterophylla* var. *heterophylla***,
  Synonyms:
  *Corylus hasibani* Siebold
  *Corylus heterophylla* var. *shenyangensis* L.Zhao & D.Chen
  *Corylus mongolica* K.Koch
  *Corylus tetraphylla* Ledeb.
  *Corylus thunbergii* K.Koch
  ***Corylus heterophylla*** var. ***sutchuenensis*** Franch.
  Synonyms:
  *Corylus kweichowensis* Hu
  *Corylus kweichowensis* var. *brevipes* W.J.Liang
  *Corylus kweichowensis* var. *sutchuenensis* (Franch.) C.C.Yang
  *Corylus sutchuenensis* (Franch.) *Nakai*
  Literature: Govaerts, R. (2003).
- ***Corylus potaninii*** Bobrov – Asian hazel
  Literature: Govaerts, R. (2003).

**Ib** – Involucrum long, twice as long as the fruit (hazelnut) or even longer, forming a "beak"

- ***Corylus cornuta*** Marshall – beaked hazel
  Accepted Infraspecifics:
  ***Corylus cornuta* subsp. *californica*** (A.DC.) A.E.Murray
  Synonyms:
  *Corylus californica* (A.DC.) A.Heller
  *Corylus cornuta* var. *californica* (A.DC.) Sharp.
  *Corylus cornuta* var. *glandulosa* B.Boivin
  *Corylus cornuta* f. *glandulosa* (B.Boivin) T.C.Brayshaw
  *Corylus rostrata* var. *californica* A.DC.
  *Corylus rostrata* var. *tracyi* Jeps.
  ***Corylus cornuta* subsp. *cornuta***
  Synonyms:
  *Corylus cornuta* Du Roi ex Steud.
  *Corylus cornuta* f. *inermis* Fernald
  *Corylus cornuta* var. *megaphylla* Vict. & J.Rousseau
  *Corylus mexicana* K.Koch
  *Corylus rostrata* Aiton
  Literature: Herkert et al., (2002).
- ***Corylus maxima*** Mill.– the Filbert
  Synonyms:
  *Corylus arborescens* G.Gaertn., B.Mey. & Scherb.
  *Corylus balcana* P.D.Sell
  *Corylus balcana* f. *atropurpurea* P.D.Sell
  *Corylus intermedia* Fingerh.
  *Corylus sativa* Poit. & Turpin
  *Corylus tubulosa* Willd.
  Literature: Dimopoulos, P. & al. (2016).
- ***Corylus colchica*** Albov – Colchican Filbert
  Literature: Govaerts, R. (2003).
- ***Corylus sieboldiana*** Blume – Asian beaked hazel
  Accepted Infraspecifics:
  ***Corylus sieboldiana* var. *mandshurica***
  Synonyms:
  *Corylus brevituba* Kom.
  *Corylus mandshurica* Maxim.
  *Corylus mandshurica* f. *brevituba* (Kom.) Kitag.
  *Corylus mandshurica* f. *glandulosa* S.L.Tung
  ***Corylus sieboldiana* var. *sieboldiana***
  Synonyms:
  *Corylus brevirostris* (C.K.Schneid.) Miyabe
  *Corylus hallaisanensis* Nakai
  *Corylus sieboldiana* var. *hallaisanensis* (Nakai) M.Kim
  Literature: Govaerts, R. (2003).

**II** – Tree with one stem, 20–35 m high. Fruit (hazelnut) surrounded by a rigid, prickly involucrum,

**IIa** – Involucrum moderately prickly and with glandular hairs

- ***Corylus colurna*** L. – Turkish hazel
  Synonyms:
  Corylus abchasica Kem.-Nath.
  Corylus arborescens Münchh.
  Corylus bizantina Desf.
  Corylus cervorum Petrov
  Corylus eggrissiensis Kem.-Nath
  Corylus kachetuca Kem.-Nath.
  Literature: Govaerts, R. (2003).
- ***Corylus wangii*** Hu – Wang's hazel
  Literature: Govaerts, R. (2003).
- ***Corylus fargesii*** (Franch.) C.K.Schneid. – Farges' hazel
  Literature: Govaerts, R. (2003).
- ***Corylus chinensis*** Franch. – Chinese hazel
  Synonyms:
  *Corylus papyracea* Hickel
  Literature: Govaerts, R. (2003).
- ***Corylus jacquemontii*** Decne. – Jacquemont's hazel
  Synonyms:
  *Corylus lacera* Wall.
  *Corylus tiliacea* Decne.
  Literature: Govaerts, R. (2003).

**IIb** - Involucrum with dense spines, resembling a chestnut burr

- ***Corylus ferox*** Wall. – Himalayan hazel (Himalayas, Tibet and southwest China).
  Accepted Infraspecifics:
  ***Corylus ferox* var. *ferox***
  ***Corylus ferox* var. *tibetica*** (Batalin) Franch.
  Synonyms:
  *Corylus tibetica* Batalin
  Literature: Govaerts, R. (2003).

The oldest confirmed species of hazel *is Corylus johnsonii* Pigg, Manchester & Wehr, found as a fossil in Ypresian rocks (Lower Eocene 47.8 -56.0 million years ago) in Ferry County (Washington) ( https://treesforlife.org.uk/into-the-forest/trees-plants-animals/trees/hazel/hazel-mythology - and-folklore/). This was a period of global warming when forests reached the poles and the dominance of *Dicotyledonae*.

There are several **hybrids**. Crossbreeding can occur between different species of this genus, e.g. *Corylus* × *colurnoides* C.K.Schneid. (*C. avellana* × *C. colurna*), sin. *Corylus x intermedia* Loid.

In horticulture, the following **cultivars** are grown: *C. avellana* "Kontorta" because of the crooked and knotty stem and branches; *C. avellana* "Pendula" with hanging "weeping" branches and *C. maxima* "Purpurea, because of its purple leaves.

Due to their flexibility, branches are used for wattle-and-daub building and agricultural fencing. Due to the increased coppice vigour, the branches regenerate quickly after cutting the shoots. Hazel is used in land reclamation to bind the soil and in windbreaks. The fruit of all hazels is edible. Common hazel, *C. avellana* is mostly grown for this purpose. The fruit of other species is also used, but apart from the common hazel, the Filbert (Huxley, 1992) is the only species with commercial importance. *Corylus colurna* is used as the stock for grafting cultivated varieties.

### 3.2. Distribution of taxa within the Corylus L genus.

**North America**

The following taxa are widespread in **North America:**

**1. *Corylus americana*** Walter, Fl. Carol. 236. 1788. – American hazel.
Distribution: Canada to N. Central & E. U.S.A. (Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Manitoba, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Ontario, Pennsylvania, Québec, Rhode I., Saskatchewan, South Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin),
In America, it is considered a weed species in forests.
Literature: Govaerts, R. (2003).

**2. *Corylus cornuta*** Marshall, Arbust. Amer. 37. 1785. – beaked hazel.
***Corylus cornuta* subsp. *californica*** (A.DC.) A.E.Murray
Distribution: British Columbia to California
***Corylus cornuta* subsp. *cornuta***
Distribution: Canada to N. & E. U.S.A. (Alabama, Alberta, British Columbia, Colorado, Connecticut, Georgia, Idaho, Illinois, Iowa, Kentucky, Labrador, Maine, Manitoba, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Brunswick, New Hampshire, New Jersey, New York, Newfoundland, North Carolina, North Dakota, Nova Scotia, Ohio, Ontario, Pennsylvania, Prince Edward I., Québec, Rhode I., Saskatchewan, South Carolina, South Dakota, Tennessee, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming)
Literature: Herkert et al. (2002).

**3. *Corylus avellana*** Linnaeus, Sp. Pl. 2: 998. 1753. – common hazel. It is listed in the flora of North America, but it was introduced to this continent from Europe.

There are 14 accepted species in **Asia**, 9 of which are found in **China** (Wu, et al. (1999). Flora of China 4:):

**1. *Corylus yunnanensis*** (Franchet) A. Camus, Bull. Mus. Natl. Hist. Nat., sér. 2. 1: 438. 1929. – Yunnan hazel.
Distribution: China South-Central,
Literature: Wu, et al. (1999). Flora of China 4:
Its habitats are thickets on mountain slopes at altitudes of 1600-3700 m.

**2. *Corylus wulingensis*** Q.X.Liu & C.M.Zhang – Asian hazel,
Distribution: China Southeast (Hunan),
Literature: Govaerts, R. (2003).

**3. *Corylus heterophylla*** Fischer ex Trautvetter, Pl. Imag. Descr. 10. 1844. – Asian hazel.
***Corylus heterophylla* var. *heterophylla***,
Distribution: SE. Siberia, S. Russian Far East, E. Mongolia, N. & NE. China, Korea, N. & Central Japan (Amur, China North-Central, Chita, Japan, Khabarovsk, Korea, Manchuria, Mongolia, Primorye),
***Corylus heterophylla* var. *sutchuenensis*** Franch.
Distribution: China South-Central, China Southeast (Yunnan, Sichuan, Guizhou, Hubei, Hunan)
It inhabits broadleaved forests of thickets of temperate climate, on mountain slopes, at altitudes of 400-2500 m.
Literature: Govaerts, R. (2003).

**4. *Corylus potaninii*** Bobrov – Asian hazel.
Distribution: China South-Central
Literature: Govaerts, R. (2003).

**5. *Corylus sieboldiana*** *Blume* – Asian beaked hazel, Japanese hazel.
***Corylus sieboldiana* var. *mandshurica***
Distribution: SE. Siberia, China to N. & Central Japan (Amur, Chita, Japan, Khabarovsk, Korea, Manchuria, Primorye)
***Corylus sieboldiana* var. *sieboldiana***
Distribution: S. Korea, Japan.
It inhabits forests and thickets of temperate climate, at 400-2600 m a.s.l.
Literature: Govaerts, R. (2003).

**6. *Corylus wangii*** Hu, Bull. Fan Mem. Inst. Biol., n.s. 8: 31. 1938. – Wang's hazel
.Distribution: China South-Central (Yunnan)
It inhabits broadleaved forests in the temperate zone up to 3000 m above sea level. Endangered species. It is similar to *Corilus jackuemontii* Decaisne, from the Himalayas.
Literature: Govaerts, R. (2003).
**7. *Corylus fargesii*** C. K. Schneider, Ill. Handb. Laubholzk. 2: 896. 1912. – Farges' hazel.

Distribution: China (China North-Central, China South-Central, China Southeast, Inner Mongolia)
It inhabits forests in mountain valleys of 800-3000 m above sea level.
Literature: Govaerts, R. (2003).

**8. *Corylus chinensis*** Franchet, J. Bot. (Morot). 13: 197. 1899. Rare and vulnerable species.
Distribution: S. Central China
It inhabits forests on moist mountain slopes of 1200-3500 m above sea level.
Literature: Govaerts, R. (2003).

**9. *Corylus ferox*** Wallich, Pl. Asiat. Rar. 1: 77. 1830. – Himalayan hazel.
***Corylus ferox* var. *ferox***
Distribution: Central Himalayas to S. Central China (Assam, China South-Central, Eastern Himalayas, Myanmar, Nepal)
***Corylus ferox* var. *tibetica*** (Batalin) Franch.
Distribution: Tibet to Central & N. China (China North-Central, China South-Central, Inner Mongolia, Tibet)
It inhabits forests on mountain slopes of 1500-3800 m above sea level.
Literature: Govaerts, R. (2003).

**10. *Corylus colchica*** Albov 1985. – Colchican filbert
Distribution: W. Transcaucasus (Armenia and Georgia endemic)
It forms thickets on the northern edge of the forest zone. It is frost-resistant
Literature: Govaerts, R. (2003).

**11. Corylus jacquemontii** – Jacquemont's hazel.
Distribution: Kashmir to W. Nepal (Nepal, Western Himalayas, India)
It inhabits forests and thickets at 1800-3000 m above sea level.
Literature: Govaerts, R. (2003).

**12. *Corylus colurna*** Linnaeus – Turkish hazel.
Distribution in Asia: SW Asia, N. Iran to Afghanistan (Iran, Transcaucasus, Turkey, Afghanistan)
Literature: Govaerts, R. (2003).

**13. *Corylus maxima*** Mill. – the Filbert .
Distribution in Asia: SW Asia (Turkey)
Literature: Dimopoulos, P. et al., (2016).

**14. *Corylus avellana*** L. – common hazel.
***Corylus avellana* var. *avellana*** L.
Distribution in Asia: (Transcaucasus, Turkey),
***Corylus avellana* var. *pontica*** (K.Koch) H.J.P.Winkl.,
Distribution in Asia: N. Turkey, W. Transcaucasus (East Aegean Is., Transcaucasus, Turkey)
Its habitats are forests and thickets.

Literature: Dimopoulos, et al., (2013).

**Europe**

The last 3 species that are found in Southeast Asia are also widespread in Europe:

**1. *Corylus avellana*** L. – common hazel.

***Corylus avellana* var. *avellana*** L.
Distribution in Europe: (Albania, Austria, Baltic States, Belarus, Belgium, Bulgaria, Central European Russia, Corsica, Czech, Denmark, East European Russia, Finland, France, Faeroe Islands, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Crimea, Montenegro, the Netherlands, North European Russia, North Caucasus, North Macedonia, Northwest European Russia, Norway, Poland, Portugal, Romania, Sardinia, Serbia, Sicily, Slovakia, South European Russia, Spain, Sweden, Switzerland, Ukraine),
It is widely distributed in Europe. Its habitats are forests and thickets.
Literature: Dimopoulos, P., et al., (2013).

**2. *Corylus maxima*** Mill. – the Filbert
Distribution in Europe: SE Europe (Bulgaria, Greece, North Macedonia, Turkey-in-Europe)
Literature: Dimopoulos, P. et al. (2016).

**3. *Corylus colurna*** Linnaeus – Turkish hazel, Turkish filbert
Distribution in Europe: SE. Europe, (Bosnia and Herzegovina, Albania, Bulgaria, Greece, Montenegro, North Caucasus, North Macedonia, Romania, Serbia, Turkey-in-Europe)
Literature: Govaerts, R. (2003).

### 3.3. Species: Corylus colurna L – Turkish hazel

***C. colurna* L.** 1753. Sp. Pl.: 999; Pančić 1874. Fl. Knež. Srbije: 627; Hayek 1924. Prodr. Fl. Penins. Balc. 1:69; *C. pontica* Koch 1849 in Linnaea 22:329. – Turkish hazel or Turkish filbert.

According to *Flora of Serbia II* (Stevanović, (ed.) 2012), it is a tree up to 25 (30) m high and up to 75 (100) cm in diameter, with a conical to broad rounded crown. It reaches the age of over 200 years.
**The bark** is grayish-white to dark gray, soft, thick, corky, with regular shallow longitudinal cracks.
**Shoots** – annual are hairy and yellowish; biennial are corky and light gray.
**Buds** – egg-shaped, large, 6 to 7 mm long, hairy, dark-brown.
**Leaves** – widely oval or obovate, dark green on the upper side, pubescent along veins underside, 7 to 12 cm long and 5 to 10 cm wide, roughly double-serrated, sharply tapered towards the top. The leaf base is more or less heart-shaped. The leaf blade ends in nerves in the base near the petiole.The petiole is 2 to 5 cm long, noticeably

longer than in common hazel, bare, with loose simple hairs, rarely with dense glandular hairs.

**Male catkins** – up to 12 cm long and 5 to 6 mm wide in diameter, in clusters of 2 or 3.

**Fruit** – hazelnut (filbert) enclosed in a fleshy, often densely glandular-hairy sheath that is open in the upper part, narrow from the very base, elongated, hard. The long, thread-like extensions of the sheath bent on all sides greatly exceed the fruit and cover it. The fruit grows in clusters of 3 to 8. The nut is smaller than in *C. avellana*, 17 to 20 mm long and 12 to 18 mm wide, widest in the middle or in the lower portion. The scar extends from the base over the lateral sides, sometimes covering half of the hazelnut. The fruit ripens in September and October, when it falls off and is collected.

**Germination** – underground, cotyledons remain in the sheath, the first leaves are close-fitting, alternate, undeveloped, the subsequent leaves are elongated-ovate, with coarsely and unevenly double-serrated margins.

**Habitat**. It grows in shady forests, at an altitude of up to 1500 m, mostly on limestone but also on other rocks, often in canyons and gorges and on plateaus above them. It builds a number of communities of mixed composition and structure, such as: Fago-intermedio-Colurnetum B.Jov., Fagetum montanum colurnetosum B.Jov., Carpinetum orientalis serbicum colurnetosum B.Jov., Colruno-Pinetum nigrae B.Jov., Fago-Colurnetum mixtum Mišić, Querco-Colurnetum mixtum Mišić, Syringo-Colurnetum mixtum Mišić, Syringo-Aceri monspessulani-Coryletum colurnae Mišić, Syringo-Aceri intermedii-Coryletum colurnae B. Jov., etc.

**General distribution.** – Central and Eastern Dinarides (Bosnia and Herzegovina and Montenegro), central and eastern parts of the Balkan Peninsula (Serbia, Albania, Macedonia), northern Greece (Epirus), Bulgaria, southern Carpathians (Romania), northern parts of Asia Minor (Turkey), Caucasus (Armenia and Georgia), mountains of northern Iran to Afghanistan. It has a special place in the dendroflora of Serbia as a Tertiary relict that was widespread on the Balkan Peninsula as early as the Oligocene. It belongs to the following floral element: central-eastern Dinaric-Balkan-southern Carpathian-Euxin-Caucasian-northern Iranian; submerid; col-mont.

**Distribution in Serbia**. NE: Đerdap (Čoka Njalta, Pesača, Gospođin Vir, Lepenski Vir, Boljetin, Veliki Kazan, Mali Kazan, Mali Štrbac and Veliki Štrbac), Greben-Miroč, Pek Gorge near Debeli Lug, Ribare, Vitovnica Gorge, Krepoljin, Gornjačka Gorge, Lazareva River Canyon near Zlot, Malinik, Dubašnica, between Majdanpek and Rudna, Selačka River Canyon near s. Suvodol, Svrljiški Timok Gorge, Resava Gorge, Grza Gorge, Ivanštica Gorge, Moravica Gorge, Ozren, Devica, Rtanj, Tupižnica: E: Sićevačka Gorge (Oblik, Vis, Kunovica), Jelašnica Gorge, Suva Planina, Šljivovički Vis, Vlaška Planina; Jerma Gorge; Vidlič; Greben Mountain; slopes of Stara Planina – Toplodolska River Basin; Sukovska River Gorge – Jerma, Pčinj Gorge, Kozjak, W: Tara (Vijača), Divčibare, Povlen (Kukalj) SW: Mileševka Gorge, around Tutin; C: Mali Jastrebac, Kopaonik, M: Paštrik, Kodža Balkan, Koprivnik (Peć); K: Milanovac Planina, Đonaj, Suva Planina (Novo Selo), Grmija, Drenica Planina (Klečka, Crn (Ladrović)), Čičavica (Šalce), Suk, Crnoljeva planina.

**Economic significance.** The wood is dense, firm, and has a beautiful pink tinge. It can be processed, polished, and used for making furniture, veneers, and various

turning items. Its can bind soil particles. It is used in shelterbelts and windbreaks. Due to the regular and beautiful crown, it is often used as an ornamental tree in avenues, parks, and gardens. Regarding its plantation forms, there rare hybrid specimens of common hazel with Turkish hazel and vice versa Corylus x colurnoides, which are characterized by predominantly intermediary properties.

### 3.4. Phylogeny of Corylus colurna L.

Turkish hazel (*Corylus colurna* L.) belongs to the group of relict representatives of the dendroflora of Southeast Europe. In the absence of fossils from the Miocene-Pliocene period in Europe, its relict character is indicated primarily by the habitus of the tall tree and recent relatedness to species from China and the Himalayas. Namely, *Corylus colurna* belongs to the section *Corylus* Li & Chang 1979 and the subsection Colurnae Witcher 1999, which also includes *C. Chinensis*, *C. Fargesii*. *C.* wangii from China and *C. jacquemontii* from the Himalayas. Close relatedness of these 5 species is indicated by ITS sequence analyzes (Witcher & Wen, 2001). Such disjunct distribution of related species of Holarctic deciduous dendroflora is also found in genera such as *Castanea, Liquidambar, Ostrya, Platanus, Aesculus, Styrax, Sibbirea*, but also in whole genera such as *Quercus, Fagus, Acer, Fraxinus, Carpinus, Tilia*, etc., indicating the historical unity of the arcto-tertiary geoflora.

## 4. DISCUSSION

The results of the research list a total of 16 accepted species within the genus of *Corylus* L. that are on the WCSP, with all the synonyms under which these species are described, as well as their lower taxonomic units (subspecies, variety and form). There are two species on the list that are not present in the flora of China: ***Corylus wulingensis*** Q.X.Liu & C.M.Zhang and ***Corylus potaninii*** Bobrov. There is little information about them in the literature, although they are internationally recognized. On the other hand, the flora of China includes the other two species – ***Corylus formosana*** Hayata (Gen. Ind. Pl. Form. 72. 1916) and ***Corylus sieboldiana*** Blume. *Corylus formosana* Hayata has been described in Taiwan but has not been recognozed as a species (Flora of China 4: 286–289. 1999). *Corylus sieboldiana* Blume is included in the WCSP but according to its description and range of distribution, it is described as *Corylus mandshurica* Maxim in the Flora of China. On the WCSP, *Corylus mandshurica* Maxim. is synonymous with *Corylus sieboldiana* Blume.

According to Fukarek (1956), ***Corylus colurna*** L. is an ancient Tertiary species that was widespread in the Balkans as early as the Oligocene, when beech, hornbeam, and other recent species had already been widespread here, as well as many species from some genera that have completely disappeared from this area (Pterocarya, Sequoia, Cinnamomum, Glyptostrobus and others).

Today, the range of distribution of ***Corylus colurna*** L. stretches from the western parts of the Balkan Peninsula, through Southeast Asia to the slopes of the Himalayas. The largest range of its distribution on the Balkan Peninsula is located in Serbia and Bulgaria. ***Corylus colurna*** L. was once thought to extend to western

China as *Corylus colurna* var. *chinensi*. (Ascherson P. in Graebner P. 1908), Fukarek (1956). However, according to the WCSP, *Corylus chinensis* is a distinct Chinese species belonging to the same section and subsection as *Corylus colurna*. According to the same authors, even *Corylus heterophylla* (Asian hazel), which belongs to a completely different section and subsection, was identified with *Corylus colurna*, which was completely wrong.

Fukarek (1956) cites references of various authors who claim that *Corylus byzantina* Duhamel and *Corylus pontica* K. Koch are separate species, or that *Corylus pontica* is related to *Corylus maxima*. However, according to the current classification, *Corylus byzantina* is nothing but a synonym for *Corylus colurna* and *Corylus pontica* is a variety of the common n hazel *Corylus avellana* var. *pontica* (K.Koch) H.J.P.Winkl. with a range of distribution in N. Turkey, W. Transcaucasus (East Aegean Is., Transcaucasus, Turkey). Likewise, *Corylus jacquemontii* Decassne (Jacqumont hazel or Himalayan hazel) is presented as a synonym or variety of the *Corylus colurna* L. However, it is accepted as a distinct species according to the WCSP.

Very little is known about the variability of *Corylus colurna*. The variety of *glandulifera* DC. was described in Greece in 1906, Maire et Petitmengin (1908). This variety was also found in Herzegovina, Korica (1950).

As a relict species, it builds polydominant forest communities in Serbia, most often in the northern sides of canyons, gorges, mountain slopes, and karst plateaus.

## 5. CONCLUSIONS

The genus *Corylus*, according to some authors belongs to the family *Betulaceae*, while others classify it as a distinct family – *Corylaceae*.

Scientists do not agree on the number of species either. Namely, the genus has 14, 16, 18, or 20 species. For one species there are several synonyms, subspecies, and varieties, which in some cases are described as distinct species. All this creates additional confusion in the perception of the total number of species.

According to the WCSP (World Checklist of Selected Plant Families), there are officially 16 species. In this paper, all accepted species are classified into 2 groups according to habitus and anatomical-morphological characteristics of fruit domes, and v each group into 2 subgroups:

**I** Fruit (hazelnut) surrounded by soft, leafy involucrum, shrub with several stems, shoots up to 12 m high:

**Ia** Involucrum short, approximately the same length as the fruit (hazelnut)

- *Corylus americana* – American hazel (Eastern North America)
- *Corylus avellana* – common hazel (Eureope and western Asia)
- *Corylus yunnanensis* – Yunnan hazel (central and southern China)
- *Corylus wulingensis* – Asian hazel,
- *Corylus heterophylla* – Asian hazel,
- *Corylus potaninii* Bobrov – Asian hazel.

**Ib** Involucrum long, twice as long as the fruit (hazelnut) or even longer, forming a "beak"

- *Corylus cornuta* – beaked hazel (North America)
- *Corylus maxima* – the Filbert (SE Europe and SW Asia)
- *Corylus colchica* – Colchican Filbert (Caucasus – Armenia and Georgia endemic)
- *Corylus sieboldiana* – Asian beaked hazel (SE Asia and Japan)

**II** Fruit (hazelnut) surrounded by a rigid, prickly involucrum. Tree with one stem, 20–35 m in height.

**IIa** Involucrum moderately prickly and with glandular hairs

- *Corylus colurna* – Turkish hazel (southeastern Europe and southwestern Asia)
- *Corylus wangii* – Wang's hazel (southwestern China)
- *Corylus fargesii* – Farges' hazel (western China)
- *Corylus chinensis* – Chinese hazel (western China)
- *Corylus jacquemontii* – Jacquemont's hazel (Himalayas – India)

**IIb** Involucrum with dense spines, resembling a chestnut burr

- *Corylus ferox* – Himalayan hazel (Himalayas, Tibet and southwestern China).

There are 2 indigenous species on the North American continent. There are 3 species distributed on the Eurasian continent, while 10 more species are distributed in Asia alone, 8 of which are distributed in China.

Turkish hazel (Corylus colurna L.) is widespread in southeastern Europe and southwestern Asia. It belongs to the group of relict representatives of the dendroflora of Southeast Europe. Its relict character in Europe is indicated primarily by the of the tall tree habitus and recent relatedness to species from China and the Himalayas. Namely, *Corylus colurna* belongs to the section *Corylus* Li & Chang 1979 and the subsection *Colurnae* Witcher 1999, which also includes *C. Chinensis, C. Fargesii. C. wangii* from China and *C. jacquemontii* from the Himalayas. The main scientific contribution of this paper lies in the comprehensive set of data collected on the genus *Corylus* L, systematic classification of its species based on morphoanatomical characteristics and comprehensive data regarding the representatives of this genus.

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## *CORYLUS* L. GENUS, ITS DIVERSITY, GEOGRAPHICAL DISTRIBUTION AND MORPHO-ANATOMICAL CHARACTERISTICS WITH SPECIAL REFERENCE TO THE SYSTEMATIC CLASSIFICATION AND PHYLOGENICS OF TURKISH HAZEL (*CORYLUS COLURNA* L.)

*Vlado ČOKEŠA, Branka PAVLOVIĆ, Snežana STAJIĆ, Zoran PODUŠKA, Đorđe JOVIĆ*

### Summary

Some authors classify *Corylus* L. in the *Betulaceae* family, while according to others it belongs to the *Corylaceae* family. There is no agreement among botanists on the total number of species of this genus. Thus, in the literature, there are data on 14, 16, 18, or 20 taxa at the species level. The paper presents the species that are on the WCSP (World Checklist of Selected Plant Families) as officially accepted, with all their synonyms and taxa of lower ranks (subspecies, variety, form). Each species is given its range of distribution in the world. Special attention is given to *Corylus colurna* L. and its relatedness with other species within the section and subsection. The paper provides a clear and systematic presentation of all representatives of the genus *Corylus* L. and the reader can find all the most important information and resolve doubts about the representatives of this genus.

## ROD *CORYLUS* L., DIVERZITET, GEOGRAFSKA SPECIJACIJA I MORFO-ANATOMSKE KARAKTERISTIKE SA POSEBNIM OSVRTOM NA SISTEMATSKO MESTO I FILOGENIJU MEČJE LESKE (*CORYLUS COLURNA* L.)

*Vlado ČOKEŠA, Branka PAVLOVIĆ, Snežana STAJIĆ, Zoran PODUŠKA, Đorđe JOVIĆ*

### Rezime

Rod *Corylus* L. je prema nekim autorima svrstan u familiju *Betulaceae* dok je prema drugim svrstan u familiju *Corylaceae*. Kod botaničara ne postoji slaganje o ukupnom broju vrsta ovog roda. Tako u literaturi postoje podaci o 14, 16, 18 ili 20 taksona na nivou vrste. U radu su date vrste koje se nalaze na WCSP (World Checklist of Selected Plant Families) listi kao zvanično priznate sa svim svojim sinonimima i taksonima nižeg ranga (subspecies, varijetet, forma). Za svaku vrstu je data njena distribucija u svetu. Poseban osvrt je dat na vrstu *Corylus colurna* L. i njene srodničke odnose u okviru sekcije i podsekcije u kojoj se nalazi. Rad nam pruža preglednost i sistematski prikaz svih predstavnika roda *Corylus* L. gde čitalac moče naći sve najbitnije informacije i otkloniti nedoumice oko predstavnika ovog roda.

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# VARIABILITY OF MORPHOMETRIC CHARACTERISTICS OF HUNGARIAN OAK (*Quercus frainetto* Ten.) ACORN

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**Abstract:** *The results of morphometric analysis of Hungarian oak seeds originating from Lipovica Forest Management Unit are presented in this paper. The seeds have been collected from 50 trees evenly distributed on the forest management unit area. The length, width and mass of acorns are measured on the sample consisting of 50 acorns per tree. The volume and shape index of acorns are calculated based on the measured values of their length and width. The mean values of morphometric characteristics obtained in research indicate there is a high variability among the studied genotypes. The latter has also been confirmed by means of an analysis of variance which determined statistically significant differences between the sampled mother trees for all the observed morphometric characteristics. The results obtained represent a good starting point for future research on breeding of the species and can be utilised for improvement of the mass production of high quality Hungarian oak planting material in Serbia.*

**Key words:** Hungarian oak, acorn, population, genetic variability.

# VARIJABILNOST MORFOMETRIJSKIH SVOJSTAVA ŽIRA SLADUNA (*Quercus frainetto* Ten.)

**Izvod:** *U radu su prikazani rezultati morfometrijske analize semena hrasta sladuna poreklom iz GJ „Lipovica“. Seme je sakupljeno sa 50 stabala ravnomerno raspoređenih po površini gazdinske jedinice, a na uzorku od 50 žireva po stablu izmereni su dužina, širina i masa žira. Na osnovu izmerenih vrednosti dužine i širine izračunati su zapremina i indeks oblika žira. Prosečne vrednosti morfometrijskih svojstava, dobijene u istraživanjima, ukazuju na visoku varijabilnost između proučavanih genotipova. To je potvđeno i analizom varijanse,*

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*gde su utvrđene statistički značajne razlike između uzorkovanih materinskih stabala za sva posmatrana morfometrijska svojstva. Dobijeni rezultati predstavljaju dobru polaznu osnovu za buduća istraživanja u oplemenjivanju vrste i mogu poslužiti za unapređenje masovne proizvodnje kvalitetnog repromaterijala sladuna u Srbiji.*

**Ključne reči:** sladun, žir, populacija, genetička varijabilnost.

## 1. INTRODUCTION

The Hungarian oak (*Quercus frainetto* Ten.) is an oak species growing in thermophilous broadleaved forests in Southeastern Europe. The largest part of prevalence is on the Balkan Peninsula, but it also occurs in the Northwest of Turkey and the South of Italy. It grows in a wide vegetation belt rich in woody species. It mainly grows in habitats with subcontinental climate conditions, frequent summer droughts, highest amount of precipitation during spring, wide temperature range and low winter temperatures (Horvat et al., 1974). The Hungarian oak as one of the edifiers, is most often present in Serbia together with Turkey oak in climatogenic community of Hungarian oak and Turkey oak *Quercetum frainetto-cerridis* Rudski 1949. Except typical climatic-zonal forest *Quercetum farnetto-cerris* Rud.1949 a number of sub-associations representing different ecological variants of Hungarian oak and Turkey oak forests are described in Serbia (Stajić et al., 2008). Except the sub-associations, several geographic variants have also been singled out within the Hungarian oak and Turkey oak forest understood in a broad sense. (Tomić and Rakonjac, 2013). It is in contact with inhabited areas and agricultural land. Therefore, it is under constant pressure which leads to gradual reduction of area of these forests. The areas covered by Hungarian oak forests reduced significantly in the last century due to anthropogenic influence. This has had a very negative effect on genetic diversity of Hungarian oak. The natural regeneration of Hungarian oak is very difficult. It is mainly regenerated vegetatively which additionally contributes to the reduction of genetic diversity.

Forests are classified in the most complex ecosystems on the Earth due to the high level of diversity in terms of genetic resources, abundance of species and habitat diversity (Geburek and Konrad, 2008). Due to constant pressure exerted on forests in the last few centuries and disappearance of natural forests, biodiversity is endangered (Carabeo et al., 2016). The long-term survival of species is closely related to their genetic diversity (Gapare, 2014). Under the influence of changed environmental conditions, biotic pathogens and damages survival and evolution of species depend on the level of genetic diversity (Reed and Frankham, 2003). The research dealing with genetic diversity and identifying populations with high genetic variability can help in reducing loss of biological diversity (Souto et al., 2015).

An increasing number of researchers in Serbia and abroad is engaged in research of quality and quantity of yield of forest trees. The degree of exploration of genetic variability of quantity and quality of seed yield of various forest tree species and possibility of their use in our conditions is still below the actual needs and it is not in line with the economic significance this field could provide (Popović et al., 2015). The results of the studies of Tucović, (1975), Tucović and Stilinović, (1982),

Šijačić-Nikolić et al., (2007, 2010), Lučić et al., (2011), Popović et al., (2012, 2015), Nonić, M. et al. (2012) and other authors have contributed to gradual completion of knowledge related to intrapopulation and interpopulation variability of various species of forest trees on the level of seed and juvenile stage of development.

The objective of the research in this paper is to determine intrapopulation variability of Hungarian oak according to the morphological characteristics of acorns. The results obtained in the research can be used as preliminary introduction on genetic variability of the studied population, proposal of measures for preservation of the available gene pool and improvement of production of high quality seed and planting material.

## 2. MATERIAL AND METHODS

The acorns from the yield of 2019 originating from Lipovica Forest Management Unit, Belgrade Forest Estate, Belgrade were used for research in this paper. On the basis of phenotypic characteristics and abundance of yield 50 mother trees were singled out. The mother trees are evenly distributed on the area of the forest management unit and minimum distance between them is 50 m in order to avoid relatedness. About 3 kg of ocularly healthy and undamaged acorns was collected per tree regardless of their dimensions. After the collection acorns were dried up to 35% humidity and stored at the temperature of 3-5 ºC.

The analyses of measured and derived morphometric characteristics were carried out on a random sample consisting of 50 acorns per mother tree. Length, width in the widest part and mass of acorns were measured. The length and width of acorns were measured by vernier caliper with the accuracy of 0.01 mm and mass by electronic scale with the accuracy of 0.01 g. Shape index, volume of acorns and average number of acorns in 1 kg were calculated based on the measured values. The shape index of an acorn was calculated as the ratio of the length and width of the acorn. The volume of an acorn was calculated according to the formula for the volume of cylinder (the shape of an acorn was approximated by cylinder). The average number of acorns in 1 kg was calculated based on the average mass of one acorn, separately for each of the sampled mother trees. (Ivanković et al., 2011).

Morphological characteristics of acorns were described by descriptive statistical indicators: arithmetic mean (x), standard deviation (SD) and coefficient of variation (CV %). One-way analysis of variance (ANOVA) was used to determine intrapopulation variability. A mother tree was the analysed variability factor. All the above statistical analyses were carried out using the statistical program STATISTICA 7.0 (StatSoft Inc., 2004).

## 3. RESULTS AND DISCUSSION

The mean value of acorn length at the level of population amounted to 24.84 mm and ranged from 20.13 mm (Tree 9) to 30.19 mm (Tree 44), with standard deviation from 1.08 mm to 4.06 mm (Table 1).

The mean value of acorn width in the widest part amounted to 11.79 mm, with the range from 10.6 mm (Tree 11) to 14.55 mm (Tree 42) and standard deviation from 0.64 mm to 1.47 mm (Table 1).

The highest mean value of acorn mass amounted to 3.71 g (Tree 20) and the lowest was 1.18 g (Tree 9), while mean value at the level of stand amounted to 2.13 g with standard deviation from 0.3 g to 1.04 g (Table 1).

The acorn shape index ranged from 1.65 (Tree 25) to 2.45 (Tree 48), with mean value at the level of stand amounting to 1.98 and standard deviation from 0.1 to 0.39 (Table 1).

The mean value of acorn volume at the level of stand amounted to 3.18 $cm^3$. The acorn volume ranged from 2.03 $cm^3$ (Tree 11) to 4.81 $cm^3$ (Tree 20) with standard deviation from 0.35 $cm^3$ to 1.22 $cm^3$ (Table 1).

When comparing the mean values of morphological characteristics of acorns determined in this paper with the data cited in literature, it is evident that they are quite similar, which is expected given that a similar methodology was used.

**Table 1.** *Descriptive statistics of the measured acorn characteristics*

| Tree | Length (mm) | | | Width (mm) | | | Mass (g) | | | Shape index | | | Volume ($mm^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | CV | M | SD | CV | M | SD | CV | M | SD | CV | M | SD | CV |
| **1** | 24.47 | 2.19 | 8.96 | 12.39 | 0.96 | 7.73 | 2.56 | 0.56 | 21.88 | 1.98 | 0.11 | 5.74 | 3.00 | 0.66 | 21.95 |
| **2** | 24.62 | 2.83 | 11.51 | 13.01 | 0.90 | 6.94 | 2.63 | 0.72 | 27.53 | 1.89 | 0.19 | 10.01 | 3.31 | 0.73 | 21.87 |
| **3** | 22.09 | 1.83 | 8.30 | 12.01 | 0.69 | 5.78 | 1.20 | 0.46 | 38.31 | 1.84 | 0.17 | 9.18 | 2.51 | 0.39 | 15.43 |
| **4** | 22.16 | 1.52 | 6.85 | 11.60 | 0.83 | 7.18 | 1.46 | 0.43 | 29.67 | 1.92 | 0.16 | 8.35 | 2.36 | 0.41 | 17.40 |
| **5** | 23.79 | 2.95 | 12.40 | 11.08 | 1.41 | 12.75 | 1.31 | 0.52 | 39.88 | 2.18 | 0.39 | 17.90 | 2.33 | 0.70 | 29.85 |
| **6** | 22.29 | 1.66 | 7.43 | 11.36 | 1.04 | 9.19 | 1.30 | 0.54 | 41.74 | 1.97 | 0.21 | 10.44 | 2.28 | 0.49 | 21.49 |
| **7** | 21.89 | 1.96 | 8.96 | 11.42 | 0.70 | 6.12 | 1.31 | 0.49 | 37.48 | 1.92 | 0.18 | 9.40 | 2.26 | 0.39 | 17.39 |
| **8** | 26.04 | 1.93 | 7.40 | 13.63 | 0.81 | 5.98 | 2.69 | 0.64 | 23.92 | 1.91 | 0.12 | 6.35 | 3.83 | 0.64 | 16.85 |
| **9** | 20.13 | 2.15 | 10.70 | 11.36 | 0.96 | 8.45 | 1.18 | 0.30 | 25.87 | 1.78 | 0.19 | 10.94 | 2.07 | 0.49 | 23.63 |
| **10** | 20.76 | 1.90 | 9.13 | 11.33 | 0.69 | 6.12 | 1.41 | 0.42 | 29.85 | 1.84 | 0.17 | 9.28 | 2.11 | 0.37 | 17.43 |
| **11** | 22.93 | 1.62 | 7.09 | 10.60 | 0.80 | 7.57 | 1.33 | 0.40 | 29.80 | 2.18 | 0.23 | 10.57 | 2.03 | 0.35 | 17.35 |
| **12** | 24.26 | 1.87 | 7.71 | 11.98 | 0.94 | 7.89 | 1.72 | 0.39 | 22.53 | 2.03 | 0.16 | 8.10 | 2.76 | 0.61 | 22.11 |
| **13** | 26.30 | 1.57 | 5.98 | 12.90 | 0.77 | 5.96 | 2.44 | 0.44 | 18.18 | 2.04 | 0.11 | 5.51 | 3.46 | 0.56 | 16.17 |
| **14** | 24.02 | 1.65 | 6.86 | 12.67 | 0.88 | 6.96 | 2.12 | 0.49 | 23.21 | 1.90 | 0.13 | 6.71 | 3.06 | 0.59 | 19.27 |
| **15** | 24.48 | 1.62 | 6.63 | 12.47 | 0.92 | 7.41 | 2.14 | 0.52 | 24.53 | 1.97 | 0.13 | 6.66 | 3.02 | 0.63 | 20.73 |
| **16** | 25.13 | 2.42 | 9.64 | 11.83 | 1.09 | 9.21 | 1.88 | 0.50 | 26.57 | 2.13 | 0.20 | 9.17 | 2.81 | 0.74 | 26.41 |
| **17** | 24.94 | 1.48 | 5.95 | 13.38 | 1.11 | 8.27 | 2.68 | 0.62 | 23.20 | 1.87 | 0.12 | 6.59 | 3.55 | 0.74 | 20.88 |
| **18** | 25.50 | 1.56 | 6.11 | 12.87 | 1.08 | 8.42 | 2.47 | 0.61 | 24.71 | 1.99 | 0.14 | 6.86 | 3.36 | 0.71 | 21.16 |
| **19** | 24.19 | 1.95 | 8.05 | 11.57 | 0.82 | 7.12 | 1.90 | 0.45 | 23.52 | 2.10 | 0.17 | 8.09 | 2.57 | 0.50 | 19.41 |
| **20** | 29.29 | 1.53 | 5.24 | 14.41 | 1.03 | 7.18 | 3.71 | 0.58 | 15.69 | 2.04 | 0.13 | 6.58 | 4.81 | 0.84 | 17.37 |
| **21** | 26.03 | 4.06 | 15.61 | 13.40 | 1.30 | 9.69 | 2.62 | 0.99 | 37.86 | 1.94 | 0.20 | 10.33 | 3.79 | 1.22 | 32.26 |
| **22** | 25.34 | 1.71 | 6.73 | 13.52 | 1.24 | 9.16 | 2.30 | 0.62 | 26.80 | 1.89 | 0.17 | 8.90 | 3.68 | 0.75 | 20.36 |
| **23** | 27.32 | 2.05 | 7.51 | 12.44 | 0.84 | 6.75 | 2.24 | 0.50 | 22.31 | 2.20 | 0.17 | 7.80 | 3.34 | 0.59 | 17.79 |
| **24** | 24.73 | 2.13 | 8.61 | 11.97 | 1.20 | 10.07 | 1.81 | 0.42 | 23.20 | 2.08 | 0.26 | 12.53 | 2.82 | 0.64 | 22.69 |
| **25** | 22.89 | 1.44 | 6.31 | 13.92 | 1.02 | 7.30 | 2.44 | 0.63 | 25.90 | 1.65 | 0.13 | 7.61 | 3.51 | 0.65 | 18.47 |
| **26** | 22.79 | 1.41 | 6.18 | 12.97 | 0.64 | 4.92 | 2.22 | 0.48 | 21.46 | 1.76 | 0.11 | 6.24 | 3.02 | 0.40 | 13.41 |
| **27** | 22.85 | 2.07 | 9.06 | 12.62 | 0.78 | 6.18 | 1.71 | 0.53 | 30.84 | 1.81 | 0.14 | 7.53 | 2.89 | 0.54 | 18.67 |
| **28** | 25.49 | 2.29 | 8.97 | 12.05 | 0.86 | 7.11 | 1.96 | 0.65 | 33.45 | 2.12 | 0.18 | 8.43 | 2.94 | 0.58 | 19.62 |
| **29** | 24.32 | 1.87 | 7.69 | 12.53 | 1.08 | 8.65 | 1.80 | 0.49 | 27.45 | 1.95 | 0.19 | 9.78 | 3.03 | 0.67 | 22.18 |
| **30** | 23.57 | 1.81 | 7.70 | 13.20 | 1.06 | 8.06 | 2.14 | 0.77 | 35.88 | 1.79 | 0.15 | 8.32 | 3.26 | 0.68 | 20.99 |

| Tree | Length (mm) | | | Width (mm) | | | Mass (g) | | | Shape index | | | Volume ($mm^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | SD | CV | M | SD | CV | M | SD | CV | M | SD | CV | M | SD | CV |
| **31** | 24.69 | 2.73 | 11.08 | 13.25 | 0.80 | 6.07 | 1.75 | 0.57 | 32.43 | 1.86 | 0.16 | 8.59 | 3.45 | 0.72 | 20.75 |
| **32** | 25.72 | 1.85 | 7.20 | 13.63 | 1.07 | 7.83 | 2.53 | 0.72 | 28.45 | 1.89 | 0.17 | 9.16 | 3.79 | 0.76 | 19.91 |
| **33** | 26.65 | 1.63 | 6.12 | 14.22 | 0.74 | 5.17 | 3.09 | 0.78 | 25.34 | 1.88 | 0.11 | 5.67 | 4.26 | 0.61 | 14.34 |
| **34** | 22.52 | 1.86 | 8.28 | 12.04 | 0.94 | 7.80 | 1.63 | 0.53 | 32.54 | 1.88 | 0.17 | 9.02 | 2.59 | 0.54 | 21.01 |
| **35** | 24.82 | 1.62 | 6.52 | 13.84 | 0.79 | 5.74 | 2.52 | 0.91 | 35.87 | 1.80 | 0.13 | 7.42 | 3.75 | 0.54 | 14.50 |
| **36** | 23.73 | 1.34 | 5.64 | 11.31 | 0.69 | 6.13 | 1.85 | 0.30 | 16.08 | 2.10 | 0.14 | 6.89 | 2.40 | 0.36 | 15.15 |
| **37** | 22.50 | 2.23 | 9.92 | 12.26 | 1.03 | 8.36 | 1.87 | 0.43 | 23.04 | 1.84 | 0.19 | 10.26 | 2.69 | 0.60 | 22.21 |
| **38** | 24.98 | 1.32 | 5.29 | 12.52 | 1.16 | 9.27 | 2.23 | 0.57 | 25.68 | 2.00 | 0.13 | 6.63 | 3.12 | 0.70 | 22.45 |
| **39** | 25.07 | 1.78 | 7.10 | 13.17 | 1.01 | 7.66 | 2.63 | 0.48 | 18.35 | 1.91 | 0.15 | 7.80 | 3.45 | 0.68 | 19.71 |
| **40** | 23.25 | 1.32 | 5.68 | 11.72 | 0.85 | 7.24 | 1.75 | 0.42 | 23.83 | 1.99 | 0.16 | 8.11 | 2.53 | 0.43 | 17.17 |
| **41** | 24.50 | 2.13 | 8.68 | 13.63 | 0.89 | 6.54 | 2.06 | 0.76 | 36.83 | 1.80 | 0.10 | 5.32 | 3.62 | 0.76 | 21.08 |
| **42** | 27.12 | 1.68 | 6.20 | 14.55 | 1.20 | 8.22 | 3.15 | 0.71 | 22.65 | 1.87 | 0.14 | 7.27 | 4.56 | 0.92 | 20.09 |
| **43** | 26.57 | 2.32 | 8.74 | 14.21 | 1.47 | 10.32 | 2.95 | 1.04 | 35.16 | 1.88 | 0.18 | 9.51 | 4.29 | 1.09 | 25.30 |
| **44** | 30.19 | 2.38 | 7.89 | 13.64 | 0.96 | 7.04 | 3.39 | 0.72 | 21.14 | 2.22 | 0.13 | 5.73 | 4.46 | 0.94 | 20.97 |
| **45** | 27.07 | 2.42 | 8.94 | 11.21 | 0.79 | 7.08 | 1.67 | 0.49 | 29.21 | 2.42 | 0.24 | 9.73 | 2.69 | 0.52 | 19.36 |
| **46** | 25.35 | 2.08 | 8.21 | 14.20 | 1.16 | 8.18 | 2.06 | 0.64 | 31.02 | 1.80 | 0.21 | 11.58 | 4.05 | 0.77 | 18.98 |
| **47** | 26.81 | 1.69 | 6.30 | 12.62 | 0.82 | 6.50 | 1.87 | 0.55 | 29.63 | 2.13 | 0.12 | 5.53 | 3.38 | 0.56 | 16.65 |
| **48** | 29.51 | 1.08 | 3.66 | 11.90 | 0.84 | 7.02 | 2.16 | 0.34 | 15.60 | 2.49 | 0.17 | 6.84 | 3.30 | 0.51 | 15.60 |
| **49** | 28.04 | 2.37 | 8.45 | 13.15 | 0.95 | 7.23 | 2.50 | 0.65 | 26.12 | 2.14 | 0.16 | 7.42 | 3.85 | 0.80 | 20.87 |
| **50** | 28.29 | 3.04 | 10.73 | 11.45 | 0.80 | 7.03 | 1.96 | 0.56 | 28.49 | 2.47 | 0.17 | 7.04 | 2.96 | 0.69 | 23.42 |
| **Mean** | 24.84 | 2.93 | 11.79 | 12.62 | 1.38 | 10.91 | 2.13 | 0.81 | 38.19 | 1.98 | 0.24 | 12.32 | 3.18 | 0.93 | 29.36 |

The most variable characteristic at the level of stand is acorn mass (38.19 %), while acorn width at the widest part is the characteristic showing the lowest variability (10.91 %) (Table 1).

The average number of acorns in 1 kg at the level of stand amounts to 470 pieces and it ranges from 269 pieces per kg (Tree 20) to 849 pieces per kg (Tree 9).

**Table 2.** *The analysis of variance for measured morphometric characteristics of acorn*

| Parameter | SS Effect | df Effect | MS Effect | SS Error | df Error | MS Error | F | p |
|---|---|---|---|---|---|---|---|---|
| **Acorn length** | 6899.9 | 49 | 140.8 | 5958.1 | 1450 | 4.1 | 34.3 | 0.0000 |
| **Acorn width** | 1485.2 | 49 | 30.3 | 1356.3 | 1450 | 0.9 | 32.4 | 0.0000 |
| **Acorn mass** | 486.525 | 49 | 9.929 | 501.475 | 1450 | 0.346 | 28.71 | 0.0000 |
| **Shape index** | 46.689 | 49 | 0.953 | 42.6 | 1450 | 0.029 | 32.4 | 0.0000 |
| **Acorn volume** | 676.36 | 49 | 13.8 | 629.6 | 1450 | 0.43 | 31.79 | 0.0000 |

The results of the performed analysis of variance are presented in Table 2. The studied source of variability was a tree (family) within a population. The results obtained have shown that there are statistically significant differences caused by the studied source of variability for all studied morphometric characteristics of acorns which confirms the hypothesis about significant intrapopulation differentiation. A research on interpopulation and intrapopulation variability of Hungarian oak in east Croatia was conducted by Prokupić (2020). A study confirmed a satisfying level of variability, using leaf morphological characteristics.

Large statistically significant differences detected between individual parent trees (genotypes) within a population indicate there is a high level of intrapopulation genetic diversity. Statistically significant differences between the studied parent trees of pedunculate oak for the analysed morphometric characteristics of acorn clearly indicate genetic differentiation and high level of intrapopulation variability (Popović et al.. 2020). The high level of intrapopulation variability in a bald cypress

stand is determined on the basis of morphometric characteristics of cones (Popović et al., 2012). The occurrence of a high level of intrapopulation variability is characteristic of the majority of forest tree species and it can be explained by the gene flow process (exchange of genes between different populations through natural processes and also by human actions) and low level of local adaptedness (Bogdan, 2009).

## 4. CONCLUSION

The conducted research of morphometric characteristics of Hungarian oak acorn on the level of population contributes to better knowledge of the analysed characteristics and their effect on differentiation of the studied genotypes.

The following mean values are determined on the level of the studied genotypes: acorn length 24.84 mm, acorn width 12.62 mm, mass 2.13 g, shape index 1.98 and volume 3.18 $cm^3$. There are, on average, 470 pieces of acorn per kilogram.

Statistically significant differences between the studied parent trees for all the analysed morphometric characteristics of acorn clearly indicate genetic differentiation and high level of intrapopulation variability.

The results obtained can be used for preliminary assessment of genetic variability of the studied population, proposal of measures for conservation and sustainable use of the available gene pool and improvement of production of Hungarian oak plant material in Serbia.

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## VARIABILITY OF MORPHOMETRIC CHARACTERISTICS OF HUNGARIAN OAK (*Quercus frainetto* Ten.) ACORN

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### Summary

The Hungarian oak (*Quercus frainetto* Ten.) is an oak species growing in thermophilous broadleaved forests in Southeastern Europe. The areas covered by Hungarian oak forests are reduced significantly due to anthropogenic influence exerted in the last century. This had very negative effect to genetic diversity of Hungarian oak. The natural regeneration of Hungarian oak is very difficult. It is mainly regenerated vegetatively which additionally contributes to the reduction of genetic diversity.

The objective of the research in this paper is to determine intrapopulation variability of Hungarian oak according to the morphological characteristics of acorns.

The results of morphometric analysis of Hungarian oak seeds originating from Lipovica Forest Management Unit are presented in this paper. The seeds have been collected from 50 trees selected based on phenotypical characteristics and abundance of yield, evenly distributed on the forest management unit area. The analyses of measured and derived morphometric characteristics were carried out on a random sample consisting of 50 acorns per mother tree. Length, width in the widest part and mass of acorns were measured. Shape index, volume of acorns and average number of acorns in 1 kg were calculated based on the measured values.

Mean values determined on the level of the studied genotypes are as follows: acorn length 24.84 mm, acorn width 12.62 mm, mass 2.13 g, shape index 1.98 and volume 3.18 $cm^3$. There are, on average, 470 pieces of acorn per kilogram.

The results of the performed analysis of variance have shown that there are statistically significant differences caused by the studied source of variability (genotype) for all studied morphometric characteristics of acorns. Large statistically significant differences detected between individual parent trees (genotypes) within a population indicate there is a high level of intrapopulation genetic diversity.

The results obtained can be used for preliminary assessment of genetic variability of the studied population, proposal of measures for conservation and sustainable use of the available gene pool and improvement of production of Hungarian oak plant material in Serbia.

## VARIJABILNOST MORFOMETRIJSKIH SVOJSTAVA ŽIRA SLADUNA (*Quercus frainetto* Ten.)

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### Rezime

Sladun (*Quercus frainetto* Ten.) je vrsta hrasta koja raste u termofilnim listopadnim šumama u jugoistočnoj Evropi. Zbog antropogenog uticaja u prošlom veku, površine po sladunovim šumama su značajno redukovane, a to je veoma negativno uticalo na njegov genetički diverzitet. Prirodno obnavljanje sladuna je veoma otežano, uglavnom se obnavlja vegetativnim putem, što dodtno utiče na smanjenje genetičkog diverziteta.

Cilj istraživanja u ovom radu je da se utvrdi unutarpopulaciona varijabilnost sladuna prema morfološkim svojstvima žireva.

U radu su prikazani rezultati morfometrijske analize semena hrasta sladuna poreklom iz GJ „Lipovica“. Seme je sakupljeno sa 50 stabala selektovanih na osnovu fenotipskih karakteristika i obilnosti uroda, ravnomerno raspoređenih po površini gazdinske jedinice. Analize merenih i izvedenih morfometrijskih svojstava vršene su na slučajnom uzorku koji je činilo 50 žireva po svakom materinskom stablu. Mereni su dužina, širina na najširem delu i masa žireva. Na osnovu izmerenih vrednosti izračunata su sledeća svojstva: indeks oblika, zapremina žireva i prosečan broj žireva u jednom kilogramu.

Na nivou proučavanih genotipova utvrđene su sledeće prosečne vrednosti: dužina žira 24,84 mm, širina žira 12,62 mm, masa 2,13 g, indeks oblika 1,98 i zapremina 3,18 $cm^3$. U jednom kilogramu prosečno ima 470 komada žireva.

Rezultati provedene analize varijanse su pokazali postojanje statistički značajnih razlika uzrokovanih posmatranim izvorom varijabilnosti (genotip) za sva istraživana morfometrijska svojstva žira. Visoke statistički značajne razlike utvrđene između individualnih roditeljskih stabala (genotipova) unutar populacije ukazuju na visok nivo unutarpopulacone genetske raznolikosti.

Dobijeni rezultati mogu poslužiti za preliminarnu procenu genetičkog varijabiliteta istraživane populacije, predlog mera za očuvanje i održivo korišćenje raspoloživog genofonda i unapređenje proizvodnje repromaterijala hrasta sladuna u Srbiji.

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# VARIABILITY OF POTASSIUM CONTENT IN THE NEEDLES OF DOUGLAS-FIR PROVENANCES OF CANADIAN ORIGIN

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**Abstract:** *The provenance test model is based on the analysis of growth, anatomical, physiological, chemical, mechanical, and other properties of an allochthonous species to justify its transfer from the place of origin to new ecosystems. Douglas-fir is one of the most common allochthonous conifer species in the forest plantations of Europe. Given that the analysis of different physiological properties of trees is important for the introduction of specified provenances into new habitats, this paper presents the results of an investigation of the variability of potassium content in young Douglas-fir needles of 14 Canadian provenances raised on two experimental sites in Belgrade. Potassium is an essential element involved in a number of biochemical and physiological processes and plays a significant role in the adaptation of plants on biotic and abiotic stress factors. Determination of the deviation of potassium content in the needles of each Douglas-fir provenance studied was performed using the Z-test.*

**Keywords:** Douglas-fir, provenance, introduction, potassium, Serbia

# VARIJABILNOST SADRŽAJA KALIJUMA U ČETINAMA KANADSKIH PROVENIJENCIJA DUGLAZIJE

**Izvod:** *Model provenijeničnog testa zasniva se na analizama rasta, anatomskih, fizioloških, hemijskih, mehaničkih, kao i drugih osobina alohtone vrste, s ciljem provere opravdanosti njene introducije iz zemlje porekla u nove ekosisteme. Duglazija je jedna od najčešće gajenih alohtonih vrsta četinara u plantažama i šumskim kulturama Evrope. Kako*

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*je analiza različitih fizioloških svojstava drvenastih vrsta od značaja pri introdukciji provenijencija u nova staništa, u radu su predstavljeni rezultati istraživanja varijabilnosti sadržaja kalijuma u mladim četinama 14 kanadskih provenijencija duglazije gajenih na dva eksperimentalna polja u Beogradu. Kalijum je esencijalni element koji učestvuje u nizu biohemijskih i fizioloških procesa i ima značajnu ulogu pri adaptaciji biljaka u uslovima biotičkog i abiotičkog stresa. Odstupanje sadržaja kalijuma u četinama svake ispitivane provenijencije određeno je Z-testom.*

**Ključne reči**: duglazija, provenijencije, introdukcija, kalijum, Srbija

## 1. INTRODUCTION

Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco, fam. Pinaceae] is a very tall and fast-growing conifer species native to North America. Under optimal conditions, this species reaches a height of over 100 m, a diameter of 4 m, and an age of 1,300 years or more. Its wide geographical range in terms of latitude (from central British Columbia to the mountains of central Mexico), longitude (from New Mexico to Vancouver) and altitude (from 0 m a. s. l. to 3,000 m a. s. l.) (Hermann, Lavender, 1990) has produced a number of provenances. At the present time, due to its economic importance and the assumption that it can resist climate change, Douglas-fir is an integral part of forest management in many European countries (Lavender and Hermann, 2014). It is the second most abundant species in European forests, covering more than 800,000 ha (Spiecker *et al.*, 2019).

Being a highly productive introduced species, not only in Europe but also in the world, Douglas-fir was a subject of numerous studies and a topic of many scientific conferences. Based on the studies conducted in North America (e.g., Herman and Lavender, 1987, 1990), and the provenance trials of this species in Europe (e.g., Da Ronch *et al.*, 2016; Spiecker *et al.*, 2019), detailed knowledge of the genetic potential of Douglas-fir provenances has been acquired. In Serbia, the study and testing of Douglas-fir provenances from North America have begun in 1978 at the Institute of Forestry, Belgrade, and continued by setting up provenance trials on several sites (e.g., Lavadinović, 1995; Lavadinović and Koprivica, 1996, 1999, 2000; Lavadinović and Isajev, 2005; Lavadinović, 2009). The trials of the introduced Douglas-fir provenances of Canadian origin have been performed by laboratory analysis of seed germination, measurement of tray plants, determination of survival percentage of seedling nursery plants, the establishment of experimental plots, and long-term measurement of plant taxation elements (Popović *et al.*, 2013).

The main reason for the establishment of a provenance test is to determine the economic justification for the introduction of new species and to assess the risk arising from the transfer of their seeds from the area of origin to new ecological conditions. The introduction must involve only those species that attain the maximum production qualities and economic effectiveness in the natural area (Popović *et al.*, 2013). Consequently, the provenance test model is usually based on the analysis of growth, anatomical, physiological, chemical, mechanical, and other properties of an allochthonous species. Since the analysis of different physiological properties of trees is important for the introduction of specified provenances to new habitats, several papers have been published on the subject of nutrient content in

the needles of Douglas-fir provenances raised in Serbia (Lavadinović *et al.*, 2012, 2014, 2015, 2018, 2019). As a contribution to the study of nutrition in Douglas-fir provenances, this paper presents an analysis of the variability of potassium content in the needles of Douglas-fir provenances, originating from a number of Canadian sites of different geographical latitudes and longitudes, and altitudes.

Potassium has considerable importance in the physiological processes of plants. As a biogenic macronutrient, potassium activates more than 50 enzymes, and as a cofactor, it participates in a series of enzymatic reactions that take place in photosynthesis, respiration, and other processes. Potassium plays a significant role in the neutralization of excess organic acids in cells, hydration of colloids of protoplasm, osmoregulation, as well as in the mechanism of opening and closing stomatal pores. It is an important nutrient in the processes of synthesis, transport, and accumulation of carbohydrates and it increases resistance to drought and other stress factors (low temperatures, salts, diseases, air pollution, etc.). Potassium plays a significant role in the regulation of active transport across cell membranes and the uptake of other essential elements, as well as in the protection against oxidative stress because it regulates the activity of enzymes involved in the detoxification of reactive oxygen (Wang *et al.*, 2013).

## 2. MATERIAL AND METHODS

The present study is based on an analysis of the variability of potassium content in young needles of different Douglas-fir provenances. The study included 14 Douglas-fir provenances of Canadian origin of latitude ranging from 49°10' to 51°35', longitude from 115°20' to 120°10', altitude from 105 to 1,070 m (Table 1).

**Table 1.** *The origin of the analyzed Douglas-fir provenances*

| Provenance code | Mark | Locality | Latitude | Longitude | Altitude (m) |
|---|---|---|---|---|---|
| 03333 | 1 | Cranbrook | 49˚25' | 115˚20' | 105 |
| 00848 | 2 | Inonoaklin | 49˚50' | 118˚10' | 671 |
| 30667 | 3 | Mann Creek | 51˚35' | 120˚10' | 600 |
| 05227 | 4 | Gavia Lake | 50˚56' | 116˚35' | 1,070 |
| 05226 | 5 | Nine Bay | 50˚58' | 115˚32' | 975 |
| 03356 | 6 | Trout Creek | 49˚40' | 119˚52' | 684 |
| 03360 | 7 | Michell Creek | 49˚54' | 119˚37' | 1,035 |
| 01198 | 8 | Salmo | 49˚15' | 117˚30' | 793 |
| 30460 | 9 | Mara Lake | 50˚48' | 119˚00' | 188 |
| 00278 | 10 | Monte Creek | 50˚37' | 119˚52' | 701 |
| 03383 | 11 | Sheep Creek | 49˚10' | 117˚15' | 1,000 |
| 30461 | 12 | Cooke Creek | 50˚38' | 118˚49' | 900 |
| 03389 | 13 | Benton Creek | 49˚12' | 117˚25' | 933 |
| 05092 | 14 | Sun Creek | 50˚08' | 115˚52' | 1,000 |

The provenance trials were set up on two sites in Belgrade, Serbia. In the Arboretum of the Faculty of Forestry (44°46'59.8"N, 20°25'37.9"E), the soil type was eutric cambisol, while in the Sremčica nursery (44°41'07.7"N, 20°22'08.7"E), it was vertisol. The seedlings were produced in containers, and at the age of 3 years they were transplanted into experimental plots with a distance of 2 x 2 m (60 plants from each provenance). On the sites where the analyzed trees had been established,

the microclimate conditions were relatively similar. The relief was flat (with no prominent exposures) and the altitudes were approximately the same. All analyzed individuals were of 12 years of age.

For the analysis of potassium content in different Douglas-fir provenances, the one-year-old needles from the top third of the tree crowns were sampled and analyzed. The needles were dried to the absolutely dry state at 550°C and grounded to a fine powder. The potassium content was determined by the ash analysis, after conversion to chlorides, using the complexometric determination technique.

The deviation of potassium content in the needles of each Douglas-fir provenance was determined by the Z-test, according to the following formula:

$$Z = (\bar{X} - x) / \sigma$$

where $\bar{X}$ is the mean value of potassium content in the needles of all provenances; x is the potassium content in each provenance; σ is the standard deviation of potassium content in the needles.

All obtained numerical data were analyzed using the statistical software STATISTICA (StatSoft Inc., Tulsa, OK, 1997).

## 3. RESULTS AND DISCUSSION

The results of the analysis of variability of potassium content in the needles of 14 Canadian Douglas-fir provenances, raised on two experimental sites and two soil types in Belgrade, are presented in Table 2 and Graph 1.

**Table 2.** *Statistical analysis of potassium content in young needles of 14 Canadian Douglas-fir provenances raised on two experimental sites and two soil types in Belgrade, Republic of Serbia*

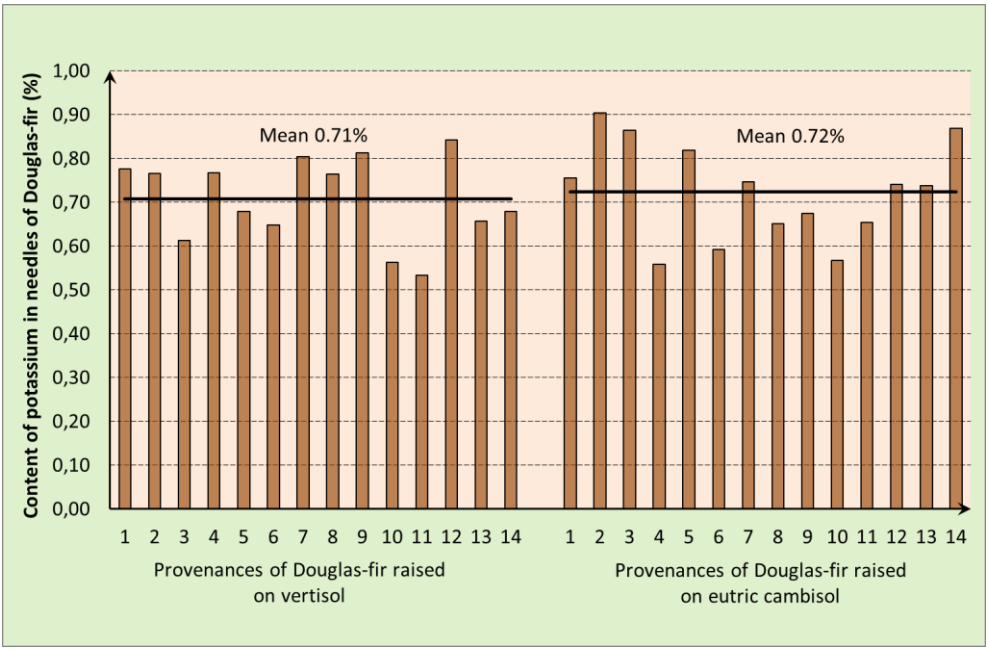
| **Provenance** | | | **Sremčica** (Vertisol) | | **Arboretum** (Eutric cambisol) | |
|---|---|---|---|---|---|---|
| **Mark** | **Code** | **Origin** | **K** (%) | **Z** | **K** (%) | **Z** |
| 1 | 03333 | Cranbrook | 0.78 | -0.5860 | 0.75 | -0.3812 |
| 2 | 00848 | Inonoaklin | 0.77 | -0.4781 | 0.90 | -1.8250 |
| 3 | 30667 | Mann Creek | 0.61 | 0.9922 | 0.86 | -1.4351 |
| 4 | 05227 | Gavia Lake | 0.77 | -0.5050 | 0.56 | 1.5199 |
| 5 | 05226 | Nine Bay | 0.68 | 0.3521 | 0.82 | -0.9981 |
| 6 | 03356 | Trout Creek | 0.65 | 0.6496 | 0.59 | 1.1885 |
| 7 | 03360 | Michell Creek | 0.80 | -0.8564 | 0.75 | -0.3015 |
| 8 | 01198 | Salmo | 0.76 | -0.4698 | 0.65 | 0.6235 |
| 9 | 30460 | Mara Lake | 0.81 | -0.9392 | 0.67 | 0.4028 |
| 10 | 00278 | Monte Creek | 0.56 | 1.4722 | 0.57 | 1.4364 |
| 11 | 03383 | Sheep Creek | 0.53 | 1.7582 | 0.65 | 0.6011 |
| 12 | 30461 | Cooke Creek | 0.84 | -1.2236 | 0.74 | -0.2362 |
| 13 | 03389 | Benton Creek | 0.66 | 0.5689 | 0.74 | -0.2106 |
| 14 | 05092 | Sun Creek | 0.68 | 0.3565 | 0.87 | -1.4761 |
| | | **Mean** | 0.71 | | 0.72 | |
| | | **S** | 0.0965 | | 0.1130 | |
| | | **Min.** | 0.53 | | 0.56 | |
| | | **Max.** | 0.84 | | 0.90 | |

Based on the results obtained, the mean value of potassium content in the needles of the Douglas-fir provenances raised on eutric cambisol is 0.71%. The maximum value of potassium content (0.84%) was determined in the provenance

12, originating from Cooke Creek (provenance code 30461), while the minimum value (0.53%) was determined in the provenance 11, originating from Sheep Creek (code 03383).

The mean, maximum and minimum values of potassium content in the needles of the Douglas-fir provenances raised on vertisol were approximate to the values determined for the provenances raised on eutric cambisol. The mean value of potassium content in the needles of the provenances raised on vertisol is 0.72%. The maximum uptake of potassium (0.90%) was detected in the provenance 2, originating from Inonoaklin (code 00848), while the minimum amount (0.56%) of potassium has been absorbed by the provenance 4 from Gavia Lake (code 05227).

Although all analyzed trees had been raised under the same site and stand conditions (soil type and local climate), the high variability of potassium content between the provenances on both sites (and soil types) was detected. The existence of differences in the concentrations of particular chemical elements in provenances may indicate their peculiarity in the adsorption of these elements (Lavadinović *et al.*, 2019). Since all environmental conditions that have a significant impact on physiological processes in plants (including uptake of nutrients) had been relatively identical on the experimental sites, the detected variability was arguably a result of the genetic traits of the analyzed provenances, i.e., their ability to exploit the soil potentials in terms of potassium uptake.




**Graph 1.** *Variability of potassium content in the needles of 14 Canadian Douglas-fir provenances raised on two experimental sites and two soil types in Belgrade*

On both sites, the provenances 1, 2, 7 and 12 (from Cranbrook, Inonoaklin, Michell Creek and Cooke Creek, respectively) had high potassium content as compared to the mean value of potassium content determined for all provenances

(0.72%). In contrast, on both sites, lower potassium content than the stated mean value was detected in the provenances 6, 10 and 11 (from Trout Creek, Monte Creek and Sheep Creek, respectively). On vertisol, the provenances 4, 8 and 9 (from Gavia Lake, Salmo and Mara Lake, respectively) had higher potassium content than the stated mean value, but this was not the case on eutric cambisol. On eutric cambisol, in comparison to the stated mean value, high potassium content was detected in the provenances 3, 5, 13 and 14 (from Mann Creek, Nine Bay, Benton Creek and Sun Creek, respectively) while on vertisol the same provenances had lower potassium content than the stated mean value.

The presented results are comparable with those published in the literature. The potassium content in the needles of Douglas-fir provenances examined by Lavadinović *et al.* (2019) ranged from 0.83% to 1.40%, and the mean value was 1.03%. The highest amount of potassium has been found in the provenance marked as "Oregon 205–14", the only provenance with potassium content that significantly deviated from the mean value (Lavadinović *et al.*, 2019). According to Đunisijević-Bojović (2019), the potassium content in leaves usually ranges from 0.75% to 2.5% and plants are considered to be exposed to an acute deficiency if the potassium content is below 0.6%. Therefore, it can be stated that on both experimental sites the Canadian Douglas-fir provenances 1, 2 and 7 had normal potassium content in the needles, while the Douglas-fir provenances 10 and 13 were low or deficient in potassium as compared to the literature data. The remaining provenances analyzed had normal, low or deficient potassium content in their needles depending on the site and soil type they were raised on. In contrast to previous research regarding the content of Ca, Mg, P, C, N in the needles of 14 Canadian Douglas-fir provenances tested on the same experimental sites (Lavadinović *et al.*, 2012, 2014, 2015, 2018), in the present study, there are no significant differences in the uptake of potassium between the provenances raised on vertisol and those raised on eutric cambisol.

The amount of potassium in plant tissue depends on the species, organ and age of the plant (Nešković *et al.*, 2003; Oljača *et al.*, 2006). Since the differences in the contents of particular chemical elements in provenances may indicate their peculiarities in the adsorption of these elements, it may be argued that among the 14 Canadian Douglas-fir provenances analyzed, the provenances 1, 2 and 7 have superior potassium absorption and accumulation capacity. Further studies should determine whether there are positive correlations between potassium adsorption and other provenance properties (physiological vitality and resistance to diseases, drought, low temperatures, air pollution, as well as other environmental stressors). According to Lavender and Hermann (2014), the availability of chemical elements is one of the factors that affect the resistance of Douglas-fir to frost. For instance, Alden (1971) stated that, in populations in which potassium and nitrogen were deficient, trees were significantly less resistant to cold during the acclimatization period than trees in populations that had a surplus of these elements. However, Larsen (1978) hypothesized that the better survival of winter conditions, observed in Douglas-fir with sufficient amounts of potassium in tissues, was not due to the higher resistance to frost but to drought in the frost period. Larsen (1983) studied the effect of nitrogen and potassium supply on drought resistance in 2-year-old Douglas-fir seedlings from Snoqualmie (Washington), which were grown under experimental conditions and treated by 11 different supply levels of these nutrients.

He found that potassium had a positive effect on drought resistance in the tested plants. On the other hand, the experiment by Timmis (1974), performed on one-year-old Douglas-fir seedlings from the Pacific coast, showed that seedlings free of nitrogen but rich in phosphorus and potassium were not cold-resistant enough to survive winter conditions even in their natural habitats. The results of this study indicate that the frost resistance of the analyzed plants is more dependent on the relationship between the mineral nutrients than on the availability of an individual nutrient.

The antagonism between potassium and $Na^+$, $NH_4^+$, $Ca_2^+$, $Mg_2^+$ has been observed so far, thus their relationship in the nutrient environment is extremely important from the point of view of the mineral nutrition in plants (Ingestad, 1973). The importance of potassium in plant metabolism is indicated by the fact plants absorb it most intensively in the earliest stages of their development. Furthermore, with the increase of the potassium content, the uptake of $CO_2$ and the synthesis of carbohydrates and proteins also increase in plants, while in its absence the process of photosynthesis slows down and the respiration becomes more intense (Nešković *et al.*, 2003; Oljača *et al.*, 2006). Since a good supply of basic biogenic elements prevents the occurrence of chlorosis in the post-transplant period and affects better survival, physiological vitality, and further plant growth and development (Đukić *et al.*, 2004), the inclusion of essential nutrients in nutrition is the most effective method for improving quality and biomass production of seedlings and forest trees, and it can be used to significantly shorten the rotation period (Ingestad, 1973).

## 4. CONCLUSIONS

Based on the results of the analysis of potassium content variability in the needles of 14 Canadian Douglas-fir provenances, raised on two experimental sites and two soil types in Belgrade, it can be concluded that there were no significant differences in the uptake of this element between the provenances raised on vertisol and those raised on eutric cambisol. The mean, maximum and minimum values of potassium content in young needles of the provenances raised on vertisol were approximate to the values of potassium content determined for the provenances raised on eutric cambisol.

In comparison to literature data, it can be stated that on both experimental sites the Douglas-fir provenances 1, 2 and 7 had normal potassium contents, while the provenances 10 and 13 were low or deficient in this nutrient. The remaining provenances analyzed had normal, low or deficient content of potassium in their needles depending on the site and soil type they were raised on.

Given that all environmental conditions that have a significant impact on nutrient uptake in plants had been similar on both experimental sites, it may be argued that the detected variability was a result of the genetic traits of the analyzed provenances. On both experimental sites, the highest potassium content was found in the provenances 1, 2 and 7, so they may represent superior provenances for the uptake and accumulation of this nutrient.

These findings have practical significance because the potassium content in Douglas-fir tissues is one of the factors that affect its resistance to stress factors (such as cold and drought) and it could determine the future selective application of

suitable provenances for certain habitats in forestry practice. Further studies should show whether there are positive correlations between potassium content and other provenance properties (e.g., physiological vitality and resistance to diseases).

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## VARIABILITY OF POTASSIUM CONTENT IN THE NEEDLES OF DOUGLAS-FIR PROVENANCES OF CANADIAN ORIGIN

*Filip JOVANOVIĆ, Vera LAVADINOVIĆ, Ljubinko RAKONJAC, Snežana STAJIĆ, Zoran MILETIĆ*

### Summary

Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco, fam. Pinaceae] is a very tall and fast-growing conifer native to North America. Since it comes from a wide natural range of distribution, the provenance selection is a necessary step in the confirmation of its genetic potentials after introduction into new habitats. The genetic potentials of trees could be tested by the analysis of their physiological properties. Since potassium has considerable importance in the physiological processes of plants, this paper presents an analysis of the variability of potassium content in the needles of different Douglas-fir provenances.

The study included 14 Douglas-fir provenances from Canadian sites of different geographical latitudes, longitudes, and altitudes (Table 1). In order to test their adaptability to the new climatic and environmental conditions, provenance trial plantations have been established on two sites and two soil types in Belgrade, Serbia (Arboretum of the Faculty of Forestry, and Sremčica nursery). The potassium content in young needles of each analyzed Douglas-fir provenance was determined by a laboratory ash analysis. Statistical analysis of the obtained data was conducted using the Z-test.

The results show there are no significant differences in the uptake of potassium between the provenances raised on vertisol (0.71%) and those raised on eutric cambisol (0.72%). Provenances 1, 2 and 7 had normal potassium contents in their needles, while the provenances 10 and 13 were low or deficient in this nutrient (Table 2; Graph 1). Since the environmental conditions that have a significant impact on nutrient uptake in plants had been similar on the experimental sites, it may be argued that the detected variability was a result of the genetic traits of the analyzed provenances. The highest potassium content was found in the provenances 1, 2 and 7, thus they may represent superior provenances for the uptake and accumulation of this nutrient. Further studies should show whether there are positive correlations between potassium content and other provenance properties (such as physiological vitality and resistance to diseases and air pollution).

The potassium content in tissues of Douglas-fir is one of the factors that affect the resistance of trees to stress factors (such as cold and drought) and it could determine the future selective application of suitable provenances for certain habitats in forestry practice. Thus, the results of this study may contribute to a better selection of provenances suitable for the introduction of Douglas-fir to Serbia.

## VARIJABILNOST SADRŽAJA KALIJUMA U ČETINAMA KANADSKIH PROVENIJENCIJA DUGLAZIJE

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### Rezime

Duglazija [*Pseudotsuga menziesii* (Mirb.) Franco, fam. Pinaceae] je visoko i brzorastuće četinarsko drvo, poreklom iz Severne Amerike. Budući da ima široko prirodno rasprostranjenje, odabir provenijencija predstavlja neophodan korak u potvrđivanju njenih genetičkih potencijala nakon unošenja u nova staništa. Genetički potencijali drveća mogu se ispitati analizom njihovih fizioloških svojstava. Kako kalijum igra vrlo važnu ulogu u fiziološkim procesima biljaka, u ovom radu su predstavljeni rezultati analize varijabilnosti sadržaja kalijuma u četinama različitih provenijencija duglazije.

Istraživanjem je obuhvaćeno 14 provenijencija duglazije, poreklom sa kanadskih lokaliteta različitih geografskih dužina, geografskih širina i nadmorskih visina (Tabela 1). Da bi se proverila njihova prilagođenost novim klimatskim i stanišnim prilikama, osnovane su test kulture na dva lokaliteta (i dva tipa zemljišta) na području Beograda (u Arboretumu Šumarskog fakulteta i Rasadniku „Sremčica" – „Srbija šume"). Sadržaj kalijuma u mladim četinama svake ispitivane provenijencije duglazije određen je analizom pepela. Statistička obrada dobijenih podataka je izvedena *Z*-testom.

Rezultati pokazuju da u usvajanju kalijuma nema značajnih razlika između onih provenijencija koje su odgajene na smonici (0,71%) i onih odgajenih na gajnjači (0,72%). U četinama provenijencija 1, 2 i 7 zabeležen je normalan sadržaj kalijuma, dok u četinama provenijencija 10 i 13 primećen je nizak sadržaj ili nedostatak ovog elementa (Tabela 2; Grafikon 1). Kako su uslovi sredine koji su značajni za usvajanje elemenata ishrane kod biljaka bili međusobno vrlo slični na eksperimentalnim poljima, može se pretpostaviti da je utvrđena varijabilnost rezultat genetičkih karakteristika ispitivanih provenijencija. Najveća vrednost sadržaja kalijuma je bila utvrđena za provenijencije 1, 2 i 7, te je moguće da one predstavljaju superiorne provenijencije za usvajanje i akumulaciju ovog elementa. Buduća istraživanja će pokazati da li postoji pozitivna zavisnost između sadržaja kalijuma i drugih karakteristika provenijencija (npr., vitalnost i otpornost na bolesti i zagađenje vazduha).
Sadržaj kalijuma u tkivima duglazije je jedan od faktora koji utiču na otpornost stabala na faktore stresa (npr., mraz i suša), što može opredeliti buduću selektivnu primenu provenijencija odgovarajućih za određena staništa u šumarskoj praksi. Stoga, rezultati ovog istraživanja mogu doprineti boljem odabiru odgovarajućih provenijencija za introdukciju duglazije u Srbiju.

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# PHYTOSOCIOLOGICAL CHARACTERISTICS OF SESSILE OAK AND HORNBEAM FORESTS (*QUERCO PETRAEAE-CARPINETUM BETULI* RUDSKI 1949. S.L.) IN THE AREA OF KOSMAJ

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**Abstract:** *The paper presents phytosociological characteristics of the sessile oak and hornbeam community (Querco petraeae-Carpinetum betuli Rudski 1949. s.l.) in the area of Kosmaj. Phytosociological relevés of the investigated association were taken at altitudes ranging from 339 to 410 m, with eastern to northeastern aspects, and the slope of 15-23°. The community occurs on deeply ilimerized soils – luvisols over flysch. The floristic composition of this phytosociological community is diverse, including plants from thermophilicmand mesothermal oak forests and some plants from beech forests. With regard to the spectrum of range types, the investigated community Querco petraeae-Carpinetum betuli Rudski 1949. s.l. has a Central European range of distribution. Regarding the bioloigical spectrum of life forms, most species are considered phanerophytes and hemicryptophytes, with an increased share of geophytes.*

**Keywords**: Kosmaj, protected area, sessile oak and hornbeam forest, spectra of life forms, spectra of range types.

# FITOCENOLOŠKE KARAKTERISTIKE ŠUME KITNJAKA I GRABA (*QUERCO PETRAEAE-CARPINETUM BETULI* RUDSKI 1949. S.L.) NA PODRUČJU KOSMAJA

***Izvod:*** *U radu su prikazane fitocenološke karakteristike zajednice kitnjaka i graba (Querco petraeae-Carpinetum betuli Rudski 1949. s.l.) na području Kosmaja. Fitocenološki snimci istraživane asocijacije su sa nadmorskih visina 339-410 m, ekspozicije su istočne do*

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*severoistočne, a nagib 15-23°. Geološka podloga na kojima se javlja ova zajednica je fliš, a zemljišta su duboka ilimerizovana - luvisoli. Floristički sastav ove fitocenoze je raznovrstan, jer su u njoj javljaju biljke iz termofilnih i mezotermnih hrastovih, ali i neke iz bukovih šuma. Prema spektru areal tipova proučena zajednica Querco petraeae-Carpinetum betuli Rudski 1949. s.l. ima srednjeevropski karakter, dok je prema spektru životnih oblika fanerofitsko-hemikriptofitskog karaktera, sa povećanim učešćem geofita.*

**Ključne reči**: Kosmaj, zaštićeno područje, šuma kitnjaka i graba, spektri životnih oblika, spektri areal tipova.

## 1. INTRODUCTION

Since the end of the last and the beginning of this century, increasing attention has been paid to the preservation of endangered habitats and species. Considerable importance has been given to the segments of nature that are extremely affected by anthropogenic factors and have a large number of endangered plant and animal taxa. The research presented in this paper was performed in the territory of the Kosmaj Protected Area proclaimed a landscape of exceptional features in 2005. The general goal of the protection, management, and improvement of the state of protected areas includes the improvement of measures (conservation, rehabilitation-revitalization, and reclamation) and regimes of protection and monitoring of protected areas. Given that forest phytocenoses show the most observable signs of ecosystem degradation, the study of the vegetation of protected areas that includes defining and mapping of forest communities is imposed as a process that must be taken to achieve general goals.

The sessile oak and hornbeam forests in Serbia are conditioned by orographic and edaphic factors, i.e., they occur as extrazonal vegetation and cover significantly smaller areas than in the Illyrian province. They can be found as valley and mountain variants but without significant differences in the floristic composition (Tomić and Rakonjac, 2013). In the area of the Pešter Plateau, this community occurs in fragments at the altitude of 1010-1250 m (Ratknić and Rakonjac, 2010). According to Dinić (1978; 1997), the sessile oak and hornbeam community represents a climate-regional type of forest growing on silicate rocks of small mountain massifs of northern Serbia, on the edge of the Pannonian Basin, at altitudes ranging from 300 to 600 m (Cer, Vidojevica, Avala, Fruška Gora, Miroč). This phenomenon is explained by several different factors: the origin and historical development of this area, the transitional nature of the climate, the isolated island character and low altitudes of these mountains, dislocated relief, and silicate bedrock.

This paper aims to study the phytosociological characteristics of the association of sessile oak and hornbeam in the investigated area of Kosmaj. Considering that most of the Kosmaj area has been declared a landscape of exceptional features, with significant natural, biological-ecological, aesthetic, and cultural-historical values, the research of the vegetation of this area can serve as a starting point for planning silvicultural needs as important factors related to the provision of special benefits of these forests.

## 2. RESEARCH AREA, MATERIAL AND METHOD OF WORK

Kosmaj is a low and relatively small island mountain located in the vicinity of Belgrade. Over 70% of the mountain itself is covered in forest vegetation, dominantly oak and beech coppice stands. There are also artificially-established stands.

According to Thorntwhite climate classification, this area is dominated by subhumid climate – type C2 (Stajić, S., 2016). The mean annual air temperature is 12.3°C, while it amounts to 18.9°C in the growing season. The mean annual rainfall is 696 mm, about 57% of which falls in the growing season. Mt. Kosmaj is characterized by a specific bedrock composition (Neogene sands and clays, marls, limestones, breccias, sandstones, and serpentinite) which has brought about significant soil diversity of the area.

The Braun-Blanquet method (Braun-Blanquet, 1964) was applied for the analysis of the floristic composition and production of a synthetic table. Plant species were determined based on the following literature sources: Flora of Serbia I-X (Josifović et al., 1972-1977, Sarić et al., 1986; 1992; Stevanović et al., 2012). The spectra of floral elements were determined using the systematization of phytogeographical elements created by Gajić (1980) and the spectra of life forms using the method of Kojić et al., (1997). The community was classified using the syntaxonomic classification of Tomić and Rakonjac (2013).

Soil types were determined in all sites where relevés were collected. A soil profile was opened on a representative surface area, the type of soil was determined and soil samples were taken in disturbed condition for the laboratory study of the most important physical and chemical properties.

## 3. RESULTS AND DISCUSSION

### 3.1. Environmental conditions

Based on the floristic composition, it was determined that the relevés belong to the community of sessile oak and hornbeam (*Querco petraeae-Carpinetum betuli* Rudski 1949. s.l.). The relevés of the investigated association were taken at 339-410 m a.s.l. They have eastern to northeastern aspects and the slopes of 15-23°. The underlying bedrock of the forest community is flysch.

### 3.2 Soil characteristics

According to the study results, the community of sessile oak and hornbeam (*Querco petraeae-Carpinetum betuli* Rudski 1949 s.l.) grows on ilimerized soil – luvisol, with an A-E-Bt-C profile structure. The soil profile was opened at an altitude of 339 m, on a slope of 19° and eastern aspect. The depth of the analyzed ilimerized soil was 85 cm. The soil was skeleton-poor, and rock fragments were found mainly in the deeper parts of the illuvial horizon, while the surface layers of the profile had no skeleton. The humus-accumulative horizon is intermittent so that the eluvial horizon begins just below the soil litterfall. Regarding the soil texture, horizon A belongs to sandy loams. It is poorly structured with unstable structural aggregates.

The eluvial horizon (E) is poorly structured and according to its texture belongs to clays. Below the eluvial horizon, there is a brown illuvial Bt horizon. The texture of the illuvial horizon in the analyzed profile belongs to clay loams. The reaction of the soil solution of the humus-accumulative horizon is moderately acidic. Moving to the eluvial horizon, the pH value of the soil solution, as a rule, decreases and then increases again in the illuvial horizon. Considering the content of humus, the humus-accumulative horizon is humus-rich, but the capacity of the humus horizon is small. The eluvial horizon is poor and the illuvial horizon is very poor in humus.

### 3.3 Floristic composition

The community of sessile oak and hornbeam (*Querco petraeae-Carpinetum betuli* Rudski 1949 s.l.) is found only in fragments which are presented with three relevés from Mali Kosmaj (Table 1). The floristic composition of this forest community is diverse. It includes plants from thermophilic and mesothermal oak forests and some beech forests plants.

The stands are of coppice origin. The average tree height is 21-22 m. The canopy is dense (0.8). Besides the dominant presence of the edifying sessile oak (*Quercus petraea* (Matt.) Liebl) and hornbeam (*Carpinus betulus* L.) trees, there are trees of flowering ash (*Fraxinus ornus* L.) in the tree layer. There are also individual trees of *Acer campestre* L., *Ulmus minor* Mill., *Quercus cerris* L., and *Quercus farnetto* Ten. The shrub layer is rich in species, with a total of 12 species registered, and the canopy ranges from 0.3 to 0.8. Besides hornbeam (*Carpinus betulus* L.), the most frequent species include *Fraxinus ornus* L., *Crataegus oxyacantha* L., *Acer campestre* L., *Cornus mas* L., *Ligustrum vulgare* L., *Ruscus aculeatus* L., *Rosa canina* L., *Prunus spinosa* L., *Crataegus monogyna* Jacq., *Cornus sanguinea* L. and *Pyrus pyraster* Burg.

**Table 1.** *Phytosociological table of Querco petraeae-Carpinetum betuli Rudski 1949. s.l. association*

| Association | *Querco petraeae-Carpinetum betuli* Rudski 1949. s.l. | | | |
|---|---|---|---|---|
| Subassociation | *aculeatetosum* | | | |
| Locality | Kosmaj | | | Degree of presence |
| Relevé | 1 | 2 | 3 | |
| Size ($m^2$) | 900 | 900 | 900 | |
| Altitude (m) | 410 | 339 | 393 | |
| Aspect | E-NE | E | NE | |
| Slope (°) | 17 | 23 | 15 | |
| Bedrock | Flysch | | | |
| Soil | Ilimerized soil | | | |
| Layer I | | | | |
| Crown canopy | 0,8 | 0,8 | 0,8 | |
| Mean height (m) | 22,0 | 21,0 | 22,0 | |
| Mean diameter (cm) | 30,0 | 28,0 | 22,0 | |
| Spacing (m) | 8,0 | 7,0 | 5,0 | |
| *Quercus petraea* | 4.4 | 4.5 | 5.5 | V |
| *Carpinus betulus* | 1.1 | 1.1 | 1.2 | V |
| *Fraxinus ornus* | 1.1 | + | 1.1 | V |
| *Acer campestre* | | | 1.1 | II |
| *Ulmus minor* | | | 1.1 | II |
| *Quercus cerris* | | +.1 | | II |
| *Quercus farnetto* | +.1 | | | II |

| | | | | |
|---|---|---|---|---|
| Layer II | | | | |
| Crown canopy | 0,8 | 0,7 | 0.3 | |
| *Fraxinus ornus* | 3.3 | 3.3 | 1.1 | V |
| *Crataegus oxyacantha* | 2.1 | 1.1 | 3.1 | V |
| *Acer campestre* | 2.1 | 1.1 | 2.1 | V |
| *Cornus mas* | 1.2 | 1.1 | 1.1 | V |
| *Ligustrum vulgare* | 2.3 | | 2.3 | IV |
| *Carpinus betulus* | 1.1 | 2.2 | | IV |
| *Ruscus aculeatus* | 1.3 | 2.3 | | IV |
| *Rosa canina* | 1.1 | 2.2 | | IV |
| *Prunus spinosa* | 2.2 | +.1 | | IV |
| *Crataegus monogyna* | | | 1.1 | II |
| *Cornus sanguinea* | | | 1.1 | II |
| *Pyrus pyraster* | +.1 | | | II |
| Layer III | | | | |
| Cover | 0,4 | 0,7 | 0,6 | |
| *Tamus communis* | 3.1 | 2.1 | 3.3 | V |
| *Euphorbia amygdaloides* | 2.2 | 2.3 | 2.2 | V |
| *Cardamine bulbifera* | 2.1 | 2.1 | 2.1 | V |
| *Brachypodium sylvaticum* | 1.2 | 2.2 | 1.2 | V |
| *Quercus petraea* | 1.1 | 2.1 | 2.3 | V |
| *Ruscus aculeatus* | 1.2 | 1.3 | 2.3 | V |
| *Hedera helix* | 3.1 | | 3.3 | IV |
| *Glechoma hirsuta* | 2.2 | | 3.3 | IV |
| *Carex pilosa* | 2.2 | | 3.3 | IV |
| *Carex sylvatica* | 2.3 | 2.2 | | IV |
| *Chaerophyllum temulum* | 2.2 | 2.1 | | IV |
| *Crataegus oxyacantha* | 2.1 | | 2.1 | IV |
| *Lathyrus venetus* | 2.1 | 2.1 | | IV |
| *Helleborus odorus* | 1.1 | | 2.1 | IV |
| *Acer campestre* | 2.1 | | 1.1 | IV |
| *Lonicera caprifolium* | 2.1 | | 1.1 | IV |
| *Fragaria vesca* | 2.1 | | 1.1 | IV |
| *Bilderdykia convolvulus* | | 2.1 | +.1 | IV |
| *Carpinus betulus* | | 1.1 | 1.1 | IV |
| *Mycelis muralis* | | 1.1 | 1.1 | IV |
| *Ajuga reptans* | | 1.1 | +.1 | IV |
| *Poa nemoralis* | | 2.2 | | II |
| *Galium schultesii* | | 3.3 | | II |
| *Moehringia trinervia* | | | 2.3 | II |
| *Lathyrus vernus* | | | 2.1 | II |
| *Rubus canescens* | | 1.3 | | II |
| *Dactylis glomerata* | | 1.2 | | II |
| *Carex divulsa* | | 1.2 | | II |
| *Festuca ovina* | | 1.2 | | II |
| *Polygonatum odoratum* | | | 1.2 | II |
| *Galium aparine* | | | 1.2 | II |
| *Rubus hirtus* | 1.1 | | | II |
| *Viola hirta* | 1.1 | | | II |
| *Lapsana communis* | | 1.1 | | II |
| *Calamintha vulgaris* | | 1.1 | | II |
| *Quercus cerris* | | 1.1 | | II |
| *Crataegus monogyna* | | 1.1 | | II |
| *Hypericum hirsutum* | | 1.1 | | II |
| *Campanula patula* | | 1.1 | | II |
| *Veronica chamaedrys* | | 1.1 | | II |
| *Lamium maculatum* | | 1.1 | | II |
| *Cornus sanguinea* | | | 1.1 | II |
| *Ligustrum vulgare* | | | 1.1 | II |
| *Clematis vitalba* | | | 1.1 | II |
| *Geum urbanum* | | | 1.1 | II |

| | | | | |
|---|---|---|---|---|
| *Geranium robertianum* | | | 1.1 | II |
| *Circaea lutetiana* | | | 1.1 | II |
| *Rumex sanguineus* | | | 1.1 | II |
| *Ulmus minor* | | | 1.1 | II |
| *Doronicum columnae* | | | 1.1 | II |
| *Asparagus tenuifolius* | | | 1.1 | II |
| *Rosa arvensis* | | | 1.1 | II |
| *Asperula odorata* | +.1 | | | II |
| *Scrophularia nodosa* | | | +.1 | II |
| *Campanula persicifolia* | | | +.1 | II |
| *Lilium martagon* | | | +.1 | II |
| *Prunus avium* | | + | | II |
| *Fagus moesiaca* | + | | | II |
| *Silene viridiflora* | | + | | II |

There is a total of 59 species in the ground flora layer. The coverage is 0.4 to 0.7. Besides the edifying sessile oak and hornbeam, the species with the highest degree of presence in the ground flora layer include *Tamus communis* L., *Euphorbia amygdaloides* L., *Cardamine bulbifera* (L.) Crantz., *Brachypodium sylvaticum* (Huds.) Beauv., *Hedera helix* L., *Glechoma hirsuta* Waldst. & Kit., *Carex pilosa* Scop., *Carex sylvatica* Huds., *Chaerophyllum temulum* L., *Crataegus oxyacantha* L., *Lathyrus venetus* (Miller) Wohlf., *Helleborus odorus* Waldst. & Kit., *Acer campestre* L., *Lonicera caprifolium* L., *Fragaria vesca* L, *Bilderdykia convolvulus* (L.) Dumort., *Mycelis muralis* (L.) Dum., *Ajuga reptans* L., etc.

The floristic composition is characterized by the presence of the Mediterranean floral element – butcher's-broom (*Ruscus aculeatus* L.), which is the reason the *aculeatetosum* subassociation has been singled out. The forest of sessile oak and hornbeam with butcher's-broom is recorded in the northern part of Šumadija, on the edge of the Pannonian Basin, influenced by the climate of the Pannonian Plain, on one side and small mountain massifs that are colder and wetter on the other side (Dinić, 1997). It is most similar to the forest of the Illyrian province *Epimedio-Carpinetum betuli* (Horv. 38) Bor. 1963. *ruscetosum* of the Pannonian part of eastern Croatia and northeastern Bosnia (Tomić and Rakonjac, 2013). This community is most widely represented on Fruška Gora at altitudes of 300-500 m (Tomić and Rakonjac, 2013), and it also occurs on Mt. Avala (Borisavljević et al., 1955).

The mesophilic character of the community, which can be easily recognized by the composition of species in the ground flora layer, is also determined by the combination of the following site factors: shaded positions, relatively high air humidity and soil moisture, as well as deep ilimerized soils of moderately acidic reaction. The share of multi-seeded hawthorn (*Crataegus oxyacantha* L.) in the floristic composition is significant. It is a species of suboceanic climate, and as such, it is far more sensitive to the continental character of the climate than the single-seeded hawthorn (*Crataegus monogyna* Jacq.). It mainly grows on the fresh soil of the oak belt. On the other hand, there are some xerothermic species of the zonal vegetation of Hungarian oak and Turkey oak forest, such as *Quercus cerris* L., *Quercus frainetto* Ten., *Pyrus pyraster* L., *Cornus mas* L.

### 3.4 Spectrum of floral elements

Based on the analysis of the spectrum of floral elements (Table 2), it can be concluded that the community of *Querco petraeae-Carpinetum betuli* Rudski 1949 s.l. is predominated by plant species of the Central European range type. Their share amounts to 32%. They are followed by plant species of the Eurasian range type (24%), Submediterranean (12%), Pontic (9%), Subatlantic (9%), Circumpolar (8%), Balkan (5%) and Subboreal type (1%).

On the whole, the community of sessile oak and hornbeam (*Querco petraeae-Carpinetum betuli* Rudski 1949 s.l.) has the greatest share (41%) of mesophilic plants (Central European and Subatlantic range types), which confirms the mesophilic character of this community. They are followed by xerothermophilic plants with 26% (Pontic, Submediterranean and Balkan range types) and plants of wide ecological amplitude with 24% (Eurasian range types), while there are only 1% of Subboreal floral elements.

**Table 2.** *Spectrum of floral elements in the community of Querco petraeae-Carpinetum betuli Rudski 1949. s.l.*

| Range types | Num. | Aggreagate range types | Num. | Share (%) | |
|---|---|---|---|---|---|
| Subpontic | 1 | Pontic | 6 | 9% | 26% |
| Subpontic-subpannonian | 1 | | | | |
| Pontic-submediterranean | 2 | | | | |
| Pontic-Eastern submediterranean | 2 | | | | |
| Submediterranean | 5 | Submediterranean | 8 | 12% | |
| Eastern submediterranean | 3 | | | | |
| Subbalkan-Apennine | 1 | Balkan | 3 | 5% | |
| Moesian | 1 | | | | |
| Central Balkan | 1 | | | | |
| Central European | 4 | Central European | 21 | 32% | 41% |
| Sub-Central European | 17 | | | | |
| Subatlantic-submediterranean | 6 | Subatlantic | 6 | 9% | |
| Eurasian | 8 | Eurasian | 16 | 24% | 24% |
| Subeurasian | 5 | | | | |
| Sub-South Siberian | 3 | | | | |
| Circumpolar | 2 | Circumpolar | 5 | 8% | 8% |
| Sub-Circumpolar | 3 | | | | |
| Subboreal-circumpolar | 1 | Subboreal | 1 | 1% | 1% |
| Total: | 66 | Total: | 66 | 100% | 100% |

The significant share of submediterranean floral elements in this community points to its relative thermophilicity. Abundant presence of plants of subatlantic-subediterranean floral element, such as *Ruscus aculeatus* L., *Euphorbia amygdaloides* L., *Hedera helix* L. and *Tamus communis* L. indicates a favorable phytoclimate of this forest, where these plants have found favorable conditions for their growth.

### 3.5 Spectrum of life forms

The analysis of the spectrum of life forms (Table 3) shows that the investigated community of *Querco petraeae-Carpinetum betuli* Rudski 1949 s.l is predominated by phanerophytes with 38% (pure phanerophytes, nanophanerophytes, and phanerophytic vines). Hemicryptophytes also have a high share, accounting for 33%.

The share of geophytes is also high (15%), which indicates wet climate and soil conditions. Plants of the transitional category of therophytes to hamephytes are much less represented with 8%, while the therophytes and herbaceous hamephytes have the smallest share of 3%, each.

**Table 3.** *Spectrum of life forms in Querco petraeae-Carpinetum betuli Rudski 1949. s.l. forest community*

| fr | | | | | | | |
|---|---|---|---|---|---|---|---|
| P | Np | Pl | Zc | H | G | T | Th |
| 20% | 17% | 1% | 3% | 33% | 15% | 3% | 8% |
| 38% | | | | | | | |

Legend: P-phanerophyte; Np-nanophanerophyte; Pv-phanerophytic vine; Hc-herbaceous chamaephyte; H-hemicryptophyte; G-geophyte; T-therophyte; Th-therophyte/ chamaephyte.

A similar biological spectrum, as well as the spectrum of life forms, is stated by Cvjetićanin et al., (2013) for the community of sessile oak and hornbeam on Miroč, where this community was recorded at altitudes ranging from 390 to 430 m.

## 4. CONCLUSION

The community of sessile oak and hornbeam *(Querco petraeae-Carpinetum betuli* Rudski 1949 s.l.) in the area of Kosmaj occurs only in fragments which are presented with three relevés from Mali Kosmaj. The underlying bedrock of the community is flysch, and the soils are deeply ilimerized – luvisols.

Relevés were taken at altitudes ranging from 339 to 410 m, eastern to northeastern aspects, and the slope of 15-23°. The mesophilic character of this community can easily be recognized by the characteristic set of species, most often found in the sessile oak-hornbeam forests of Serbia, which is determined by a combination of site factors. This is also indicated by the abundant presence of plants of the subatlantic-submediterranean floral element, such as *Ruscus aculeatus* L., *Euphorbia amygdaloides* L., *Hedera helix* L. and *Tamus communis*.

A distinctive feature of this sessile oak-hornbeam forest is the presence of butcher's-broom (*Ruscus aculeatus* L.), a submediterranean species that is found in Serbia only in the warmest Pontic-Pannonian part.

According to the spectrum of range types, the investigated sessile oak and hornbeam community (*Querco petraeae-Carpinetum betuli* Rudski 1949 s.l.) has a Central European character, while the prevailing life forms include phanerophyte-hemicryptophytes, with an increased share of geophytes.

The goals of multipurpose silviculture in special-purpose forests can be achieved by applying the close to nature silviculture, where the natural site potential

is optimally used to preserve their naturalness, biodiversity and genetic variability, improve the condition and increase productivity. Therefore, the research of vegetation in this area is the starting point for planning silvicultural needs as important factors related to the provision of special benefits of these forests.

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## PHYTOSOCIOLOGICAL CHARACTERISTICS OF SESSILE OAK AND HORNBEAM FORESTS (*QUERCO PETRAEAE-CARPINETUM BETULI* RUDSKI 1949. S.L.) IN THE AREA OF KOSMAJ

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### Summary

The paper presents the results of the phytosociological research of sessile oak and hornbeam forests (*Querco petraeae-Carpinetum betuli* Rudski 1949 s.l.) conducted in the Kosmaj Protected Area. The sessile oak and hornbeam forests in Serbia are conditioned by orographic and edaphic factors, i.e., they occur as extrazonal vegetation and cover significantly smaller areas than in the Illyrian province. They can be found as valley and mountain variants but without significant differences in the floristic composition. The community of sessile and hornbeam in this area is found only in fragments that are presented with three relevés from Mali Kosmaj. Phytosociological relevés of the investigated association were taken at altitudes ranging from 339 to 410 m., with eastern to northeastern aspects, and the slope of 15-23°. The community occurs on deeply ilimerized soils – luvisols over flysch.

The floristic composition of this phytosociological community is diverse, including plants from thermophilic and mesothermal oak forests and some plants from beech forests. In the tree layer, besides the dominant share of edifying sessile oak (*Quercus petraea* (Matt.) Liebl) and hornbeam (*Carpinus betulus* L.), there are: *Acer campestre* L., *Ulmus minor* Mill., *Quercus cerris* L., and *Quercus farnetto* Ten. The shrub layer is rich in species, with a total of 12 species registered. There is a total of 59 species in the ground flora layer. There are plants of thermophilic and mesothermal oak forests and some beech forests plants. The mesophilic character of this community is pronounced, which is also indicated by the abundant presence of plants of the subatlantic-submediterranean floral element, such as *Ruscus aculeatus* L., *Euphorbia amygdaloides* L., *Hedera helix* L. and *Tamus communis*. The floristic composition is characterized by the presence of the Mediterranean floral element of the butcher's-broom (*Ruscus aculeatus* L.), which is the reason the *aculeatetosum* subassociation has been singled out.

With regard to the spectrum of range types, the investigated community *Querco petraeae-Carpinetum betuli Rudski 1949. s.l.* has a Central European range of distribution. Regarding the biological spectrum of life forms, the prevailing life forms include phanerophyte-hemicryptophytes, with an increased share of geophytes.

Considering that most of the Kosmaj area is a protected area with significant natural, biological-ecological, aesthetic and cultural-historical values, the research of vegetation of this area can serve as the starting point for planning silvicultural needs as important factors related to the provision of special benefits of these forests.

# FITOCENOLOŠKE KARAKTERISTIKE ŠUME KITNJAKA I GRABA (*QUERCO PETRAEAE-CARPINETUM BETULI* RUDSKI 1949. S.L.) NA PODRUČJU KOSMAJA

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## Rezime

U radu su prikazani rezultati fitocenoloških istraživanja šume kitnjaka i graba (*Querco petraeae-Carpinetum betuli* Rudski 1949. s.l.) koja su sprovedena u zaštićenom području Kosmaj. Šume kitnjaka i graba u Srbiji su orografsko-edafski uslovljene, tj. javljaju se kao ekstrazonalna vegetacija i pokrivaju znatno manje površine nego u ilirskoj provinciji. Javljaju se u dolinskoj i brdskoj varijanti, ali bez većih razlika u floističkom sastavu. Zajednica kitnjaka i graba na ovom području zastupljena je samo fragmentarno i predstavljena je sa tri fitocenološka snimka sa Malog Kosmaja. Fitocenološki snimci istraživane asocijacije su sa nadmorskih visina 339-410 m, ekspozicije su istočne do severoistočne, a nagib 15-23°. Geološka podloga na kojima se javlja ova zajednica je fliš, a zemljišta su duboka ilimerizovana - luvisoli.

Floristički sastav ove fitocenoze je raznovrstan, jer su u njoj javljaju biljke iz termofilnih i mezotermnih hrastovih, ali istovremeno i neke iz bukovih šuma. U spratu drveća pored dominantnih edifikatora kitnjaka (*Quercus petraea* (Matt.) Liebl) i graba (*Carpinus betulus* L.) javljaju se: *Fraxinus ornus* L., *Acer campestre* L., *Ulmus minor* Mill., *Quercus cerris* L., *Quercus farnetto* Ten. Sprat žbunja je bogat po broju vrsta, u njemu je registrovano ukupno 12 vrsta. U spratu prizemne flore registrovano je ukupno 59 vrsta. Prisutne su biljke iz termofilnih i mezotermnih hrastovih, ali i neke iz bukovih šuma. Izražen je mezofilni karakter ove zajednice, na šta ukazuje i obilno prisusuvo biljaka subatlansko-submediteranskog flornog elementa, kao što su *Ruscus aculeatus* L., *Euphorbia amygdaloides* L., *Hedera helix* L. i *Tamus communis*. Karakteristično je prisustvo mediteranskog flornog elementa oštrolisne kostrike (*Ruscus aculeatus* L.), zbog čega je izdvojena subasocija *aculeatetosum*.

Analizom spektra areal tipova utvrđeno je da istraživana zajednica kitnjaka i graba ima srednjeevropski karakter, dok je prema spektru životnih oblika fanerofitsko-hemikriptofitskog karaktera, sa povećanim učešćem geofita.

S obzorom da je Kosmaj zaštićeno područje, sa značajnim prirodnim, biološko-ekološkim, estetskim i kuumlturno-istorijskim vrednostima, istraživanje vegetacije ovog područja predstavlja polaznu osnovu za planiranje uzgojnih potreba, kao važnih činilaca u obezbeđenju posebnih namena, koje ove šume imaju.

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# PHYTOCOENOLOGICAL CHARACTERISTICS OF BEECH FORESTS AT LOCALITY VISOKA STENA THE THIRD YEAR AFTER THE WILDFIRE ON VIDLIČ MOUNTAIN

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**Abstract:** *In this paper, the influence of wildfire on beech forests the third year after the fire at locality Visoka Stena on the Vidlič Mountain is followed. The results of field studies are presented in the form of phytocoenological table. The quantitative increase in the number of species diversity index in comparison to the previous two seasons was registered. Increasing number of woody and shrubby representatives of plants influences more favorable conditions for survival, germination, and further development of beech saplings in their shadows, which, with a greater wealth of nutrients in the soil than before the fire, are the good prerequisites for gradual natural regeneration of beech forests.*

**Keywords:** wildfire, beech forest, diversity

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# FITOCENOLOŠKE KARAKTERISTIKE BUKOVIH ŠUMA NA LOKALITETU VISOKA STENA TREĆE GODINE POSLE POŽARA NA PLANINI VIDLIČ

**Izvod:** *U radu je prikazan uticaj požara na bukove šume na lokalitetu Visoka stena na planini Vidlič treće godine posle požara. Rezultati terenskih istraživanja su prikazani u vidu fitocenološke tabele. Zabeleženo je kvantitativno povećanje indeksa diverziteta u odnosu na prethodne dve sezone. Povećanje broja drvenastih i žbunastih predstavnika dovodi do povoljnijih uslova za klijanje, opstanak i dalji razvoj bukovog podmladka u njihovoj senci što, uz veće bogatstvo hranljivih materija u zemljištu nego pre požara, predstavljaju dobre preduslove za postepeno obnavljanje bukovih šuma prirodnim putem.*

**Ključne reči:** požar, bukova šuma, diverzitet

## 1. INTRODUCTION

Frequent droughts, dry and hot summers, and sometimes even autumns with the slightest human negligence led to large fires in nature. The intensity and duration of a fire are the two most important components in assessing its severity, which affects the magnitude of the damage, that it causes (Certini, G., 2005). The fire destroys the vegetation, and on the other hand, it affects the formation of new ecological conditions.

The area of our country is a climatogenic forest area. Therefore, forest fires in our literature are given a great importance. Forest fires can cause enormous consequences and devasting impact on forest ecosystems. For short period of time forest fires can burn large forest mass and make the forest ecosystem an erasure. Even so, the forest vegetation has a very important and essential ability. It is capacity for natural regeneration. The forest ecosystem can be revitalized and naturally restored even after the catastrophic effects of fire (Velkovski, N. *et al*., 2012). After the layer of ash on the soil surface is formed, almost a year after fire, habitat revitalization occurs, which continues through a series of successive stages, starting from initial formations up to the more stable phytocenoses (Vukićević, E., 1965). Each succesional stage of vegetation is characterized by certain floristic composition and environmental conditions, while late subsequent communities are usually les dynamic and more stable (Marković, S.M. *et al*., 2018a).

Beech is a mesophilic species. In the beech forests, the floor of herbaceous layer is poorly developed, the moisture content is high, and there is no combustible material such as resin and explosively burning conifers. Due to these facts, some authors on a scale of 1 to 5 for beech, as well as for other mesophilic species of deciduous trees, state that they have the weakest flammability and classify it in the 5th category in the classification of fire hazards (Ratknić, M. *et al*., 2006). However, although beech is a mesophilic species, it is a tree with a thin bark, and we can classify it among the species sensitive to fire, which is confirmed by some other authors (Dimitrov, according to Petrović, N., 1965).

The forest fires are related to the current climatic conditions (air and soil temperature, humidity in the habitat, wind direction and speed of wind), forest structure (age and types of trees, number of layers, layers density), and the character of the substrate. The danger of wildfire depends mostly on the humidity of the forest soil, but also on the air temperature. The wind affects the occurrence of fire in two ways: on the one hand it dries out the moisture in the soil and the burning material, and on the other hand it helps the spread and speed of the fire (Kamilovski, M., 1965). According to Petrović, N. (1956), beech forests in the eastern part of Serbia are susceptible to frequent east and southeast winds, which can affect the occurrence and spread of fires.

According to Nikolov, N. (2015) between 2004 and 2013, 3800 ha, of which 2250 ha categorized as forests, were destroyed by wildfires in Serbia. In the period of 2003 – 2007 year, 580 wildfires were counted and most of them (370) were in 2007 (Tabaković-Tošić, M. et al., 2009). The fire on Vidlič Mountain happened in the summer 2007 and burned over 1000 ha of forest area, that was impacted by uncontrolled wildfire (Panić, M., 2007). The vegetation dynamic of burned xeric grasslands and rocky grounds in three consecutive seasons (2008-2010) was followed, and a comparison between the stages of vegetation established at the burned sites with the vegetation of similar, unburned habitats was carried out (Marković, S.M. *et al.*, 2018a). Floristic composition of oak forests and oriental hornbeam scrubs in the first three years after a wildfire was done by Rakonjac, Lj. *et al*. (2018). Phytocoenological study of vegetation of beech forest at locality Visoka stena the first year after fire was carried out by Marković, M. *et al*. (2018b), and the second year by Rakonjac, Lj. *et al.* (2020). The aim of this paper is to consider the phytocoenological changes during the third year after the fire at the locality Visoka stena on the Vidlič Mountain. The stages of natural gradual recovery of beech forest vegetation, which was affected by the fire, can be established, by comparing the floristic composition of the analyzed stands from year to year after the fire.

## 2. MATERIAL AND METHODS

The field research of the areas of beech forest affected by the fire on Mt. Vidlič were conducted in 2010. The identification of the collected plant material was performed according to Josifović, M. (1970-1986), and the nomenclature was adjusted in accordance with Flora Europaea (Tutin, T.G. *et al.*, 1964-1980; Tutin, T.G. *et al.*, 1993). 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 Niš: Herbarium Moesiacum (HMN).

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, J. (1964) were presented in the form of phytocoenological table. Eight relevés on the stands **a**-**h** were sampled. Alpha diversity of species in the community, within the minimum range, was performed in the software package of the "Flora" program (Karadžić, B., *et al.*, 1998).

The results of the study of the floristic composition of beech forest the third year after the wildfire at the same locality were compared with the already

published results relating to the first and second year after the wildfire (Marković, M. *et al*., 2018b; Rakonjac, Lj. *et al.* 2020).

## 3. RESULTS AND DUSCISSIONS

Relevés of beech forest affected by the fire at locality Visoka stena on Vidlič Mountain have been sampled at altitudes of 1035 to 1370 m, with exposures: W, NW, N and NE, terrain inclination 5 to 70° (Table 1), with number of species from 29 to 69 and the value of Simpson's diversity index ranging from 0.959 to 0.983. The total of 168 species and subspecies were recorded in the stands a-i which indicates great diversity.

**Table 1.** *Beech forests at locality Visoka stena the third year after fire on the Vidlič Mountain (2010)*

| Altitude (m) | 1035 | 1150 | 1170 | 1140 | 1135 | 1130 | 1050 | 1050 | D |
|---|---|---|---|---|---|---|---|---|---|
| Exposure | W | NW | N | NW | N | NE | NW | NW | e |
| Terrain inclination (°) | 70° | 5° | 60° | 20° | 30° | 60° | 40° | 30° | g |
| Relevé area (m) | 10x10 | 10x10 | 10x10 | 3x3 | 10x10 | 10x10 | 5x10 | 10x10 | r |
| General vegetation coverage (%) | 80 | 80 | 60 | 80 | 90 | 70 | 80 | 65 | e |
| Vegetation height (m) | 2,5 | 6,5 | 1,5 | 1 | 1,5 | 0,8 | 1,5 | 2 | o |
| Relevé number | **a** | **b** | **c** | **d** | **e** | **f** | **g** | **h** | f |
| Floristic composition: | | | | | | | | | p |
| **Threes layer:** | | | | | | | | | r. |
| *Salix caprea* L. | . | . | . | . | . | . | . | +.1 | I |
| *Populus tremula* L. | . | . | . | . | . | . | . | +.1 | I |
| *Fagus moesiaca* (K. Maly) Czecz. | . | 2.2 | . | . | . | . | . | . | I |
| **Schrub layer:** | | | | | | | | | |
| *Rubus idaeus* L. | . | +.1 | 1.2 | +.2 | +.1 | +.1 | +.1 | +.1 | V |
| *Acer campestre* L. | . | 1.1 | +.1 | +.1 | +.2 | . | +.1 | +.1 | IV |
| *Salix caprea* L. | +.1 | +.1 | . | +.1 | . | +.1 | . | +.2 | IV |
| *Corylus avellana* L. | +.1 | . | 1.1 | +.1 | . | +.1 | +.1 | . | IV |
| *Chamaecytisus ciliatus* (Wahlenb.) Rothm. | +.1 | . | +.1 | . | . | +.1 | +.1 | +.1 | IV |
| *Sorbus aria* (L.) Crantz. | +.1 | . | . | +.1 | +.1 | +.1 | +.1 | . | IV |
| *Spiraea chamaedryfolia* L. | . | +.1 | 3.3 | . | +.1 | 2.2 | 3.3 | . | IV |
| *Clematis vitalba* L. | +.1 | . | +.1 | . | . | . | +.1 | +.1 | III |
| *Sambucus ebulus* L. | . | +.1 | +.1 | . | +.1 | . | . | +.1 | III |
| *Sorbus torminalis* (L.) Crantz | +.1 | +.1 | . | +.1 | . | . | . | . | II |
| *Populus tremula* L. | . | +.1 | . | . | +.1 | +.1 | . | . | II |
| *Crataegus monogyna* | +.1 | +.1 | . | . | . | . | . | . | II |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Jacq. | | | | | | | | | |
| *Lonicera xylosteum* L. | . | . | . | +.1 | +.1 | . | . | . | II |
| *Chamaecytisus elongatus* (L.) Link. | +.1 | . | . | . | . | . | . | . | I |
| *Rosa canina* L. | +.1 | . | . | . | . | . | . | . | I |
| *Rosa rubiginosa* L. | . | +.1 | . | . | . | . | . | . | I |
| *Rosa pimpinellifolia* L. | . | +.1 | . | . | . | . | . | . | I |
| *Sambucus racemosa* L. | . | +.1 | . | . | . | . | . | . | I |
| *Cotoneaster integerrimus* Medicus | . | . | . | +.1 | . | . | . | . | I |
| *Rosa arvensis* Hudson | . | . | . | +.1 | . | . | . | . | I |
| *Daphne mezereum* L. | . | . | . | . | . | +.1 | . | . | I |
| *Sorbus aucuparia* L. | . | . | . | . | . | . | +.1 | . | I |
| *Acer pseudoplatanus* L. | . | . | . | . | . | . | +.1 | . | I |
| *Fraxinus ornus* L. | . | . | . | . | . | . | . | +.1 | I |
| **Herbaceous layer:** | | | | | | | | | |
| *Galium mollugo* L. | 1.1 | +.1 | +.1 | 1.1 | +.1 | +.1 | 2.2 | 1.3 | V |
| *Doronicum columnae* Ten. | +.1 | +.2 | +.1 | +.1 | +.1 | . | 1.1 | +.1 | V |
| *Sedum album* L. | +.1 | . | +.1 | +.1 | 1.1 | +.1 | +.1 | +.1 | V |
| *Vicia cracca* L. | . | +.2 | +.1 | +.1 | +.1 | 2.3 | . | 2.3 | IV |
| *Lamium maculatum* L. | . | +.2 | 1.1 | +.1 | +.1 | . | +.1 | +.1 | IV |
| *Coronilla varia* L. | . | 1.1 | +.1 | 1.1 | . | +.1 | 1.2 | +.1 | IV |
| *Epilobium angustifolium L.* | . | +.1 | 1.1 | . | 3.3 | 2.2 | +.1 | 3.3 | IV |
| *Leucanthemum vulgare* Lam. | +.2 | . | +.1 | +.1 | . | 1.1 | +.1 | . | IV |
| *Poa angustifolia* L. | +.1 | . | . | . | +.1 | 1.3 | 1.3 | +.3 | III |
| *Moehringia muscosa* L. | . | +.2 | +.3 | . | +.1 | . | +.2 | +.1 | IV |
| *Mycelis muralis* (L.) Dumort. | . | +.1 | +.1 | . | 1.1 | . | +.1 | +.1 | IV |
| *Lilium martagon* L. | . | +.1 | . | +.1 | . | +.1 | +.1 | +.1 | IV |
| *Lathyrus pratensis* L. | +.1 | +.2 | . | +.1 | 2.2 | . | . | . | III |
| *Knautia drymeia* Heuffel | +.1 | . | +.1 | 1.1 | . | +.1 | . | . | III |
| *Geranium macrorrhizum* L. | +.2 | . | 1.2 | . | . | . | +.2 | +.1 | III |
| *Veronica chamaedrys* L. | +.2 | . | +.1 | . | . | +.1 | +.1 | . | III |
| *Medicago lupulina* L. | +.2 | . | . | . | . | 2.2 | 1.1 | +.2 | III |
| *Helianthemum nummularium* (L.) Miller | 2.2 | . | . | . | . | 1.2 | 1.1 | +.1 | III |
| *Fragaria viridis* Duchesne | 1.1 | . | . | . | . | +.1 | +.1 | +.1 | III |
| *Hieracium murorum* L. | . | +.1 | +.1 | 2.2 | . | +.1 | . | . | III |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Poa nemoralis* L. | . | 2.3 | 1.3 | 2.2 | . | . | +.2 | . | III |
| *Taraxacum officinale* Weber | . | +.1 | +.1 | . | +.1 | . | . | +.1 | III |
| *Saxifraga tridactylites* L. | . | +.1 | +.2 | . | . | +.1 | +.1 | . | III |
| *Trifolium pratense* L. | 1.1 | +.1 | . | . | . | 1.2 | . | . | II |
| *Cynanchum vincetoxicum* (L.) Pers. | +.1 | +.1 | . | . | . | . | +.1 | . | II |
| *Digitalis ambigua* Murr. (*Digitalis grandiflora* Miller) | +.1 | +.1 | . | . | . | . | +.1 | . | II |
| *Sedum hispanicum* L. | +.1 | . | +.1 | . | . | +.1 | . | . | II |
| *Campanula patula* L. | +.1 | . | . | . | +.1 | +.1 | . | . | II |
| *Myosotis arvensis* (L.) Hill | +.1 | . | . | . | +.1 | +.1 | . | . | II |
| *Silene italica* (L.) Pers. | 2.2 | . | . | . | . | +.1 | 2.3 | . | II |
| *Acinos alpinus* (L.) Moench. | 2.2 | . | . | . | . | +.2 | +.1 | . | II |
| *Minuartia verna* (L.) Hiern. | +.1 | . | . | . | . | +.1 | 1.1 | . | II |
| *Myosotis sylvatica* Hoffm. | . | +.1 | +.1 | . | . | . | 1.3 | . | II |
| *Aegopodium podagraria* L. | . | 3.4 | . | 1.1 | +.1 | . | . | . | II |
| *Euphorbia polychroma* A. Kerner | . | +.1 | . | +.1 | +.1 | . | . | . | II |
| *Euphorbia amygdaloides* L. | . | +.1 | . | . | +.1 | +.1 | . | . | II |
| *Arabis procurrens* Waldst. & Kit. | . | . | +.1 | +.1 | +.1 | . | . | . | II |
| *Libanotis montana* Crantz | . | . | +.1 | +.1 | . | +.1 | . | . | II |
| *Thymus glabrescens* Willd. | +.1 | . | +.2 | . | . | . | . | . | II |
| *Trifolium repens* L. | +.1 | . | . | . | . | +.1 | . | . | II |
| *Carex ornithopoda* Willd. | +.1 | . | . | . | . | +.1 | . | . | II |
| *Teucrium chamaedrys* L. | 2.2 | . | . | . | . | . | 2.2 | . | II |
| *Viola tricolor* L. | +.1 | . | . | . | . | . | 1.1 | . | II |
| *Clinopodium vulgare* L. | +.1 | . | . | . | . | . | +.1 | . | II |
| *Vicia incana* Gouan. | +.1 | . | . | . | . | . | +.2 | . | II |
| *Myosotis scorpioides* L. | +.1 | . | . | . | . | . | +.1 | . | II |
| *Festuca valesiaca* Schleicher ex Gaudin | +.1 | . | . | . | . | . | . | +.2 | II |
| *Viola arvensis* Murray | +.1 | . | . | . | . | . | . | +.1 | II |
| *Galium vernum* Scop. | . | +.2 | . | . | . | . | . | +.1 | II |
| *Lathyrus venetus* (Miller) Wohlf. | . | +.1 | . | +.1 | . | . | . | . | II |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Asplenium trichomanes* L. | . | . | +.1 | +.1 | . | . | . | . | II |
| *Pteridium aquilinum* (L.) Kuhn | . | . | +.1 | . | 1.1 | . | . | . | II |
| *Geranium robertianum* L. | . | . | 1.1 | . | . | +.1 | . | . | II |
| *Hypericum richeri* Vill. | . | . | +.1 | . | . | +.1 | . | . | II |
| *Senecio vernalis* Waldst. & Kit. | . | . | +.1 | . | . | +.1 | . | . | II |
| *Scabiosa ochroleuca* L. | . | . | +.1 | . | . | . | +.1 | . | II |
| *Campanula persicifolia* L. | . | . | . | +.1 | +.1 | . | . | . | II |
| *Galium cruciata* L. | . | . | . | +.1 | . | . | +.1 | . | II |
| *Hypochoeris maculata* L. | . | . | . | +.1 | . | . | . | +.1 | II |
| *Aremonia agrimonioides* (L.) DC. | . | . | . | . | +.1 | +.1 | . | . | II |
| *Polygala comosa* Schkuhr | . | . | . | . | . | +.1 | +.1 | . | II |
| *Hypericum perforatum* L. | . | . | . | . | . | . | +.1 | +.1 | II |
| *Anthyllis vulneraria* L. | 3.3 | . | . | . | . | . | . | . | I |
| *Carex verna* Chaix.(*Carex caryophyllea* Latour.) | 1.2 | . | . | . | . | . | . | . | I |
| *Trifolium alpestre* L. | 1.2 | . | . | . | . | . | . | . | I |
| *Polygala vulgaris* L. | 1.1 | . | . | . | . | . | . | . | I |
| *Medicago falcata* L. | +.2 | . | . | . | . | . | . | . | I |
| *Alyssum repens* Baumg. | +.2 | . | . | . | . | . | . | . | I |
| *Festuca drymeja* Mert. & Koch | . | 2.3 | . | . | . | . | . | . | I |
| *Carex strigosa* Hudson | . | 1.2 | . | . | . | . | . | . | I |
| *Brachypodium pinnatum* (L.) Beauv. | . | +.2 | . | . | . | . | . | . | I |
| *Carex pilosa* Scop. | . | +.2 | . | . | . | . | . | . | I |
| *Senecio rupestris* Waldst. & Kit. | . | +.2 | . | . | . | . | . | . | I |
| *Cerastium caespitosum* Gilib. | . | . | +.2 | . | . | . | . | . | I |
| *Cerastium glomeratum* Thuill. | . | . | . | . | . | 1.1 | . | . | I |
| *Festuca varia* Haenke | . | . | . | . | . | . | +.2 | . | I |

Legend: Degree of pr. – Degree of presence

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

**Relevé a:** *Ajuga reptans* L., *Arabis hirsuta* (L.) Scop., *Avenula compressa* (Heuffel) W. Sauer & Chmelitschek, *Carex halleriana* Asso, *Carex stellulata* Good, *Cerastium pumilum* Curtis, *Erysimum diffusum* Ehrh., *Ferulago sylvatica* (Besser) Reichenb, *Festuca xanthina* Roemer & Schultes, *Geranium molle* L., *Koeleria gracilis* Pers., *Poa*

*bulbosa* L., *Poa compressa* L., *Plantago lanceolata* L., *Potentilla cinerea* Chaix ex Vill., *Potentilla recta* L., *Primula veris* L., *Ranunculus bulbosus* L., *Reseda lutea* L., *Rumex acetosa* L., *Sanguisorba minor* Scop., *Scabiosa banatica* Waldst. et Kit., *Thesium linophyllon* L.;

**Relevé b:** *Brachypodium sylvaticum* (Hudson) Beauv., *Dactylis glomerata* L., *Fagus moesiaca* (K. Maly) Czecz., *Galium album* Miller, *Melica ciliata* L., *Melittis melissophyllum* L., *Potentilla micrantha* Ramond ex DC.;

**Relevé c:** *Asplenium ruta-muraria* L., *Campanula rotundifolia* L., *Cystopteris fragilis* (L.) Bernh., *Dianthus petraeus* Waldst. & Kit., *Epilobium montanum* L., *Hypericum maculatum* Crantz, *Fragaria moschata* Duchesne, *Moehringia trinervia* (L.) Clairv., *Saxifraga paniculata* Miller, *Saxifraga rotundifolia* L., *Urtica dioica* L., *Veronica orchidea* Crantz;

**Relevé d:** *Botrichium lunaria* (L.) Shwartz, *Hieracium bifidum* Kit., *Poa trivialis* L.;

**Relevé e:** *Trifolium diffusum* Ehrh., *Viola sylvestris* Lam.;

**Relevé f:** *Campanula bononiensis* L., *Chelidonium majus* L., *Fragaria vesca* L., *Gymnadenia conopsea* (L.) R. Br., *Hieracium cymosum* L., *Hieracium bauhinii* Besser, *Koeleria eryostachya* Pančić, *Laserpitium latifolium* L., *Lychnis viscaria* L., *Ranunculus polyanthemos* L., *Scabiosa ucranica* L.;

**Relevé g:** *Campanula sphaerothrix* Griseb., *Linaria vulgaris* Miller, *Poa alpina* L., *Thymus pulegioides* L.;

**Relevé h:** *Erysimum odoratum* Ehrh., Gentianella ciliata (L.) Borkh., *Lathyrus vernus* (L.) Bernh., *Leontodon hispidus* L., *Medicago minima* (L.) Bartal., *Scrophularia nodosa* L.

The stand **a** of locality Visoka stena was located nearby beech forest, that was not affected by fire. The number of species in the shrub layer in this relevé was increased from year to year. The first year after fire it was registered 4 (Marković, M. *et al*., 2018b), the second year 6 (Rakonjac, Lj. *et al*., 2020), and the third year 9 shrubby representatives (Table 1). The first year after fire in this stand the annual plant species *Geranium dissectum* was dominated with its abundance and coverage (3.3), which was assumed to be related to its short reproductive cycle (Marković, M. *et al*., 2018b). In the second year after the fire, there were registered significant changes in the composition of the dominant species. Annual plant species *Geranium dissectum*, that was dominant in the first year after the fire, the second year was replaced by perennial plants *Trifolium badium* (2.3) and *Anthyllis vulneraria* (2.2) (Rakonjac, Lj., *et al*., 2020). The third year after the fire, the yellow color of the inflorescences of the plant species *Anthyllis vulneraria* was dominated in the aspectivity of this relevé (Figure 1) with a high abundance and coverage (3.3), and the plant species *Trifolium badium* was disappeared. An increased abundance and coverage of perennial hamephytes has also been registered: *Acinos alpinus*, *Helianthemum nummularium*, which means that these communities were gained a more stable stage. The abundance and coverage of plant species *Fragaria viridis* and *Silene italica* were increased, in comparison with

the second year after the fire (Rakonjac, Lj. *et al*., 2020), and these two species were not registered in the first year after fire (Marković, M. *et al*., 2018b). The second and third years of succession, a larger number of plants from the grass family was recorded: *Agrostis capillaris*, *Poa badensis*, *Brachypodium sylvaticum*, *Avenula compressa*, *Festuca valesiaca*. Expansion of the remnant rhizome of the grasses seems to be very important moment in succession, as the grasses are powerful colonists. Generally, achieving the "grasses stage", significantly facilitate succesion, making the vegetation recovery time shorter than it was expected.


**Figure 1.** *The aspectivity of stand* ***a*** *with dominance of the yellow inflorescences of plant species Anthyllis vulneraria the third year after fire at locality Visoka stena*

The stand at site **b** was characterized by the fact that the beech forest was not completely burned, but only partial damage occurred. Beech trees, about 6 m high, were burned near the ground, and in the upper part they turned green with leaves in the first year after the fire (Marković, M. *et al*., 2018b). In this stand the first year after fire it was registered 8 (Marković, M. *et al*., 2018b), the second year 11 (Rakonjac, Lj. *et al*., 2020), and the third year 12 shrubby representatives (Table 1). Qualitative changes were occurred in the herbaceous layer, which refer to the composition of the species. The second year after the fire, the perennial plant *Aegopodium podagraria* (Figure 2) was observed (Rakonjac, Lj. *et al*., 2020), with increasing numbers of abundance and coverage values in the third year after the fire (from 2.2 second year to 3.4 third year). The presence of this plant species was indicated a nitrophilous and wet habitat. The second and third years after fire, a larger number of plants species *Poa nemoralis* from the grass family was recorded: the second and third year in comparison with the first year. *Brachypodium sylvaticum* from the grass family was registered the second year (Rakonjac, Lj. *et*

*al*., 2020), and *Festuca drymeia* from the same family was registered the third year after fire (Table 1).

**Figure 2.** *The perennial plant Aegopodium podagraria in the stand at site* ***b***

The stand at site **c** was located at altitude of 1170 m, with a terrain inclination of 60°. The abundance and coverage of the dominant shrub species *Spiraea chamaedryfolia* of this relevé was remained unchanged for all three years of succession monitoring (3.3). The increased numbers of abundance and coverage of shrubs *Rubus idaeus* and *Corylus avellana*, was observed, as well as herbaceous species from geranium genus: *Geranium macrorrhizum* and *Geranium robertianum*. The presence of the nitrophilous species *Lamium maculatum*, grass species *Poa nemoralis* and *Epilobium angustifolium* have increased.

The stand at site **d** was located at small area (3 x 3m) along a huge rock, that was look like a haystack (Figure 3). The species *Poa nemoralis* was dominated the first year after the fire with abundance and coverage of 4.4 (Marković, M. *et al*., 2018b), which was decreased in the second year after the fire on 2.2 (Rakonjac, Lj. *et al*., 2020). Qualitative changes in this relevé from year to year after fire were significant, which is indicated by the large number of species with small cover in only one year of monitoring.

The stand at site **e** was located nearby mentioned stands. The dominant plant species *Epilobium angustifolium* was with abundance and coverage 3.3, and species *Lathyrus pratensis* was with abundance and coverage 2.2. The common name of *Epilobium angustifolium* is "fireweed", that derives from the species' abundance as a colonizer on burnt sites after forest fires.

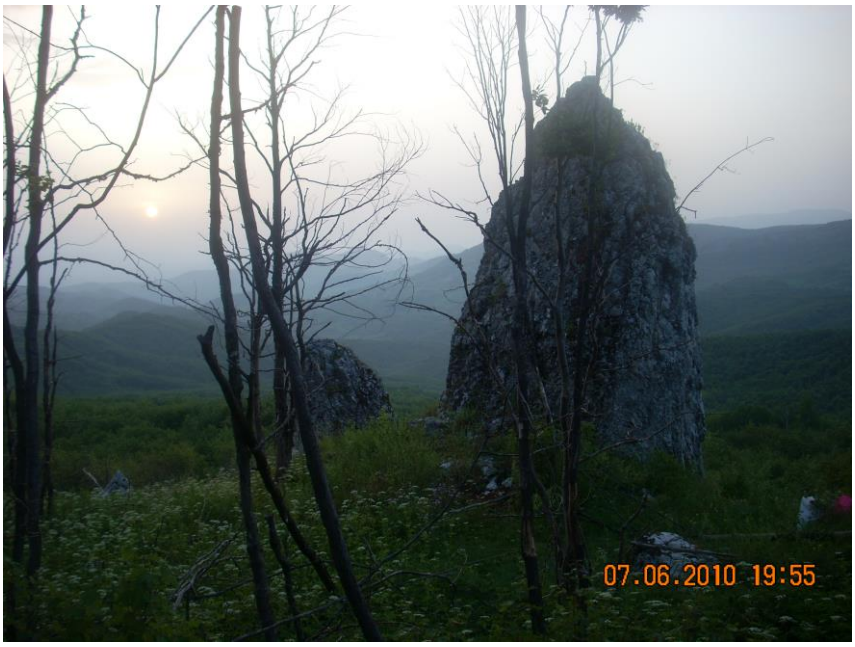


**Figure 3.** The stand at site **d** nearby a huge rock

The shrub species *Spiraea chamaedryfolia* has a slightly higher presence in the stand at locality **f**. The quantitative values of coverage and abundance of this shrub were increased from year to year (Marković, M. *et al*., 2018b; Rakonjac, Lj. *et al*., 2020). The significant qualitative changes in this stand during the succession monitoring were observed. It has been noticed that different types of grass plant species were changed during the first three years after fire. The grass species *Poa nemoralis* and *Poa compressa* were recorded in the second year after the fire (Rakonjac, Lj. *et al*., 2020), and grass species *Koeleria eriostachya* the third year after fire (Table 1). The grass species *Poa angustifolia* was presented the second and third years after the fire, and the number of coverage and sociality increase in the third year compared to the second year after fire.

In the stand at the locality **g**, the first year after the fire, the species from the grass family *Poa angustifolia* was dominated plant species (Marković, M. *et al*., 2018b). The quantitative values of coverage and abundance of this grass species were decreased in the second year after fire, while values of these parametres were increased for species: *Teucrium chamaedrys* and *Galium mollugo* (Rakonjac, Lj. *et al*., 2020). The species *Silene italica*, *Myosotis sylvatica* and *Helianthemum nummularium* not were represented in the first year after the fire (Marković, M. *et al*., 2018b), and they were observed in the second and third year after fire when they have a high coverage and abundance (1 or 2). Some of the herbaceous plants, which were recorded in the first year after the fire, were disappeared from this stand in the second year, and they were not registred in the third year after fire. These are mostly annual plant species: *Geranium dissectum*, *Galium lucidum*, *Polygala vulgaris*. Two mesophilic therophytes, *Cardamine impatiens* and *Medicago arabica*, which were not present in the first year after fire,

were occurred in the second year after fire (Rakonjac, Lj. *et al*., 2020) with small numbers of coverage, and the third year they were not been recorded.

The stand at locality **h** was characterized by domination of species *Epilobium angustifolium* and *Rubus idaeus*. The first year after fire *Rubus idaeus* was dominated in the shrub layer (Marković, M. *et al*., 2018b), while the second and third year *Populus tremula* was dominated species. The coverage and abundance of the species *Epilobium angustifolium* were increased in the second and third year after the fire, compared to the first year after the fire (Rakonjac, Lj. *et al*., 2020) (Table 1). In this relevé, a woody species *Salix caprea* has been recorded in the threes layer, and there are 8 plants in the shrub layer, which was unchanged as in the previous two monitoring seasons (Marković, M. *et al*., 2018b; Rakonjac, Lj. *et al*., 2020). New species that were recorded in the third year of succession are mostly perennial. The therophytes which were presented in the first and second year after fire were disappeared from the phytocoenological composition of the community. This means that succession was acquired a stage with domination of perennials. They can create the conditions and prepare the ground for other plants, especially vegetative shoots of woody plants *Populus tremula* and *Salix caprea* from the shrub layer, to move through a few years from shrub layer to threes layer and form a pioneer forest. The beech saplings can be formed and developed in shadows of their crowns, which, with are the good starting point for natural regeneration of beech forest.

In Table 2 orographic data and diversity at beech forest fires at the locality Visoka stena the third year after fire (2010), as well as the previous two seasons are presented. The highest diversity was shown by stand **a** (0.983), and the lowest diversity of stands **e** (0.959).

**Table 2.** *Orographic data in the areas of beech forest affected by fire at locality Visoka stena, species richness and alpha diversity by Whitaker, R.H. (1972), in the first - 2008 (Marković, M. et al., 2018b), second - 2009 (Rakonjac, Lj. et al*., 2020*), and third - 2010 year after fire on Vidlič Mountain*

| Relevé | Altitude (m) | Exposure | Terrain inclination (°) | Species richness 2008. | Diversity index 2008. | Species richness 2009. | Diversity index 2009. | Species richness 2010. | Diversity index 2010. |
|---|---|---|---|---|---|---|---|---|---|
| **a** | 1115 | W | 70 | 49 | 0.977 | 66 | 0.983 | 69 | 0.983 |
| **b** | 1150 | NW | 5 | 50 | 0.978 | 47 | 0.977 | 47 | 0.975 |
| **c** | 1170 | N | 60 | 35 | 0.967 | 46 | 0.975 | 48 | 0.977 |
| **d** | 1140 | NW | 20 | 14 | 0.903 | 36 | 0.970 | 33 | 0.966 |
| **e** | 1135 | N | 30 | 23 | 0.953 | 22 | 0.945 | 29 | 0.959 |
| **f** | 1130 | NE | 60 | 24 | 0.957 | 53 | 0.979 | 51 | 0.978 |
| **g** | 1050 | NW | 40 | 56 | 0.980 | 69 | 0.984 | 46 | 0.974 |
| **h** | 1050 | NW | 30 | 29 | 0.962 | 34 | 0.964 | 37 | 0.968 |
| **i** | 1100 | SW | 30 | - | - | 42 | 0.974 | - | - |

The average value of diversity in the first year after the fire was 0.959, in the second year was 0.972, and in the third year was 0.973. The second and third year after fire, diversity was increased compared to the first year, so that communities were more stable. Increasing diversity year after year after the fire demonstrates intense process of species immigration from surounding unburned vegetation *via* empty sites of burned plots.

The third year after the fire at locality Visoka Stena of the Vidlič Mountain, the increased number of shrubs was registred. There are more favorable conditions for survival and further development of beech seedlings in their shadows. It is a good precondition for gradual natural regeneration of beech forest. Favorable soil conditions can also contribute to the successful germination of seeds and the development of beech saplings on the surface area after the fire. By burning a thick layer of dry leaves during the fire, it is possible for beech seeds to fall directly on the soil, that is richer in nutrients than before the fire. Reduced amount of undecomposed organic matter and increased insolation affect more favorable aeration conditions, as well as an increase in bacteria (Vukićević, E., 1965). These are the good conditions for germination and development of beech saplings. Except from seeds, beech can well regenerated on fire affected habitats vegetatively. Many trees, which were damaged by fire in the stand at site b, can give good shoots from stumps.

## 4. CONCLUSION

The third year after wildfire at locality Visoka stena on the Vidlič Mountain was characterized by an increase in the number of perennial plants. Bunch grasses and other perennial species became dominant. As expected, sparse members of phanerophytes in the threes and shrub layer, remained fire non-affected; while some of them additionally increased in the third year after fire. In their shadows, better conditions were created for the development of beech seedlings. More favorable soil conditions, which are richer in nutrients than before the fire, also contribute to the development of beech saplings. After the initial fall, diversity generally increases in almost all burned sites in comparation to the previous seasons, so that the formed stands are more stable. They represent transitional stages in the process of reforestation of beech forest.

Further monitoring of the floristic composition and structure of the beech forests and phytocoenological characteristics of the described stands is necessary, especially at the cites which were completely burned in the wildfire, as well as the analysis of the diversity of beech forests damaged by wildfires. The aim of further monitoring can be to establish the stages in the process of spontaneous natural regeneration of the beech forests after wildfires in Serbia.

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## PHYTOCOENOLOGICAL CHARACTERISTICS OF BEECH FORESTS AT LOCALITY VISOKA STENA THE THIRD YEAR AFTER THE WILDFIRE ON VIDLIČ MOUNTAIN

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### Summary

The paper presents the phytocenological characteristics of burned beech forests in the third year after the fire at locality Visoka Stena on the Vidlič Mountain. The obtained results were compared with the floristic composition of the previous two seasons at the same locality.

An increase in plants from the grass family was noticed in the stand on the site **a** and in the immediate vicinity of the unburned beech forest, which is a very important moment in the succession, because the grasses are powerful colonists. In the same stand, there is an increase in the number of shrubby representatives in relation to the previous two seasons, in which shadows the conditions for the development of beech seedlings, can be expected in the following years.

In the stand on the site **b**, in which the beech forest has not completely burned down, but only partial damage has occurred, the appearance of new beech shoots from stumps is expected.

In the stand on the site **c**, the dominant shrub species *Spiraea chamaedryfolia* retained unchanged abundance and coverage for all three years of succession monitoring (3.3). However, an increase in the abundance and coverage of shrub species was observed: *Rubus idaeus* and *Corylus avellana*, as well as a larger number of herbaceous representatives.

In the stand on the site **d**, the qualitative changes from year to year are significant, which is indicated by the large number of species with a small number and cover only in one year of succession monitoring.

In the stands on the site **e**, the dominant plant species *Epilobium angustifolium* was with abundance and coverage 3.3, and species *Lathyrus pratensis* was with abundance and coverage 2.2.

In the stand on the site **f**, it was noticed that different types of grasses alternate in the process of succession. The species *Koeleria eriostachya* was recorded in the third year after the fire, the species *Poa angustifolia* was present in the second and third year after the fire, and its abundance and coverage increased in the third year after fire in comparison with the second year of succession monitoring.

In the stand on the site **g**, some of the herbaceous plants that were recorded in the first year after the fire were disappeared from the stand in the second year, and there were

not noticed none in the third year of succession. These were mainly annual plants (*Geranium dissectum, Galium lucidum, Polygala vulgaris*).

The stand on the site **h** were dominated by perennials, which further prepare the ground for other plants, especially vegetative shoots of woody plants *Populus tremula* and *Salix caprea* from the shrub layer, so that in the further process of succession they move from shrub layer to threes layer. They can influence the conditions in which the formation of young beech forest is expected.

There was a quantitative increase in the mean value of the Simpson diversity index (0.973) compared to the first (0.959) and second year (0.972) after the fire. The increase of diversity reflects the more intensive process of species immigration from neighboring unburned areas. Increasing the number of woody and shrubby representatives can enable the survival and further development of beech seedlings in their shadows. Favorable soil conditions also contribute to the favorable germination and development of beech saplings. It is richer in nutrients than before the fire.

## FITOCENOLOŠKE KARAKTERISTIKE BUKOVIH ŠUMA NA LOKALITETU VISOKA STENA TREĆE GODINE POSLE POŽARA NA PLANINI VIDLIČ

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### Rezime

U radu su prikazane fitocenološke karakteristike opožarenih bukovih šuma treće godine posle požara na lokalitetu Visoka Stena na planini Vidlič. Dobijeni rezultati su upoređeni sa florističkim sastavom prethodne dve sezone na istom lokalitetu.

U sastojini na lokalitetu **a** u neposrednoj blizini neopožarene bukove šume zabeleženo je povećanje biljaka iz porodice trava, što predstavlja veoma važan trenutak u sukcesiji, jer su trave moćni kolonisti. U istoj sastojini dolazi do povećenja broja žbunastih predstavnika u odnosu na prethodne dve sezone, u čijim se senkama stiču uslovi za razvoj bukovih klijanaca, čije prisustvo nije zabeleženo, ali se očekuje narednih godina praćenja.

U sastojini na lokalitetu **b,** u kojoj bukova šuma nije u potpunosti izgorela, već je došlo samo do delimičnog oštećenja, očekuje se pojava novih bukovih izdanake iz panjeva.

U sastojini na lokalitetu **c** dominantna žbunasta vrsta *Spiraea chamaedryfolia* zadržala je nepromenjenu brojnost i pokrovnost sve tri godine praćenja sukcesije (3.3). Međutim, zapaženo je povećanje brojnosti, pokrovnosti i socijalnosti žbunastih vrsta: *Rubus idaeus* i *Corylus avellana*, kao i većeg broja zeljastih predstavnika.

U sastojina na lokalitetu **d** kvalitativne promene iz godine u godinu su znatne, na šta ukazuje veliki broj vrsta sa malom brojnošću i pokrovnošću samo u po jednoj godini praćenja sukcesije.

U sastojini na lokalitetu **e** dominira biljna vrsta *Epilobium angustifolium* sa brojnošću i pokrovnošću 3.3, kao i vrsta *Lathyrus pratensis* sa brojnošću i pokrovnošću 2.2.

U sastojini na lokalitetu **f**, zapaženo je da se u procesu sukcesije smenjuju različite vrste trava. Vrsta *Koeleria eriostachya* zabeležena je treće godine posle požara, vrsta *Poa angustifolia* je prisutna druge i treće godine nakon požara, a brojnost i pokrovnost se povećavaju treće u odnosu na drugu godinu praćenja sukcesije.

U sastojini na lokalitetu **g** neke od zeljastih biljaka koje su zabeležene prve godine posle požara nestaju iz sastojine već druge godine, a nema ih ni treće godine sukcesije. To su uglavnom jednogodišnje biljke (*Geranium dissectum, Galium lucidum, Polygala vulgaris*).

Sastojina na lokalitetu **h** sukcesija zadobija stadijum sa dominacijom višegodišnjih biljaka, koje dalje pripremaju teren drugim biljkama, a pogotovo vegetativnim izbojcima drvenastih biljaka *Populus tremula* i *Salix caprea* iz sprata žbunova, kako bi u daljem procesu sukcesije prešle iz sprata žbunova u sprat drveća. Oni mogu stvoriti uslove u kojima se očekuje razvitak mlade bukove šume.

Zabeleženo je kvantitativno povećanje srednje vrednosti Simpsonovog indeksa diverziteta (0.973) u poređenju sa prvom (0.959) i drugom godinom (0.972) posle požara. Povećanje diverziteta odražava intenzivniji proces imigracije vrsta sa susednih neopožarenih površina. Povećanje broja drvenastih i žbunastih predstavnika može da omogući opstanak i dalji razvoj bukovih klijanaca u njihovoj senci. Povoljnom klijanju i razvoju bukovog podmladka doprinose i povoljni uslovi zemljišta. Ono je bogatije hranljivim elementima nego pre požara.

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# THE MOST IMPORTANT MYCOSES OF AUSTRIAN PINE (*PINUS NIGRA* ARNOLD.) IN THE AVALA AREA

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**Abstract**: *Austrian pine is one of the species most often used for afforestation in our conditions. In the area of Avala, afforestation with Austrian and Scots pine began in 1899. The stands of Austrian pine located on the northern and northwestern foothills of the Avala Landscape of Outstanding Features are 115 years old, while the stands on the southern and southeastern side are about 65 years old. Two-year research in the area of Avala recorded the presence of 18 species of fungi on Austrian pine. Out of that number, 6 fungi were found on needles, 5 on needles and seeds, 2 on roots and stem bases, 1 on cones, 3 on trunks and branches and 1 species in vascular bundles. Of all the species, the greatest damage is caused by Sphaeropsis sapinea and species of the Armillaria genus.*

**Keyword**s: Austrian pine, mycoses, fungi, Avala

# NAJVAŽNIJE MIKOZE CRNOG BORA (*PINUS NIGRA* ARNOLD.) NA PODRUČJU AVALE

**Izvod**: *Crni bor je jedna od vrsta koja se u našim uslovima najčešće koristi za pošumljavanje. Na području Avale pošumljavanja crnim i belim borom počela su još 1899 godine. Sastojine crnog bora koje se nalaze na severnoj i severozapadnoj strani podnožja PIO Avala su starosti 115 godina, dok su sastojine koje se nalaze na južnoj i jugoistočnoj strani starosti oko 65 godina. Tokom dvogodišnjih istraživanja na području Avale na crnom boru je zabeleženo prisustvo 18 vrsta gljiva. Na četinama konstatovano je prisustvo 6 gljiva, na četinama i semenu 5, na korenu i pridanku 2, na šišaricama 1, deblu i granama 3 i u*

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*sprovodnim sudovima 1 vrsta. Od svih vrsta najveće štete pričinjavaju Sphaeropsis sapinea i vrste roda Armillaria.*

**Ključne reči**: crni bor, mikoze, gljive, Avala

## 1. INTRODUCTION

Avala, the northernmost mountain in Šumadija, stands out in the wider area of Belgrade with its altitude of 506 meters. By the decision of the City of Belgrade of 2007, Avala was protected as a Landscape of Outstanding Features. It belongs to the Šumadija Mountain Range that represent a transitional zone between the Dinaric and Rhodope mountain ranges.

The area of the protected natural asset is characterized by the diversity and abundance of plant species. The recent flora of Avala consists of about 600 plant species from two classes, 86 families and 317 genera. A total of 6 forest and 4 meadow communities have been recognized and described on Mt.Avala. In the period from 1899 to 1906, Austrian and Scots pine plantations were established to replace clearings and thickets (Obratov-Petković, D., Đukić, M., 2000).

The family *Pinaceae* contains 11 genera, with 195 species of trees and infrequent shrubs. The *Pinaceae* family has the following three subfamilies: *Abietoideae*, *Pinoideae*, and *Laricioideae*. The *Pinoideae* subfamily includes only the *Pinus* genus, which is divided into 2 subgenera: *Pinus* and *Strobus*. Austrian pine belongs to the *Pinaceae* family, *Pinoideae* subfamily and *Pinus* genus and subgenus. Austrian pine is native to southern Europe, northwestern Africa, and western Asia. It belongs to the sub-Mediterranean floral element. In Serbia, it is found in the northwestern and central parts, and not so often in eastern Serbia. Earlier research identified several subspecies, but recent research has shown that there are only two subspecies, of which only ssp. *nigra* grows in Serbia (Cvjetićanin, R., et al., 2016).

In his research, Farjon, A. (2017) determines 5 subspecies of Austrian pine: *Pinus nigra* ssp. *nigra* (native to the east of Austria, north of Italy, Balkan Peninsula, Bulgaria, Romania, and the European portion of Turkey), *Pinus nigra* ssp. *laricio* (Corsica in France, southern Apennines and Sicily in Italy), *Pinus nigra* ssp. *pallasiana* (Kütahya Province in Turkey), *Pinus nigra* ssp. *dalmatica* (Croatia) and *Pinus nigra* ssp. *salzmannii* (southwestern Europe, Heraulz and Pyrenees in France, Spain, the region of Diebel Djurdur in Algeria, and the Rif Mountain Range in the north of Morocco).

Austrian pine is one of the species most often used for afforestation in our conditions. Its needles are dark green. It forms a wide crown and reaches large dimensions. Austrian pine prefers bright and warm exposures and is very resistant to adverse environmental conditions. It grows well on all soil types, even on extremely poor and shallow soils. Apart from being drought-prone and wind-resistant, it tolerates urban conditions.

Austrian pine in PA Avala is located in five compartments and 11 sections, on the northern and southern slopes. It builds pure or mixed stands. The stands of Austrian pine on the northern and northwestern foothills of Avala are 117 years old and the stands on the southern and southeastern side are about 67 years old.

## 2. MATERIAL AND METHOD

The research was conducted during 2018 and 2019 in the area of PA Avala in compartment 15 (section i), compartment 21 (sections a, b, c, d, e), compartment 23 (sections d, h), compartment 25 (sections k, n), and compartment 29 (section a).

The visual appearance of fruiting body was used in the identification of species. When it was not possible, the material with disease symptoms was transferred to the laboratory, where it was analyzed using standard phytopathological methods.

Tissues from which the material was isolated were first washed with running water for at least 30 minutes. Fungi were isolated from the freshly infected parts of lesion tissue which were cut into pieces smaller than 5 mm. Saprophytic species were isolated from older infected tissues. The pieces of excised tissue were surface-sterilized in sodium hypochlorite solution (2-6% active chlorine) for 2 minutes or in 70% ethanol for a few seconds and then washed in sterile distilled water. They were then transferred to appropriate nutritional media under aseptic conditions. Petri dishes were put into an incubator at appropriate temperatures, and the suitable time for species identification was determined through daily observation. Fungus cultures usually grew at temperatures between 21 and 25°C, but sometimes they were incubated at lower temperatures (below 15°C) or higher temperatures (above 34°C).

The formation of fruiting bodies was accelerated by changing external conditions (temperature, light regime), nutrition of fungi (replacement of nutrient-rich media with water-agar media), or long-term culture development. Identification was usually performed based on the culture characteristics, as well as morphological and physiological characteristics of the fungus using the following keys: Bondarceva, M. A. (1998), Dennis, R. W. G. (1978), Ellis, M., B., Ellis, J., B. (1985), Lanier, L., et. al. (1978), Minter, W.D. (1981) and Sutton B.C. (1980). The classification of fungi was performed according to the database available at www.indexfungorum.org/Names/Names.asp.

## 3. RESULTS AND DISCUSSION

The species of fungi identified on Austrian pine in the area of Avala are shown in Table 1.

**Table 1.** *Fungus species identified on Austrian pine in the area of Avala*

| Latin name | Classification | Affected plant part | Significance |
|---|---|---|---|
| *Alternaria alternata* (Fr.) Kassler | *Ascomycota, Pleosporaceae* | Older needles, seed | + |
| *Armillaria spp.* | *Basidiomycota, Physalacriaceae* | Root and stem base | + + + |
| *Auriscalpium vulgare* Gray | *Basidiomycota, Auriscalpiaceae* | Fallen cones | + |
| *Botrytis cinerea* Pers. ex Fr. | *Ascomycota, Sclerotiniaceae* | Needles, shoots, and seed | + |
| *Ceratocystis spp.* | *Ascomycota, Ceratocystidaceae* | Vascular bundles of stems | + + |

| | | | |
|---|---|---|---|
| *Cenangium acuum* Cooke & Peck | *Ascomycota, Helotiaceae* | Fallen cones | + |
| *Cladosporium herbarum* (Pers.) Link | *Ascomycota, Cladosporiaceae* | Fallen cones | + |
| *Cyclaneusma niveum* (Pers.) DiCosmo, Peredo & Minter. | *Ascomycota, Marthamycetaceae* | One-year and two-year old needles | + + |
| *Epicoccum purpurascens* Ehrenb. | *Ascomycota, Didymellaceae* | Fallen cones i seme | + |
| *Fusarium moniliforme* J.Sheld. | *Ascomycota, Nectriaceae* | Needles and seed | + |
| *Heterobasidion annosum* (Fr.) Bref. | *Basidiomycota, Bondarzewiaceae* | Roots of uprooted trees | + + |
| *Lophodermium pinastri* (Schard.:Fr.) Chev. | *Ascomycota, Rhytismataceae* | Most often on fallen cones | + + |
| *Lophodermium seditiosum* Minter, Staley & Millar | *Ascomycota, Rhytismataceae* | One-year and two-year needles | + + |
| *Phellinus pini* (Thore:Fr.) Ames. | *Basidiomycota, Hymenochaetaceae* | Trunk of older trees | + + |
| *Schizophyllum commune* Fr. | *Basidiomycota, Schizophyllaceae* | Trunk and branches | + |
| *Sphaeropsis sapinea* Dyko et Sutton, | *Ascomycota, Botryosphaeriaceae* | Young shoots and cones | + + + |
| *Trichaptum abietinum* (Pers. ex J.F.Gmel.) Ryvarden | *Basidiomycota, Incertae sedis* | Trunk and branches | + |
| *Trichothecium roseum* Link. | *Incertae sedis* | Fallen cones and seed | + |

+ - Fungi occur mainly as saprophytes or rarely as facultative parasites. They are not significant pathogens of Austrian pine.
+ + - Fungi can cause significant damage to Austrian pine, but due to the small-scale presence in this area, their significance is still small.
+ + + - Fungi cause significant damage. Multi-year infections can lead to the dieback of Austrian pine.

Two-year research in the area of Avala recorded the presence of 18 species of fungi on Austrian pine. Out of that number, 6 fungi were found on needles, 5 on needles and seeds, 2 on roots and stem bases, 1 on cones, 3 on trunks and branches, and 1 species in vascular bundles.

Of all the species, the most extensive damage is caused by *Sphaeropsis sapinea* and species of the *Armillaria* genus. The latter group includes the following species: *Ceratocystis spp.*, *Cyclaneusma niveum*, *Heterobasidion annosum*, *Lophodermium pinastri*, *Lophodermium seditiosum*, and *Phellinus pini*. The other 10 species have very little significance and most often occur as saprophytes.

Species of the *Armillaria* genus are the most common causes of dieback and decay in coniferous and broadleaved cultures of all ages. Coniferous cultures established on the sites of broadleaved species are particularly affected, especially if the sites have not been previously destumped. This fungus lives on stumps as a saprophyte, and then as a parasite attacks weakened coniferous trees, or develops as a weak parasite on broadleaved trees.

Exploring the species diversity of the *Armillaria* genus Keča et al. (2006) found the following five species in Serbia and Montenegro: *A. mellea*, *A. ostoyae*, *A.*

*cepistipes*, *A. gallica*, and *A. tabescens*. The most common species *is A. gallica* and *A. tabescens* the rarest.

*S. sapinea* colonizes young shoots and a severe attack usually leaves all shoots from the current growing season necrotic. A severe attack of this fungus was recorded in most compartments in the area of Avala. Perennial infections cause physiological weakness of trees, which leads to the dieback and eventually to the death of deformed trees.

Applying artificial inoculations of *Pinus nigra* seedlings, Milijašević, T. (2000) found that *S. sapinea* acts as a parasite. Uninjured shoots may be infected from April to August, although the symptoms of the disease are more difficult to notice in the summer months. This research indicates that the fungus can cause dieback of whole plants when it colonizes both the root collar and the root and forms fruiting bodies on them.

In our conditions, *C. niveum* has two infection periods. The first period is from late April to late August, and the second from mid-October to early December. Besides this species, *C. minor*, which occurs on Scots pine, is another species common in our country. Some authors consider species of this genus primary parasites, while some cite them as weak parasites or saprophytes. By artificial inoculations of two-year-old Scots pine seedlings, Karadžić, D. (1980) found that the infection is realized through stomata and then spreads in the mesophile. The first symptoms are noticed after three months, and and the apothecia begin to form four months after the inoculation. According to this research, *C. minor* acts as a parasite under controlled conditions.

According to Lazarev, V. (1980, 2004), the biology of *Lophodermium* species is characterized by 4 phases of development: the phase of infection, the phase of latency, the phase of transition to the saprophyting nutrition, and the phase of reproduction. The phase of infection is limited to the period of a mass release of ascospores, and penetration is possible through the cuticle or the stoma. The latency phase lasts 20-30 days and sometimes may be skipped. The phase of transition to the saprophyting nutrition is characterized by the formation of lush mycelium that spreads along the needle axis. It also spreads in the radial direction by filling resin ducts. Chlorotic spots become dark red, and the formation of pycnidia begins. At the end of this phase, the entire needle is necrotic and turns dark red. In the last phase, apothecia are formed. When mature, they open with a longitudinal crack and release ascospores. Transverse black or brown lines are also formed at this stage. Studying the degree of aggressiveness of *Lophodermium* species, Lazarev, V. (1981, 2004) found L. *pinastri* on older primary needles of seedlings in forest nurseries and stands, older secondary needles (2 and 3 years), and secondary needles attached to dead branches. *L. seditiosum* was found on younger primary needles of seedlings in forest nurseries, secondary needles of various ages, and most often on needles younger than one year in forest nurseries, cultures, and stands.

In the research of parasitic and saprophytic fungi in Austrian pine cultures in Serbia, Karadžić, D., Milijašević, T. (2008) found 41 species of fungi on Austrian pine, 45 species on Scots pine, while 24 species were found on both Austrian pine and Scots pine. *Mycosphaerella pini, Sphaeropsis sapinea, Cenangium feruginosum, Gremmeniella abietina,* and *Armillaria spp* cause the most extensive damage and dieback of Austrian pine trees.

In the study of the pathogenic mycoflora of *Pinus* species, Karadžić, D., (1987) states that *Scirrhia pini, Sphaeropsis sapinea, Cenangium feruginosum,* and *Gremmeniella abietina* pose a practical problem in the establishment and maintenance of Austrian pine cultures, and perennial infections can lead to the dieback of trees. *Heterobasidion annosum* is also stated as a fungus that poses a practical problem in the establishment and maintenance of Austrian pine cultures and causes dieback.

*H. annosum* occurs less frequently on Austrian pine. In the area of Avala, it was observed on the lateral veins of one fallen tree in compartment 23 (section d). Another two species that can cause great damage to Austrian pine (*Phellinus pini* and *Ceratocystis spp.*) were found on individual (felled) trees, but have had no economic significance so far. *P. pini* occurs on old pine trees and considering Austrian pine, it attacks only trees over 100 years of age. The resistance of younger pines is explained by their greater ability to secrete resin. The resin quickly seals the injured places on the bark and thus prevents infections because the penetration of mycelium into the tree is prevented. The decaying process in the vertical direction progresses about 15 cm per year. The lower and central parts are most affected.

## 4. CONCLUSIONS

Based on two years of research, the following conclusions can be drawn:

- In the area of Avala, Austrian pine recorded the presence of 18 species of fungi. Out of that number, 6 fungi were found on needles, 5 on needles and seeds, 2 on roots and stem bases, 1 on cones, 3 on trunks, and branches and 1 species in vascular bundles

- Of all species, *Sphaeropsis sapinea* and species of the *Armillaria* genus cause the greatest damage. A severe attack of S. *sapinea* was recorded in most compartments in the area of Avala. Young needles of almost all shoots were infected. Species of the *Armillaria* genus were found on most decaying and dead Austrian pine trees. Austrian pine trees with common infections of *S. sapinea*, *C. niveum* and *L. seditiosum* are particularly endangered. These trees have a significantly decreased photosynthetic rate.

- Of other species, the presence of *Phellinus pini* should be noted. This species causes centre rot of old pine trees, with the lower and central part of the tree being affected most. In the area of Avala, it was found on several felled trees but has had no economic significance so far. However, with the increasing age of trees, greater damage can be expected.

- *H. annosum* was recorded in the area of Avala on the lateral veins of one fallen tree in compartment 23 (section d). This species poses practical problems in the establishment and maintenance of Scots pine cultures but it is not of great significance for Austrian pine.

- Species that occur on cones and seeds (*A. alternata, B. cinerea, E. purpurascens, F. moniliforme*, and *T. roseum*) can cause significant damage only if the cones and seeds are improperly collected and transported, or improperly stored.

- Other species develop mainly as saprophytes or rarely as facultative parasites. They are not significant as pathogens of Austrian pine.

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## NAJVAŽNIJE MIKOZE CRNOG BORA (*PINUS NIGRA* ARNOLD.) NA PODRUČJU AVALE

*Zlatan RADULOVIĆ, Aleksandar LUČIĆ, Katarina MLADENOVIĆ, Ivan MILENKOVIĆ*

### Rezime

Istraživanja najvažnijih mikoza crnog bora na području Avale vršena su tokom 2018. i 2019 godine u 5 odeljenja i 11 odseka. Konstatovano je prisustvo 18 vrsta gljiva. Na četinama je konstatovano prisustvo 6 gljiva, na četinama i semenu 5, na korenu i pridanku 2, na šišaricama 1, deblu i granama 3 i u sprovodnim sudovima 1 vrsta.

Od svih vrsta najveće štete pričinjavaju *Sphaeropsis sapinea* i vrste roda *Armillaria*. Jak napad *S. sapinea* zabeležen je u većini odeljenja na području Avale. Inficirane su mlade četine na skoro svim izbojcima. Vrste roda *Armillaria* konstatovane su na većini stabala u fazi sušenja, kao i na već osušenim stablima crnog bora. Na nekim stablima su konstatovane zajedničke infekcije gljivama *S. sapinea*, *C. niveum* i *L. seditiosum*. Ova stabla imaju znatno redukovan fotosintetski potencijal. *H. annosum* predstavlja praktičan problem u podizanju i održavanju kultura belog bora i nema većeg značaja za crni bor.

Od ostalih vrsta treba ukazati na prisustvo gljive *Phellinus pini.* Ova vrsta za sada nema ekonomski značaj. Međutim, sa starošću stabala mogu se očekivati i veće štete. Vrste koje se javljaju na šišaricama i semenu mogu izazvati značajnije štete samo ako se šišarice i seme nepravilno sakupljaju i transportuju, ili nepravilno skladište. Ostale vrste se razvijaju uglavnom kao saprofiti ili retko kao fakultativni paraziti. Nisu značajni kao uzročnici bolesti na crnom boru.

## THE MOST IMPORTANT MYCOSES OF AUSTRIAN PINE (*PINUS NIGRA* ARNOLD.) IN THE AVALA AREA

*Zlatan RADULOVIĆ, Aleksandar LUČIĆ, Katarina MLADENOVIĆ, Ivan MILENKOVIĆ*

### Summary

The research of the most important Austrian pine mycoses in the area of Avala was performed during 2018 and 2019 in 5 compartments and 11 sections. The presence of 18 species of fungi was determined. Out of that number, 6 fungi were found on needles, 5 on needles and seeds, 2 on roots and stem bases, 1 on cones, 3 on trunks and branches and 1 species in vascular bundles.

Of all the species, the greatest damage is caused by *Sphaeropsis sapinea* and species of the genus *Armillaria*. A severe attack of *S. sapinea* was recorded in most compartments in

the area of Avala. Young needles of almost all shoots were infected. Species of the *Armillaria* genus were found on most trees in the decaying phase, as well as on dead Austrian pine trees. Joint infections of *S. sapinea, C. niveum*, and *L. seditiosum* were found on some trees. These trees have a significantly decreased photosynthetic rate. *H. annosum* poses practical problems in the establishment and maintenance of Scots pine cultures but it is not of great significance for Austrian pine.

Other species whose presence should be noted include *Phellinus pini*. This species has had no economic significance so far. However, with the age of trees, greater damage can be expected. Species that occur on cones and seeds can cause significant damage only if the cones and seeds are improperly collected and transported, or improperly stored. Other species develop mainly as saprophytes or rarely as facultative parasites. They are not significant as pathogens of Austrian pine.

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# FOREST ECOSYSTEMS VITALITY MONITORING (ICP FORESTS, LEVEL I) WITH SPECIAL EMPHASIS TO THE AFFECTED PART OF THE SAMPLE TREES IN THE REPUBLIC OF SERBIA

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**Abstract**: *Trees condition on the sample plots of the ICP forests, Level I, is especially considered and monitored by the typically damaged and affected part of the tree on which it occurs. Due to the need to enter unique data for the measured parameters (visible damages), their codes are assigned for each damage. These are the results from Sample plots, Level I, based on the ICP methodology. The results are entered into a single database for all participating countries. Infested assimilation organs - leaves or needles are direct indicators of the condition of the trees. The most common damage to leaves is caused by miners, gnats, beetles, and insects that totally bite the leaves so parts of the leaves are completely missing (Lymantria dispar L.). The leaves are mined by Stigmellidae, Gracillariidae, Cynipidae forming galls; there are also damages from the early oak defoliators Geometridae and Tortricidae. Apart from defoliators, the most common are xylophagous insects (for example, bark beetles) as well as root pests.*

*The fungi that most commonly occur on the leaves are oak powdery mildew (Erysiphe alphitoides) and Rhytisma acerinum (which attacks species of the genus Acer). Other damages that occur are verticillium wilt (diseases of the conducting vessels), beech bark disease, then rot of the appendix, trunk, and branches. The paper presents the observed damage and diseases on the experimental plots of the ICP forests, Level I, in Serbia, according to the parts of the tree where they were discovered.*

**Keywords:** harmful insects, trunk, diseases, forest condition assessment, ICP sample plots

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# MONITORING VITALNOSTI ŠUMSKIH EKOSISTEMA (ICP ŠUME, NIVO I) SA POSEBNIM OSVRTOM NA OŠTEĆENI DEO STABLA U REPUBLICI SRBIJI

**Izvod:** *Kondiciono stanje drveća na oglednim parcelama ICP šume, Nivo 1 posebno razmatra i prati tipski oštećeni i zahvaćeni deo stabla na kojem se javlja. Zbog potrebe unošenja jedinstvenih podataka za izmerene parametre (vidljiva oštećenja), njihovi kodovi se dodeljuju za svako oštećenje. Ovo su rezultati sa oglednih površine prvog nivoa na osnovu ICP metodologije. Rezultati su uneti u jedinstvenu bazu podataka za sve države koje učestvuju. Napadnuti asimilacioni organi - list ili iglice direktni su pokazatelji kondicionog stanja drveća. Najčešće štete na lišću izazivaju mineri, galaši, savijači i insekti koji totalno izgrizaju lišće te potpuno odsustvuju delovi listova (Lymantria dispar L.). Lišće miniraju Stigmellidae, Gracillaridae; Cynipidae stvaraju gale; tu su zatim oštećenja od ranih hrastovih defolijatora Geometridae i Tortricidae. Pored defolijatora najzastupljeniji su ksilofagni insekti (na primer potkornjaci) kao i štetočine korena.*

*Gljive koja se najčešće javljaju na lišću su hrastova pepelnica (Erysiphe alphitoides) i Rhytisma acerinum (koja napada vrste roda Acer). Ostala oštećenja koja se javljaju su verticilioze (bolesti sprovodnih sudova), bolest kore bukve, zatim trulež pridanka, debla i grana.*

*U radu su prikazana oštećenja i bolesti na oglednim parcelama ICP šume Nivoa I u Srbiji, prema delovima stabla na kojima su otkrivena.*

**Ključne reči**: štetni insekti, deblo, bolesti, procena stanja šuma, ICP ogledne parcele

## 1. INTRODUCTION

The Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia – Directorate of Forests assigned the tasks of coordination and management of the programme ICP Forests to the Institute of Forestry – National Focal Centre of the Republic of Serbia. This paper aims to present the total survey analysis of **the** affected tree part and the results of last year's research, which is based on forest condition monitoring in the Republic of Serbia.

In this article, we focus on tree condition as measured by, affected tree part connected often with the degree of defoliation (needle loss), affecting the tree on sample plots in Serbia. We surveyed the regional distribution of tree health, with an extensive monitoring network, in Serbia, to answer the following questions:

(1) How large is the annual variation in defoliation between plots and within plots over years (i.e., plot×year× affected tree part interaction)?

(2) What is the relative contribution of affected tree part between the species to the variation and tree defoliation levels?

(3) How useful/sensitive are extensive tree health monitoring networks to reveal the impacts of widespread leaf/needle loss?

Country Serbia has its unique country code, number 67, based on the disposition of the countries participating in ICP programme. In 2003, after the study of the procedure of forest condition monitoring based on ICP methodology (Ferretti & Chiarucci, 2003), the training course was organised at the Institute of Forestry, for the experts selected to perform the crown condition assessment. In collaboration with

the Institute of Lowland Forestry and Environment, 103 sample plots in 16 x16 km grid were reconstructed and the crown condition of forest trees was assessed. In the area of Serbia (without Kosovo and Metohija) it was necessary to revise the old plots according to the Level I cooperative programme (Stefanović et al, 2003), as well as the control and harmonisation with the installed coordinate network at the level of Europe. NFC of Serbia also carried out the entry and application of the reconstructed sample plots in the GIS (Geographic Information System) Database (Nevenic, 2008). In 2004, it was concluded that the reconstructed 103 sample plots did not represent fully the status of vegetation cover in Serbia so that additional 20 sample plots were selected and installed on the area of central Serbia, and 7 new plots in Vojvodina. The total number of installed sample plots in the Republic of Serbia was then 130 sample plots. The Institute of Forestry, in collaboration with the Institute of Lowland Forestry and Environment, carries out the monitoring and assessment of the forest health status on the territory of Serbia. In 2004, the more in-depth monitoring of forest tree diseases and soil chemistry on additional 20 sample plots was realised by the Faculty of Forestry in Belgrade. The analysis of 106 samples of forest nutrition were analysed in the laboratories of the Institute of Forestry (43 samples) and the Faculty of Forestry (63 samples). The GIS database in NFC of Serbia was updated for the additional 20 new plots (Nevenic, 2009).

In 2020, the activities on forest condition monitoring were continued in Serbia on 130 sample plots.

## 2. METHODS AND CRITERIA

This research has been done according to the ICP Forests Methodology. In 2020, the activities on forest condition monitoring were continued in Serbia on 130 sample plots. A sample plot is spatially determined by a coordinate grid of sample plots. It is marked with a brightly colored metal stake driven in the center. The sample trees for crown condition assessment are selected systematically as a 4-point cluster. Oriented along with the main compass directions at a distance of 25 m from the grid point – stake, the 6 trees (24 sample trees per plot) nearest to the subplot center are selected as sample trees. The tree sample includes all tree species, provided the trees have a minimum height of 60 cm. The trees selected for assessment are classified according to crown canopy classes after Kraft (dominant, codominant, subdominant, sup-pressed, dying), but they must be without significant mechanical damage. The selected trees are permanently marked by numbers for future permanent assessment. The trees removed by management operations or for other reasons are replaced by the newly selected trees. If the stand is removed by clear-felling, the grid point should be kept till the establishment of the new stand. Within the national and transnational survey (Level I) crown condition is expressed by the classes of defoliation, discoloration, and combined damage classes (Seidling & Mues, 2005). Defoliation is assessed in 5% steps and it is grouped in 5 classes of unequal extent.

New is categoriation by affected tree part which is damaged by different factors in 2020. According to the part of the plant (tree) on which the damage appears on the following charts, the participation of the affected plant organs is given.

Leaves or needles with conifers, ie. the assimilation mass of the canopy itself is most massively endangered by various pathogens and insect pests of forest trees. The conclusion is that the leaf mass is the most endangered, but also the most sensitive part of the plant crucial for survival, the growth and the condition itself depends on it.

## 3. RESULTS

During this year, the defoliation of Norway spruce and black pine has remained quite constant, while the defoliation of Scots pine slightly increased compare with latest the years of the reporting period because the main damage on these species is mechanical damaging by humans on stem or natural branch clearing - natural branch dying from bottom up to top. Phytopatogens that endangered needles of coniferous are *Dothistroma pini*, or *Chrysomixa abietis* with this species.

Of all the trees assessed, 87% of the conifer, and approximately the same percentage of the broadleaves were not defoliated (leaves and needles). Only moderate defoliated (leaf or needle loss was more than 25%) on sample trees of black pine. Without defoliation (absent or bitten there were 91% in Scots pine, 94% in spruce, and 95.5% in fir, respectively.

Looking at the observed period from May to September, it can be concluded that the data for defoliation with conifers and deciduous trees were fairly balanced. With coniferous and deciduous trees condition in 2020 set aside as the most unfavorable, for branches of small diameters manifested by lower defoliation on unaffected trees. In conifers, the situation was slightly better, while the deciduous was similar. As defoliation is leaves concerned, the only real legitimacy is evident in the *strong* defoliation of conifers, however, and it is difficult to talk about the trend because of the very small number of trees affected by this category of damage (total number is 10 trees). In the observed period, *F.moesiaca* was the most resistant species; on the many sample plots, no signs (absent or bitten leaves) of the defoliation were detected, whereas the *weak* defoliation of the trees was identified. Oaks are the most susceptible to foliage loss, most notably sessile oak, with two-thirds of trees with *moderate* and *weak* leaves waste. The situation in the observed period was similar to the condition from the previous years, regarding *Q. cerris* and *Q. fraineto*. The *Slight* leaves waste of the coniferous trees was present on the spruce trees; a great number of trees were without the visible signs of this process. Fir is more vulnerable regarding decissation. Two-thirds of the observed trees of this species were with no defoliation at all, whereas the loss of the needles of the *weak* and *moderate*-intensity was identified on the other trees. The presence of the damage on the observed broadleaf trees is connected with the assessment of discoloration and defoliation. The parameters of this category and their values are close, i.e. they are approximately in the middle between the above-discussed percentages of these two processes. The phenology of the observed species, i.e. leaf rejection in the autumn, makes the broadleaves superior from this aspect. Beech was the most resistant species, these trees on all sample plots were without any damage. Spruce is the most vital conifer species, without any damage. It is followed by fir with 85.5% of trees without defoliation. During the 2020 droughts that caused the drying sessile oak forests in the mountain, regions assumed serious proportions; more and

approximately 20% of affected trees. As the main reason for the drying indicated a significant decrease in soil moisture content due to an increase in temperature and a decrease in rainfall. The incidence of increased temperature during the vegetation period and frequent dry vegetation periods were the cause of weakening these forests. Conditions formed by these micro-climate changes were the main movers and intensive local factors for gradation of plant pests (pest moths and damaging epidemics of oak powdery mildew) – just about the phenomenon of indirect impacts of climate change on forest extinction (Chiru & Chira 1998; Halmschlager 1998).

Despite the relatively small changes in foliage loss in the whole data, marked spatial and temporal variations in branches of different diameters existed during the study period. The endangered twigs in 2020 were highest in northern, central, and eastern Serbia. The highest endangered twigs values were found in the central-eastern part of the country. The endangered twigs of all sample trees was simmilar, highest in northern Vojvodina and scattered across the country. The highest values were found in the easternmost parts of Serbia in the observed period. The endangered twigs of the assessed trees seem to have intensified in 2020 in the easternmost parts of the country, as compared to a more diffuse pattern previously.

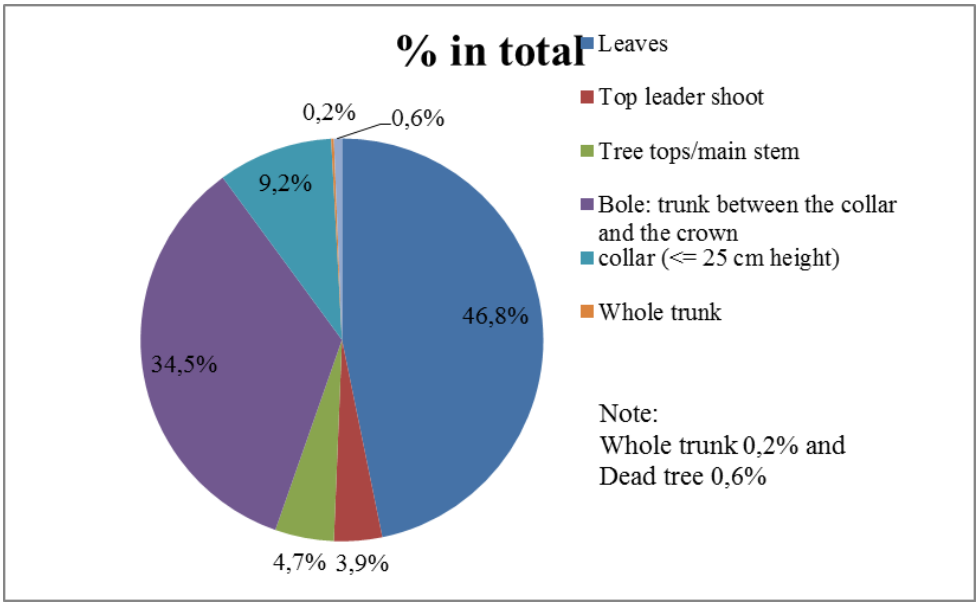


**Chart 1.** *Percentage of host plant parts damaged, presented from root to assimilation tissue*

Besides leaves and small (46, 8% ) branches, the most endangered tree part was the stem or main bole (trunk between the collar) and the crown tree part with mechanical or central decay as a reason are the most represented (34,5). After those, there are collar injuries (root or decay and mechanical wound- 9,2%). After that comes with 4,7% treetops (broken) and top leader shots (also refract on 3, 9).

The whole trunk is destroyed and almost dead with 0,2 % of the whole observed tree in the sample (Chart 1).

A dead tree is represented with 0,6 % in the whole number of trees examed.

**Picture 1**. *Laetiporus sulphureus,(Bull.) Murrill (1920), on a wild cherry, FMU Užice, wood-decay fungus*

**Picture 2.** *Cynipidae, Neuroterus Quercus baccarum L. on Turkey oak, FMU Boljevac, galls on leaves*

## 4. DISCUSSION

Forests with their sustainable management today present one of the many principal international and national policy issues. To be sustainable, forest management requires information on the factors that affect forest health per vitality, biodiversity, and ecosystem functioning status. To date, numerous studies have assessed the impact and the importance of shaping of defoliation has received renewed scientific attention, on ICP extensive level (Ferretti et al, 1999; Nevalainen et al, 2010). Tree species-specific effects are regulated by mechanisms allowing for resistance to defoliating. The short-term consequences of leaf or needle loss depend on species abilities to resist many factors, and to recover after, and on competitive interactions between species. Although the abundance of many species generally decreases during the process so some taxa may increase in number during the observed period or shortly after. The most common effects or occurrence of assimilation organs rejection must be evaluated in the wider context of global climate and habitat change (Nevenić et al, 2011) - not just pests and plant diseases (Picture 1. и 2.). Considering the predicted increase in defoliation frequency and intensity (UNECE, 2004), interdisciplinary research initiatives on this issue are needed urgently. Our results suggest that extensive monitoring networks can reveal useful information about the widespread outbreaks of pest organisms (insects and fungi) already in their increased phases, giving some time for management decisions (Edgar & Burk, 2006). In a changing climate, large-scale, regular monitoring of tree health, including abiotic and biotic causes, is more important than ever before. Biotic and abiotic - both kinds of factors in conjunction with climate and meteorological factors act on the root, collar, trunk, branches in the canopy (their drying), then twigs, and of course on assimilation tissue. Altogether, it causes a whole series of specific symptoms that affect the organs of trees. All of them appeared in 2020 in a certain percentage of all trees (Chart 2).

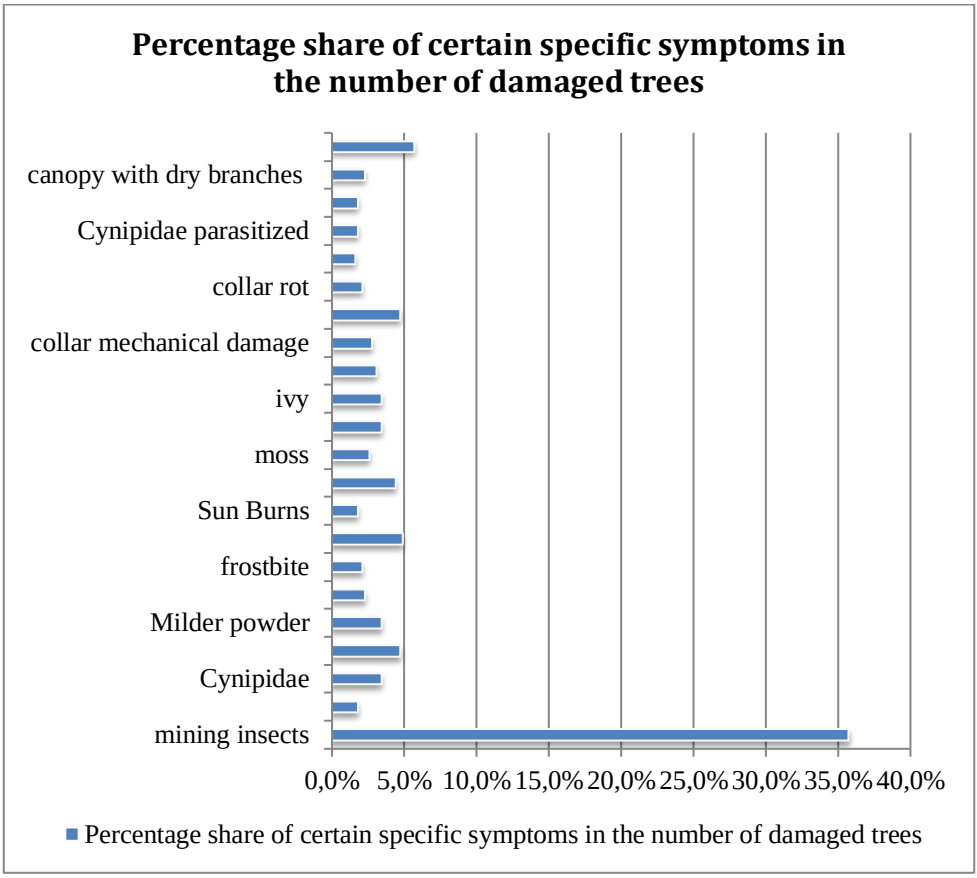


**Chart 2.** *Percentage of host plant parts damaged with obvious specific symptoms on which they occur*

## 5. CONCLUSION

The frequency of damaged different endangered tree part is thought to be the main driver of vegetation dynamics in Serbia and its temperate forests according to ICP extensive sampling. The decline of oak forests has been linked to the detrimental effects of recurrent droughts, but before of destroyed assimilation tissue due to various symptoms.

Fieldwork on data collection (observations and measurements), in the previous period, was carried out in the period June – September in the year 2020.

In deciduous forests, beech and hornbeam are proven to be the most resistant species, in a process of leaves lost than oaks. Sessile oak was the most endangered species among the broadleaved. Among the coniferous trees, spruce proved to be a resilient species, while the black pine trees were far the most vulnerable to these processes of all registered species on sample plots.

The presented study is a baseline for the monitoring of changes in forest conditions and connectivity of these results with other indicators of environmental parameters and trees affected parts. It will provide more specific information, and

making conclusions about the vitality of plants depending on environmental conditions. In the end, all comes to a final conclusion:

Leaf or needle loss is certainly are a widely underestimated ecological stress and selection forcefully exerted to forest ecosystems in Serbia. The other organs or the symptoms on them can not be ignored. Our observations have revealed several issues that should have priority in future research, such as:

1. *Environmental factors*. Variations of factors such as damage intensity, duration and return frequency, species-specific phenotypic plasticity, adaptive potential, and phylogenetic and physiological constraints must be experimentally identified concerning environmental events. This should lead to a concise classification of species and their organs according to their sensitivity with *exactly* environmental features linked to. Particular focus must be on vulnerable species and ecosystems because these will probably be the first to be seriously affected by the appearance of a recognized problem in progress.

2. *The continuity*. Long-term monitoring programs should be continued or developed since these are the only way for evaluating the impact of affected trees part as events on ecosystems. However, these programs should be coupled with integrative experimental and modeling approaches to enhance our understanding of complex plant organs drought and loss effects.

3. *Idioeclogical dimension*. The impact of affected trees part on ecosystem processes must be studied to better understand how it alters ecological functions and how these effects are influenced by species composition. All should help to define an indicator system for predicting drought sensitivity at the stand and forest levels.

3. *Clarifying the causal and consequential relationship*. Future research should focus on the simultaneous effects of different factors as causes, such as pests, forest management, pollution, and global warming. This is essential for identifying the most relevant factors that mediate the impact of damage as events on forest biodiversity.

4. *Prevention of gain losses in wood production*. The impact of strategies that are being proposed to mitigate the effects of leaf or needle loss, as other plant parts on trees on forest biodiversity should be rapidly evaluated, especially where the impact of the occurrence leads to yield reduction.

4. *Biodiversity*. The effects of defoliation events on forest biodiversity should be considered in both planning (e.g. tree species selection) and management (e.g. retention of deadwood).

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## FOREST ECOSYSTEMS VITALITY MONITORING (ICP FORESTS, LEVEL I) WITH SPECIAL EMPHASIS TO THE AFFECTED PART OF THE SAMPLE TREES IN THE REPUBLIC OF SERBIA

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### Summary

Forest Condition Monitoring, Level I, refers primarily to the monitoring and assessment of defoliation of tree crowns on the installed sample plots. The condition of forests was monitored in 2020, but with special emphasis on parts of the tree with damage, on about 130 sample plots in the Republic of Serbia, like every year.

The National Focus Center for Forest Monitoring in the Republic of Serbia, within The Institute of Forestry, actively participates in the international ICP Forest programme, improving its approaches in order to monitor synchronized work.

The paper presents damages as indicators of forest vitality, but they are presented through the affected parts of damaged trees. Their appearance shows a certain regularity and could be interpreted as a trend.

The degree of tree crown damage and entire trees on leaves and conifers were researched on about 130 permanent experimental plots in the Republic of Serbia in 2020. The

defoliation was assessed at 5%. The sample plots are systematically distributed in a 16x16 km or 4 x 4 km grid system.

The damage is presented as a percentage of the total damaged trees in Serbia. The results show which main factors cause damage to parts of the tree of deciduous and coniferous species. Within the study of the impact of regional climate change on forest communities, a better insight into the effects of damaged parts of trees, harmful trends, as well as the present forests' health state in Serbia will be provided.

## MONITORING VITALNOSTI ŠUMSKIH EKOSISTEMA (ICP ŠUME, NIVO I) SA POSEBNIM OSVRTOM NA OŠTEĆENI DEO STABLA U REPUBLICI SRBIJI

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### Rezime

Praćenje stanja šuma, Nivo I, odnosi se prvenstveno na praćenje i procenu defolijacije krošnji drveća na stalnim oglednim parcelama. Kao i svake godine u 2020. godini izvršen je monitoring stanja šuma, ali sa posebnim naglaskom na delove stabla sa oštećenjima, na oko 130 oglednih površina u Republici Srbiji.

Nacionalni fokusni centar za monitoring šuma u Republici Srbiji, u okviru Instituta za šumarstvo, aktivno učestvuje u međunarodnom programu ICP šume poboljšavajući svoje pristupe u cilju praćenja sinhronizovanog rada.

U radu su prikazane štete kao pokazatelji vitalnosti šuma, ali su one prikazane i kroz pogođene delove oštećenih stabala. Njihova pojava pokazuje određenu pravilnost i mogla bi se protumačiti kao trend.

Stepen oštećenja krošnji i celog drveća na lišću i četinama istražen je na oko 130 stalnih oglednih površina u Republici Srbiji u 2020. godini. Defolijacija je procenjena 5%. Ogledne površine su sistematično raspoređene u mrežni sistem 16x16 km ili 4 x 4 km.

Šteta je prikazana u procentima od ukupnog broj oštećenih stabala u Srbiji. Rezultati pokazuju koji glavni faktori izazivaju oštećenja na delovima stabla lišćarskih i četinarskih vrsta. U okviru proučavanja uticaja regionalnih klimatskih promena na šumske zajednice, pružiće se bolji uvid u efekte oštećenih delova stabala, štetni trendovi, kao i u trenutno zdravstveno stanje šuma u Srbiji.

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# THE HEALTH CONDITION OF TREE AND SHRUB SPECIES OF TOPČIDER PARK

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**Abstract:** *The research deals with the health condition of tree and shrub species of the natural resource known as Topčider Park assessed on the basis of the conducted visual assessment and determination of the degree of defoliation and discolouration. During the growing season 2018-2019, the health condition of plant species belonging to 50 different genera was determined. The following species were found to be healthy, without any visible damage: Cedrus atlantica, Corylus avelana, C. colurna, Juglans nigra, Maclura aurantiaca, Mahonia aquifolium, Prunus cerasifera, P. spinosa, Quercus rubra and Sambucus nigra. Trees with visible injuries included: Acer negundo, A. pseudoplatanus, Aesculus hippocastanum, Cryptomeria japonica, Fagus moesiaca, Gleditsia triacanthos, Morus alba, Platanus acerifolia, Populus alba. P. nigra, and P. tremula. Dying trees and dead trees were not recorded in Topčider Park. The plant species most threatened by the attack of pathogenic fungi and fungus-like organisms were the species of maple, horse chestnut, lime, poplar, and plane. The species of insects and mites here present did not significantly affect the health status of the investigated plant species.*

**Keywords**: visual assessment, defoliation, discolouration, Belgrade, Serbia

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# ZDRAVSTVENO STANJE DRVENASTIH I ŽBUNASTIH VRSTA TOPČIDERSKOG PARKA

**Izvod:** *Tokom istraživanja izvršena je procena zdravstvenog stanja drvenastih i žbunastih vrsta prirodnog dobra Topčiderski park na osnovu utvrđene vizuelne ocene, stepena defolijacije i dekolorizacije. Tokom vegetacijskog perioda 2018-2019 utvrđeno je zdravstveno stanje biljnih vrsta iz 50 rodova. Vrste koje su okarakterisane kao zdrave, bez vidljivih oštećenja su: Cedrus atlantica, Corylus avelana, C. colurna, Juglans nigra, Maclura aurantiaca, Mahonia aquifolium, Prunus cerasifera, P. spinosa, Quercus rubra i Sambucus nigra. Stabla sa izraženim povredama su: Acer negundo, A. pseudoplatanus, Aesculus hippocastanum, Cryptomeria japonica, Fagus moesiaca, Gleditsia triacanthos, Morus alba, Platanus acerifolia, Populus alba. P. nigra, P. tremula. Stabla u odumiranju i potpuno mrtva stabla nisu zabeležena u parku Topčider. Najugroženije biljne vrste od napada patogenih gljiva i gljivama sličnih organizama su vrste javora, divlji kesten, vrste lipa, topola i platan. Prisutne vrste insekata i grinja nisu u značajnijoj meri uticale na zdravstveno stanje istraživanih biljnih vrsta.*

**Ključne reči:** vizuelna ocena, defolijacija, dekolorizacija, Beograd, Srbija

## 1. INTRODUCTION

By the Law on Nature Protection, Topčider Park was declared a natural monument of the third category of protection in 2015 (Official Gazette of RS, No. 36/09, 88/10, 91/10). The area occupied by the park is excluded from the Special Forest Management Plan and represents a special cultural and historical entity of the City of Belgrade (Official Gazette of the SRS No. 47/87). Topčider Park has great biological value due to its diversity and age of its plant material. The plant diversity is represented by about fifty broadleaved, about twenty coniferous, and about forty shrub species, with some trees dating back to the 19th century.

Due to the changing environmental conditions in park ecosystems, tree and shrub species are at a permanently high health risk. It is necessary to assess the vitality of park species and determine biotic and abiotic factors that directly or indirectly threaten their condition so that optimal preventive action can be taken and adequate and timely care and protection measures applied.

Besides the harmful effects of phytopathogenic fungi, insects, and mites, park dendro-material is also exposed to the adverse effects of anthropogenic factors that result in numerous mechanical injuries and thus deteriorate the general health condition and decrease the ornamental value of plants. The joint action of biotic and abiotic factors leads to premature defoliation, discolouration, and finally desiccation. Therefore, the crown condition can be used to assess the tree condition as it represents a valid measure for the evaluation of the overall tree health state. Early detection, diagnosis, and assessment of the situation in the field are necessary preconditions for the successful control of diseases and pests and rehabilitation of hazardous trees in order to provide public safety in parks.

Having considered the importance of Topčider Park, the factors affecting the trees in the park, as well as the extremely negative effect of biotic factors on the health of trees, the study was aimed to assess the general health of trees in this park,

assess the vitality of some tree and shrub species in the park, and determine the sensitive and resistant species that need to be paid attention to when managing this park.

## 2. MATERIAL AND METHOD

The inspection and assessment of the health condition of tree and shrub species of Topčider Park were performed four times in two growing seasons (2018 and 2019). During the field visits, the health of the most important plant species was visually assessed and this visual assessment was used as an indicator of their condition and influence of biotic and abiotic factors expressed through the following scale: 5 – a healthy tree (without visible symptoms of damage to foliage, trunk, and branches); 4 – a slightly injured tree (occasional damage to foliage, trunk, and branches, a small percentage of dead branches); 3 – a severely injured tree (damage to foliage, trunk, and branches, dieback, decaying trunk and/or branches; rehabilitation possible); 2 – a dying tree (significantly reduced leaf surface area, advanced trunk and branch decay; safety hazard); 1 – a dead tree (Mladenović et al. 2016). The crown condition was observed through different classes of crown volume loss and discolouration of assimilation organs. The assessment of defoliation was performed in July. It was assessed by the following five classes: 0 – no defoliation (0 – 10%); 1 – slight defoliation (>10 – 25%); 2 – moderate defoliation (> 25 – 60%); 3 – severe defoliation (> 60 – <100%); 4 – dead trees (100%) (Anonymus 2006, 2010). Discolouration was assessed in August and presented in four categories: 0 - no discolouration (0 – 10%); 1 – slight discolouration (> 10 – 25%); 2 – moderate discolouration (> 25 – 60%); 3 – severe discolouration (> 60 – <100%) (Anonymus 2006, 2010). Young trees were excluded from the assessment.

In order to determine potential risks, plant material was collected and processed in the laboratory applying standard methods (Jung 2009. Jung et al. 1996, 2000; Milenković 2015; Krantz & Walter 2009, Evans & Browning 1955). Biotic agents of damage were determined using adequate keys for different groups of agents of plant diseases and pests (Agrios 2005; Alexopoulos et al.1996; Barnett and Hunter 1998; Breitenbach and Kränzlin 1986; Černy 1989; Davidson et al. 1938; Gilbertson 1979; Hagara 2012; Jung 2009; Jung et al. 1996, 2000; Karadžić 2010; Karadžić et al., 2014; Karadžić and Milenković 2014, 2015; Milenković 2015; Murrill 1903, 1908; Overholts 1953; Pegler and Waterston 1968; Ryvarden and Johansen 1980; Stalpers 1978; Wagner and Fischer 2002; Amrine et al. 2003; Baker at al. 1996; Nalepa 1910; Petanović 1988; Baker & Tuttle 1994; Mitrofanov at al., 1987; Migeon and Dorkeld 2020; Alford 1995; Johnson and Lyon 1991; Maceljski 1986, 2002; Mihajlović 2008; Petrović-Obradović 2003; Tanasijević and Simova-Tošić 1987; Strous & Winter 2000; Vacante 2015).

## 3. RESEARCH RESULTS AND DISCUSSION

The condition of the examined tree and shrub species in Topčider Park was assessed on the basis of a visual inspection (Table 1).

**Table 1.** *Visual assessment of tree and shrub species in Topčder Park*

| Plant species | Health condition | Defoliation score | Discolouration score |
|---|---|---|---|
| *Abies alba* | 4.9 | 0 | 0 |
| *Acer campestre* | 4.3 | 0 | 0.5 |
| *Acer ginnala* | 4.0 | 0.0 | 1.5 |
| *Acer negundo* | 3.4 | 1.5 | 3.1 |
| *Acer platanoides* | 5.0 | 0.0 | 0.0 |
| *Acer pseudoplatanus* | 3.9 | 0.5 | 1.2 |
| *Acer tataricum* | 4.0 | 0.0 | 1.3 |
| *Aesculus hippocastanum* | 3.4 | 2.3 | 2.2 |
| *Alnus glutinosa* | 4.1 | 1.5 | 1.0 |
| *Betula verrucosa* | 4.2 | 1.0 | 1.0 |
| *Buxus sempervirens* | 4.1 | 1.8 | 1.6 |
| Carpinus betulus | 4.1 | 1.5 | 1.0 |
| *Catalpa bignonioides* | 4.4 | 1.0 | 1.0 |
| *Cedrus atlantica* | 5.0 | 0.0 | 0.0 |
| *Celtis australis* | 4.5 | 1.5 | 1.5 |
| *Cercis siliquastrum* | 4.0 | 0.0 | 0.0 |
| *Chamaecyparis lawsoniana* | 4.2 | 0.0 | 0.0 |
| *Cornus alba* | 4.5 | 0.0 | 0.0 |
| *Corylus avelana* | 5.0 | 0.0 | 0.0 |
| *Corylus colurna* | 5.0 | 0.0 | 0.0 |
| *Cryptomeria japonica* | 3.8 | 1.5 | 1.5 |
| *Euonymus europaeus* | 4.1 | 1.5 | 1.0 |
| *Fagus moesiaca* | 3.9 | 1.2 | 1.5 |
| *Forsythia* spp. | 4.6 | 0.0 | 0.0 |
| *Fraxinus angustifolia* | 4.4 | 1.0 | 0.5 |
| *Fraxinus excelsior* | 4.1 | 1.0 | 0.5 |
| *Fraxinus ornus* | 4.0 | 1.0 | 0.5 |
| *Gleditsia triacanthos* | 3.4 | 2.0 | 1.0 |
| *Hybiscus syriacus* | 4.8 | 0.0 | 0.0 |
| *Ilex aquifolium* | 4.5 | 0.0 | 0.0 |
| *Juglans nigra* | 5.0 | 0.0 | 0.0 |
| Juglans regia | 4.0 | 1.0 | 1.0 |
| *Juniperus virginian* | 4.4 | 0.0 | 0.0 |
| *Kerria japonica* | 4.1 | 0.0 | 0.0 |
| *Ligustrum* spp. | 4.6 | 0.0 | 0.0 |
| *Lonicera x purpusii* | 4.9 | 0.0 | 0.0 |
| *Maclura aurantiaca* | 5.0 | 0.0 | 0.0 |
| *Mahonia aquifolium* | 5.0 | 0.0 | 0.0 |

| Plant species | Health condition | Defoliation score | Discolouration score |
|---|---|---|---|
| *Morus alba* | 3.9 | 1.5 | 1.0 |
| *Picea abies* | 4.0 | 1.2 | 1.5 |
| *Picea omorika* | 4.0 | 1.0 | 1.5 |
| *Picea pungens* | 4.0 | 1.1 | 1.5 |
| *Pinus nigra* | 4.4 | 1.3 | 1.0 |
| *Pinus pinaster* | 4.6 | 1.0 | 0.0 |
| *Pinus silvestirs* | 4.7 | 1.0 | 0.0 |
| *Pinus strobus* | 4.0 | 1.4 | 1.2 |
| *Pinus wallichiana* | 4.3 | 1.1 | 1.0 |
| *Platanus acerifolia* | 3.9 | 1.9 | 3.2 |
| *Platanus orientalis* | 4.0 | 1.4 | 2.0 |
| Populus alba | 3.7 | 2.2 | 2.3 |
| *Populus nigra* | 3.9 | 2.6 | 2.1 |
| *Populus tremula* | 3.9 | 2.5 | 2.3 |
| *Prunus cerasifera* | 5.0 | 0.0 | 0.0 |
| *Prunus spinosa* | 5.0 | 0.0 | 0.0 |
| *Pseudotsuga taxifolia* | 4.9 | 1.0 | 0.0 |
| *Pyrus piraster* | 4.0 | 1.1 | 1.3 |
| *Quercus rubra* | 5.0 | 0.0 | 0.0 |
| *Quercus cerris* | 4.0 | 1.3 | 1.0 |
| Quercus robur | 4.2 | 2.1 | 1.2 |
| *Robinia pseudoacacia* | 4.5 | 1.1 | 1.3 |
| *Rosa canina* | 4.8 | 1.3 | 0.0 |
| *Salix* spp. | 4.1 | 1.2 | 1.0 |
| *Sambucus nigra* | 5.0 | 0.0 | 0.0 |
| *Sorbus acuparia* | 4.6 | 1.1 | 1.2 |
| *Syringa vulgaris* | 4.1 | 2.0 | 1.0 |
| *Tamarix spp.* | 4.5 | 0.0 | 0.0 |
| *Taxus baccata* | 4.9 | 0.0 | 0.0 |
| *Thuja occidentalis* | 4.0 | 1.1 | 2.1 |
| *Thuja orientalis* | 4.3 | 1.2 | 1.0 |
| **Tilia argentea** | 4.0 | 1.3 | 0.0 |
| *Tilia cordata* | 4.0 | 1.2 | 1.0 |
| *Tilia grandifolia* | 4.0 | 1.0 | 1.1 |
| *Ulmus* spp. | 4.1 | 1.2 | 1.5 |
| *Viburnum opulus* | 4.0 | 0.0 | 0.0 |
| **average** | **4.3** | **0.9** | **0.8** |

The average health score of fir trees was 4.9. Mechanical damage was found on one of the inspected trees, while needle loss and discolouration of conifers were not determined. The following trees of the *Acer* genus were examined: field maple, box elder, sycamore maple, Norway maple, Tartar maple, and an Amur maple tree. Powdery mildew, *Uncinula aceris* Sacc., (Figure 1), was recorded on sycamore maple, as well as cicada of *Metcalfa pruinosa* (Say, 1830), mistletoe (*Viscum album* subsp. *album* L.) and carpophorec of the wood-decaying *Schizophyllum commune* Fries (1815). Top-killed trees that need to be pruned were also registered. The health condition was scored 3.9, with younger trees being in better condition. Defoliation ranged from none to slight and discolouration from slight to moderate. Field maple trees had decaying trunks, dying-back trees, and dead branches, while several trees recorded the carpophores of *Ganoderma adspersum* (Schulzer) Donk 1969. The trunks of damaged trees had carpophores of the wood-decaying *S. commune*, mechanical damage to the trunk and branches, and dieback of shoots. The average health condition score of field maple trees was 4.3, while defoliation and discolouration were none to slight. The significant presence of leaf powdery mildew was noted on box elder trees, as well as extensive mechanical damage and decay of the stem base and trunk. The average health condition score was 3.4 with severe discolouration and slight to moderate defoliation. Norway maple trees were in good health condition and scored 5.0 with only slight defoliation. Tartar maple and Amur maple trees were rated 4.0 with a slight presence of discolouration. Horse chestnut trees, one of which is a red horse chestnut tree, had frost cracks and mechanical damage to the trunks that were adequately treated. The decay of branches and higher tree parts and trunks was determined. Carpophores of wood-decaying *G. adspersum* were found on some trees and *Phytophthora* spp. were present in the stem base of some trees. *S. commune* was also observed, as well as the symptoms of chestnut leaf blotch caused by *Guignardia aesculi* (Peck) V.B. Stewart, and *Cameraria ochridella* Deschka & Dimic, 1986, the horse-chestnut leafminer. The average health score was 3.4, with slight to moderate discolouration and slight to moderate defoliation. Black alder trees had signs of decay at the site of broken branches, mechanical damage to the stem base, and damage caused by *Acalitus brevitarsus* (Fockeu, 1890,) the eriophyid alder mite, while the carpophores of *G. adspersum* could be seen on several trees in the stem base and lower parts of the trunk (Figure 1). The presence of *Phytophthora* spp. was observed on young alder trees. The mean health score was 4.1, with slight discolouration and defoliation present. Three birch trees had dead branches and mechanical damage at the stem base. The mean health score is 4.2 with slight defoliation and discolouration. The presence of the invasive pest *Cydalima perspectalis* (Walker, 1859) with low intensity of the attack was determined on boxwood shrubs. The health was assessed at 4.1. Hornbeam trees had dying branches, dieback as well as trunk cankers and leakage of exudates. The presence of *Phytophthora* spp. was noted, while several trees had *G. adspersum* carpophores. Mechanical damage to the trunk was also observed and adequately treated. The average health was rated 4.1. Defoliation ranged from slight to moderate, and discolouration was slight. Some trees of common catalpa showed signs of mechanical damage and some dying branches were noted. The average score was 4.4 with slight defoliation and discolouration. The inspected Atlas cedar trees received the highest score and had no defoliation and discolouration. The examined

nettle trees were scored 4.5 with slight defoliation and discolouration. Some cryptomeria trees were top-killed or had individual dead branches. The average score of the health condition was 3.8, while defoliation and discolouration ranged to moderate. The examined Moesian beech trees had mechanical damage of the bark, as well as necrosis with exudate leakage. The presence of *Inonotus hispidus* (Bull.) P. Karst., (1880), *Meripilus giganteus* (Pers.) Karst. (1882), *G. adspersum* and *Phytophthora* spp. was observed, while one tree was without injuries and in good health condition. The average score of the health condition was 3.9, while defoliation and discolouration ranged from not being recorded on one tree to moderate. On individual ash trees, mechanical damage to the trunk was noted and treated. There were individual dead branches with carpophores of white-rot causing *I. hispidus*. *Aceria fraxinivora* (Nalepa, 1909), a gall mite of ash flower clusters was also present. There were young trees with the symptoms of dieback and dying branches caused by *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz & Hosoya (Figure 1). Young ash trees were damaged at the stem base during manipulation. Their health score ranged from 4.0 to 4.4. Defoliation was slight and discolouration was none to slight. Some of the inspected honey locust trees had symptoms of decay and fruiting bodies of wood-decaying fungi. Repairs were put in hand and dead parts were removed. Carpophores of the wood-decaying fungus *Laetiporus sulphureus* (Bull.) Murrill, 1920 were recorded. The average score was 3.4 with moderate to slight defoliation and slight discolouration. All examined osage orange trees were received the highest score with no defoliation and discolouration present. The presence of *I. hispidus*, the agent of yellow-white trunk rot, was observed on white mulberry, and this group of trees was given an average health score of 3.9. The survey included trees of the *Picea* genus: Serbian spruce, blue spruce, and Norway spruce. The presence of the spruce bud-scale *Physokermes picea*e (Schrank, 1801), mechanical damage, and dying of the lower branches were noted on Serbian spruce and Norway spruce. The average health score was 4.0 with slight defoliation and slight to moderate discolouration of needles, especially in the lower parts of the crown. The examined Austrian and Scots pine trees showed symptoms of the anthracnose of shoots caused by *Sphaeropsis sapinea* Dyko et Sutton, as well as fungi that cause redness and shedding of pine needles (*Lophodermium pinastri* (Schrad) Chev. and *L. seditiosum* Minter, Staley & Millar). The average health condition of Austrian pine was assessed 4.4 and Scots pine 4.7 with a negligible to slight presence of defoliation and discolouration. The examination also included London plane and Oriental plane trees with various mechanical damage to the stem base, dying of individual branches as well as symptoms of scorch along the leaf veins caused by *Apiognomonia veneta* (Sacc. & Speg.) Höhn., (1920). A few trees had *G. adspersum* carpophores (Figure 1) at the stem base, and one tree was severely endangered by the presence of this fungus. Several trees were infected with the wood-decaying fungus *Perenniporia fraxinea* (Bull.) Ryvarden (1978) (Figure 1). The presence of the sycamore lace bug *Corythucha ciliata* (Say, 1832) and the mottled plane moth *Phyllonorycter platani* (Staudinger, 1870) was recorded on almost all examined trees. The average health score for the examined plane trees was 3.9/4.0, the defoliation ranged from slight to moderate, while the discolouration was around the moderate value and was mainly caused by the above organisms. The survey included trees of the *Populus* genus: aspen, white poplar, and black poplar, where some trees

were affected by the agent of white rot of the heartwood at the stem base and the *P. fraxinea* rot in the central part of the root. There was also some mechanical damage so that the average score ranged from 3.7 for white poplar to 3.9 for aspen. Defoliation and discolouration were slight to moderate. The inspected cherry plum trees and blackthorn shrubs were rated 5.0 with no defoliation and discolouration. The survey included trees of the *Quercus* genus, most of which were pedunculate oak. They had mechanical damage inflicted to stronger roots, individual dead branches, rusty brown necrosis on the trunks, while leaves had symptoms of the oak powdery mildew. The occurrence of individual dying branches was observed on Turkey oak trees, as well as the presence of powdery mildew of *Microsphaera alphitoides* Grif. & Maubl on leaves (Figure 1). Health condition scores ranged from 4.0 in Turkey oak to 5.0 in red oak. Younger trees were in better physiological condition. Defoliation was slight to moderate, while discolouration, mainly caused by leaf powdery mildew, ranged around moderate to severe values. Regarding the inspected black locust trees, dying branches and mechanical injuries were noticed. A sporadic presence of the black locust miner *Phyllonorycter robiniella* (Clemens, 1859) was observed. The average health score was 4.5, and defoliation and discolouration were slight. The examined trees of *Salix* spp. had canker wounds with exudates and fruiting bodies of the wood-decaying fungus *Phellinus igniarius* (L.) Quél. (1886). The presence of mistletoe (*Viscum album* subsp. *Album* L.) was registered. The average health condition was assessed 4.1 with slight defoliation and discolouration. Taxodium trees received the highest health score of 5.0 with no defoliation and discolouration. The examined yew trees received 4.9 as a health assessment due to the presence of mechanical damage. Northern whitecedar and Oriental arborvitae trees, *Thuja occidentalis* and *T. orientalis*, were assessed 4.0 and 4.3, respectively, with the presence of mechanical damage and individual dead branches, as well as the presence of *Pestalotiopsis funerea* (Desm.) Steyaert. Defoliation and discolouration were slight to moderate. The assessment included trees of different *Tilia* species. There were individual dead branches and one tree was top-killed. The presence of *G. adspersum* was recorded at the stem base of some trees and the presence of *S. commune* on the branches and injured lime trunks. The presence of the following mite species was observed on the examined trees: *Phytoptus tetratrichus* (Nalepa, 1890), *Eriophyes tiliae* (Pagenstecher, 1857), *Eotetranychus tiliarium* (Hermann, 1804) and *Bryobia rubrioculus* (Scheuten, 1857). The presence of mistletoe (*Viscum album* subsp. *album* L.) was noted. The average health condition score was 4.0, with slight defoliation and moderate discolouration. The presence of *Tetraneura* (*Tetraneura*) *ulmi* (Linnaeus, 1758) and mechanical damage to the stem and stem base were determined on some examined trees of *Ulmus* spp. The average score of the health condition of the trees was 4.1, defoliation was slight and discolouration slight to moderate.

It is necessary to assess the health state and determine biotic and abiotic factors that directly or indirectly threaten the condition of tree and shrub species so that optimal preventive or remedial action can be taken and adequate and timely care and protection measures applied. Observing the overall assessment of the health status of the examined tree and shrub species, it can be noticed that the greatest damage to maple was caused by the action of *G. adspersum* and *S. commune*. Horse chestnut had the greatest damage inflicted by the attack of pathogenic organisms *G.*

*aesculi*, *Phytophthora* spp. (Figure 1), *S. commune* and insects *C. ohridella*. The greatest damage to alder was caused by the wood-decaying fungus *G. adspersum*. *Phytophthora* spp. and *G. adspersum* were present on elm trees. Beech trees were most endangered by *I. hispidus*, *M. giganteus*, *G. adspersum*, and *Phytophthora* spp. Plane trees were endangered by wood-decaying fungi, such as *P. fraxinea*, *G. adspersum* and *A. veneta*, the plane lace bug *C. ciliata* and the plane tree moth *P. platani*. The health condition of poplars was most endangered by *P. fraxinea*. Tilia species were most endangered by the action of the wood-decaying fungus *G. adspersum* as well as *S. commune*.

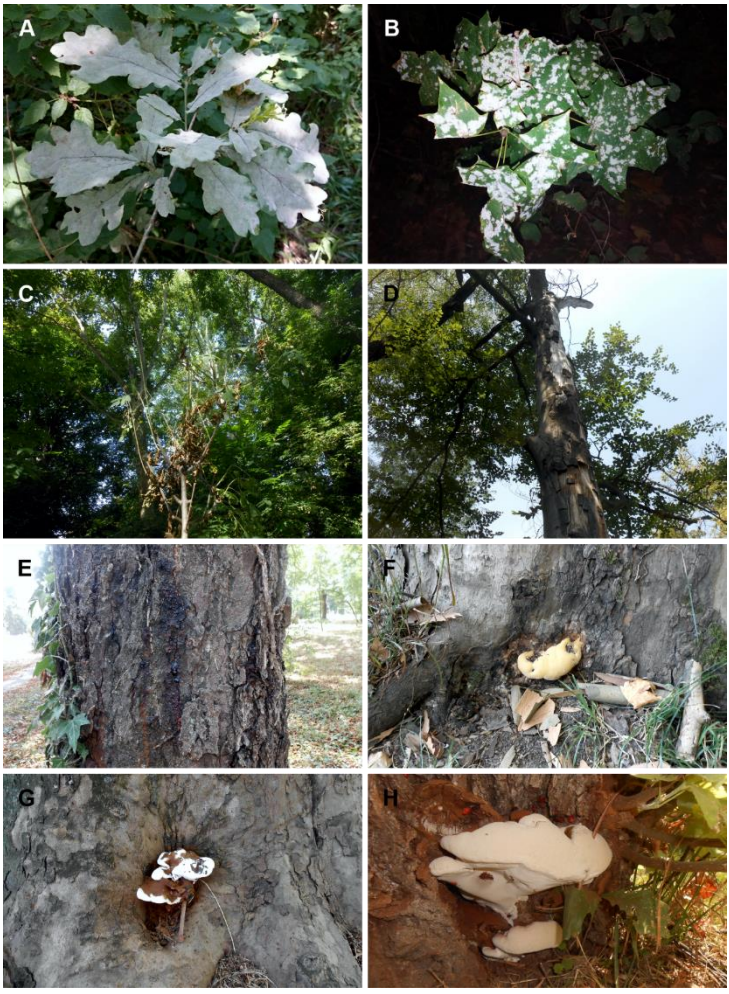


**Figure 1.** *Representative photos of the recorded damaging biotic factors on woody hosts in Topčider Park: A- Erysiphae (Microsphaera) alphitoides on the pedunculate oak leaves, B- Uncinula sp. on the sycamore maple leaves; C- Hymenoscyphus fraxineus on young common ash plants; D- a diedback beech tree affected with beech bark disease; E- Phytophthora spp. on the bark of a horse chestnut tree; F- Perenniporia fraxinea and G- Ganoderma adspersum at the stem base of a plane tree; H- Ganderma adspersum at the stem base of an alder tree.*

The species most endangered by the attack of pathogenic fungi and fungus-like organisms are maple, horse chestnut, lime, poplar, and plane.

The species of insects and mites here present did not significantly affect the development of the investigated plant species. Not only do the plane lace bug, wild chestnut miner, locust miner, sycamore moth miner, lime eriophyid mites, lime spider mite disturb the aesthetic appearance of plants, but they also increase discolouration and defoliation and physiologically weaken the plant over a long period. Combined with other adverse environmental factors, they can lead to plant dieback.

Extensive mechanical damage was identified on a large number of trees, both young and old. The damage needs to be repaired adequately to avoid direct direct penetration and further development of pathogenic fungi, especially the ones that cause wood decay.

## 4. CONCLUSIONS

Plant species with the best health and physiological condition in Topčider Park are silver fir, Norway maple, Atlas cedar, common hazel, Turkish hazel, common hibiscus, black walnut, privet, honeysuckle, osage orange, mahonia, maritime pine, Scots pine, cherry plum, blackthorn, Douglas fir, red oak, dog rose, black elder, rowan, and yew. The following species proved to be less resistant to biotic and abiotic damaging agents: box elder, horse chestnut, and honey locust. Most of the investigated trees are in the group of trees with small to pronounced injuries. Some trees of poplar, hornbeam, ash, willow, and chestnut are planned to be removed, while other trees need to be monitored in the future so that the safety of the park users would not be endangered.

Activities related to the detection, diagnosis, monitoring, control, and forecasting of the occurrence of the most significant harmful organisms in Topčider Park are needed to prevent the occurrence of new hotspots and prevent further spread and potential chain of damage.

Regarding the maintenance of Topčider Park, in order to preserve the long life and aesthetic value of the dendrofund and minimize the potential danger for the park users from fallen timber, broken branches, etc., it is necessary to apply integrated care and protection measures. The goals of the integrated approach, which includes the application of biological and chemical measures, are: an acceptable level of the harmful organism (control of the population size but not its extinction, with the determination of the threshold of the harmfulness of each harmful species); application of preventive measures (healthy planting material, adequate selection of plant species, removal of transitional hosts, etc.); determination and monitoring of the presence of harmful organisms; implementation of appropriate agro-technical and mechanical measures in eliminating the source of infection; use of biological control measures; responsible use of pesticides, etc.

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# THE HEALTH CONDITION OF TREE AND SHRUB SPECIES OF TOPČIDER PARK

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## Summary

The assessment of the health condition of tree and shrub species of the protected area Topčiderski Park was performed in two growing seasons (2018 and 2019) on the basis of the determined visual assessment, and the degree of defoliation and discolouration. Besides the vitality of park species, the study deals with the biotic (phytopathogenic fungi, insects, and mites) and abiotic factors that directly or indirectly threaten the health condition and ornamental value of the dendro-material.

The visual assessment of the health state of the most important plant species as an indicator of their condition and influence of biotic and abiotic factors was determined according to the scale: 5 – a healthy tree (without visible symptoms of damage to foliage, trunk, and branches); 4 – a slightly damaged tree (occasional damage to foliage, trunk, and branches, a small percentage of dead branches); 3 – a severely damaged tree (damage to foliage, trunk. and branches, dieback, decaying trunk and/or branches; rehabilitation possible); 2 – a dying tree (significantly reduced leaf surface area, advanced trunk and branch decay; safety hazard); 1 – a dead tree. The crown condition was observed through different classes of crown volume loss and discolouration of assimilation organs. The assessment of defoliation was performed in July assessed by the the following five classes: 0 – no defoliation (0 – 10%); 1 – slight defoliation (>10 – 25%); 2 – moderate defoliation (> 25 – 60%); 3 – severe defoliation (> 60 – <100%); 4 – dead trees (100%) (Anonymus 2006, 2010). Discolouration was assessed in August and presented in four categories: 0 – no discolouration (0 – 10%); 1 – slight discolouration (> 10 – 25%); 2 – moderate discolouration (> 25 – 60%); 3 – severe discolouration (> 60 – <100%) (Anonymus 2006, 2010). Young trees were excluded from the assessment.

In Topčider Park, the following species are in the best health and physiological condition: *Abies alba*, *Acer platanoides*, *Cedrus atlantica*, *Corylus avelana*, *C. colurna*, *Hybiscus syriacus*, *Juglans nigra*, *Ligustrum* spp., *Lonicera x purpusii*, *Maclura aurantiaca*, *Mahonia aquifolium*, *Pinus pinaster*, *P. silvestirs*, *Prunus cerasifera*, *P. spinosa*, *Pseudotsuga taxifolia*, *Quercus borealis*, *Rosa canina*, *Sambucus nigra*, *Sorbus acuparia* and *Taxus baccata*. The following species proved to be less resistant to biotic and abiotic damaging agents: *Acer negundo*, *Aesculus hippocastanum*, and *Gleditsia triacanthos*. Most of the investigated trees are in the group of trees with small to pronounced injuries. Some trees of poplar, hornbeam, ash, willow, and chestnut are planned to be removed, while other trees need to be monitored in the future so that the safety of the park users would not be endangered.

The species most endangered by the attack of pathogenic fungi and fungus-like organisms are maple, horse chestnut, lime, poplar, and plane. Observing the overall assessment of the health status of the examined tree and shrub species, it can be noticed that the greatest damage to *Acer* spp. was caused by the action of *G. adspersum* and *S. commune*. Horse chestnut *Aesculus hippocastanum* had the greatest damage inflicted by the attack of pathogenic organisms *G. aesculi*, *Phytophthora* spp. (Figure 1), *S. commune*, and insects *C. ohridella*. The greatest damage to common alder *Alnus glutinosa* was caused by the wood-decaying fungus *G. adspersum*. *Phytophthora* spp. and *G. adspersum* were present on elm trees. Balkan beech *Fagus moesiaca* was most endangered by *I. hispidus*, *M. giganteus*, *G. adspersum* and *Phytophthora* spp. Plane trees *Platanus* spp. were endangered by wood-

decaying fungi: *P. fraxinea, G. adspersum* and *A. veneta,* the plane lace bug *C. ciliate,* and the plane tree moth *P. platani*. The health condition of poplars *Populus* spp. was most endangered by *P. fraxinea*. *Tilia* spp. were most endangered by the action of wood-decaying fungus *G. adspersum* as well as *S. commune*. The species of insects and mites here present did not significantly affect the development of the investigated plant species. Not only do the plane lace bug, wild chestnut miner, locust miner, sycamore moth miner, lime eriophyd mites, and lime spider mite disturb the aesthetic appearance of plants, but they also increase discolouration and defoliation and physiologically weaken the plant over a long period. Combined with other adverse environmental factors, they can lead to plant dieback.

Extensive mechanical damage was identified on a large number of trees. This damage enables direct penetration and further development of pathogenic fungi, especially the ones that cause wood decay.

Regarding the maintenance of Topčider Park, in order to preserve the long life and aesthetic value of the dendrofund and minimize the potential danger for the park users from fallen timber, broken branches, etc., it is necessary to apply integrated care and protection measures.

## ZDRAVSTVENO STANJE DRVENASTIH I ŽBUNASTIH VRSTA TOPČIDERSKOG PARKA

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### Rezime

Procena zdravstvenog stanja drvenastih i žbunastih vrsta prirodnog dobra Topčiderski park je izvršena tokom dve vegetacijske sezone (2018. i 2019.) na osnovu utvrđene vizuelne ocene, stepena defolijacije i dekolorizacije. Pored vitalnosti parkovskih vrsta utvrđeni su biotski (fitopatogene gljive, insekati i grinje) i abiotski faktori, koji neposredno ili posredno ugrožavaju kondiciju i dekorativnost dendromaterijala.

Vizuelna ocena zdravstvenog stanja za najznačajnije biljne vrste kao pokazatelj kondicije i uticaja biotičkih i abiotičkih faktora utvrđena je prema skali: 5 – zdravo stablo (bez vidljivih simptoma oštećenja lisne mase, debla i grana); 4 – stablo sa manjim povredama (mestimična oštećenja lisne mase, debla i grana, prisustvo suvih grana u malom procentu); 3 – stablo sa izraženim povredama (prisutna oštećenja lisne mase, debla i grana, suhovrhost, trulež debla i/ili grana; moguća sanacija); 2 – stablo u odumiranju (znatno redukovana asimilaciona površina, uznapredovala trulež debla i grana; opasno po bezbednost); 1 – mrtvo stablo. Stanje kruna je posmatrano kroz različite klase gubitka zapremine krune i promene boje asimilacionih organa. Ocenjivanje defolijacije obavljeno je u julu i iskazano je u pet klasa: 0 - bez defolijacije (0 – 10%); 1 - slaba defolijacija (>10 – 25%); 2 - umerena defolijacija (>25 – 60%); 3 - jaka defolijacija (>60 – <100%); 4 - suvo stablo (100%). Utvrđivanje dekolorizacije izvršeno je tokom avgusta i prikazano je u četiri kategorije: 0 – bez dekolorizacije (0 – 10%); 1 - slaba dekolorizacija (>10 – 25%); 2 - srednja dekolorizacija (>25 – 60%); 3 - jaka dekolorizacija (>60 – <100%). Mlada stabla su izuzeta iz ocenjivanja.

U Topčiderskom parku najboljeg zdravstvenog stanja i fiziološke kondicije su sledeće vrste: *Abies alba, Acer platanoides, Cedrus atlantica, Corylus avelana, C. colurna, Hybiscus syriacus, Juglans nigra, Ligustrum* spp., *Lonicera x purpusii, Maclura aurantiaca, Mahonia aquifolium, Pinus pinaster, P. silvestirs, Prunus cerasifera, P. spinosa, Pseudotsuga taxifolia, Quercus borealis, Rosa canina, Sambucus nigra, Sorbus acuparia* i *Taxus baccata.* Manje otporne na biotička i abiotička oštećenja pokazala su se sledeće vrste: *Acer negundo, Aesculus hippocastanum* и *Gleditsia triacanthos.* Većina istraživanih stabala

su u grupi stabala sa manjim do stabala sa izraženim povredama. Pojedina stabla topole, graba, jasena, vrbe, kestena su predviđena za uklanjanje dok je ostala stabla potrebno pratiti u budućnosti kako bezbednost korisnika parka ne bi bila ugrožena.

Najugroženije biljne vrste od napada patogenih gljiva i gljivama sličnih organizama su vrste javora, divlji kesten, vrste lipa, topola i platan. Posmatrajući ukupnu ocenu zdravstvenog stanja ispitivanih drvenastih i žbunastih vrsta može se uočiti da su na javoru *Acer* spp. najveće štete zabeležene usled dejstva *G. adspersum* i *S. commune*. Na divljem kestenu *Aesculus hippocastanum*, najveće štete su uzrokovane usled napada patogenih organizama *G. aesculi*, *Phytophthora* spp. (Figure 1), *S. commune* kao i insekta *C. ohridella*. Na jovi *Alnus glutinosa* najveću štetu pričinjava gljiva truležnice *G. adspersum.* Na brestu *Ulmus* spp. prisutne su gljive *Phytophtora* spp. i *G. adspersum.* Bukvu *Fagus moesiaca* najviše ugrožavaju *I. hispidus, M. giganteus, G. adspersum i Phytophthora* spp. Platane *Platanus* spp. ugrožavaju gljive truležnice: *P. fraxinea, G. adspersum* kao i *A. veneta,* zatim prisustvo platanove mrežaste stenice *C. ciliata* i platanovog moljca minera *P. platani.* Zdravstveno stanje topola Populus spp. najviše ugrožava *P. fraxinea*. Vrste lipa *Tilia* spp. su najviše ugrožene dejstvom gljiva truležnica *G. adspersum* kao i *S. commune*. Prisutne vrste insekata i grinja nisu u značajnijoj meri uticale na razvoj istraživanih biljnih vrsta. Platanova mrežasta stenica, miner divnjeg kestena, bagremovog miner, platanov moljac miner, eriofide lipe, lipin paučinar pored toga sto narušavaju estetski izgled biljke utiču i na dekolorizaciju i defolijaciju, fizioloski slabe biljku što u dužem vremenskom periodu, udruženo sa ostalim nepovoljnim uticajima urbane sredine može dovesti do desikacije.

Utvrđena su brojna mehanička oštećenja na velikom broju stabala koje obezbedjuju direktan prodor i razvoj patogenih gljiva, posebno gljiva prouzrokovača truleži drveta.

Za održavanje parka Topčider, kako bi se očuvala dugovečnost i estetska vrednost dendrofonda a ujedno i minimizirala potencijalna opasnost za korisnike parka od izvala, lomova grana itd., neophodna je primena integralnih mera nege i zaštite.

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# THE VALUE OF BIOMASS ENERGY – THE CASE STUDY OF "CRNI VRH-DEŽEVSKI"IN THE GORNJEIBARSKO FOREST AREA

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**Abstract:** *Of all terrestrial ecosystems, forests are the most important carbon reservoirs. Therefore they deserve special care and protection. They are also an irreplaceable source of biomass for energy. Forest biomass has been used as a fuel since the earliest times, and since the late twentieth century, there has been a renewed interest in its use for the production of heat and electricity. Forest biomass has become interesting as a source of energy due to some of its characteristics, above all its availability and uniformity around the world, which implies that both developing and less developed countries can use biomass as a renewable source of energy. Furthermore, biomass fuel is considered to be $CO_2$ neutral. However, its use is not risk-free. The risks are mainly related to the sustainability of forest systems and their productivity. Therefore, the forestry profession must be extremely cautious in using forest biomass and follow the prescribed allowable cut.*

*This paper deals with the current state of biomass for energy, its estimates and properties as fuel. It studies the sustainability of biomass through the preservation of forest ecosystems and all multipurpose benefits of forests.*

**Keywords**: biomass, energy, allowable cut, volume, silviculture, estimation, heat power, renewable sources of energy

# ENERGETSKA VREDNOST BIOMASE NA PRIMERU GJ „CRNI VRH-DEŽEVSKI" U GORNJEIBARSKOM ŠUMSKOM PODRUČJU

**Izvod:** *Od sih kopnenih ekosistemima, šume su najvažniji rezervari skladišta ugljenika, pa samim tim zaslužuju posebnu negu i zaštitu. Shodno tome, oni su i nezamenljiv izvor biomase za energiju. Šumska biomasa je korišćena kao gorivo iz ranih vremena, a od kraja dvadesetog veka nadalje, došlo je do obnavljanja interesa za njegovu upotrebu za*

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*proizvodnju toplote i električne energije. Interesovanje šumske biomase kao izvora energije odnosi se na neke od njegovih karakteristika, kao što su relativna brojnost i ujednačenost širom sveta te tako i zemlje u razvoju i manje razvijene zemlje imaju pristup biomasi kao obnovljivom izvoru energije.Takođe se biomasa smatra kao neutralno gorivo u emisiji SO2. Ipak, njegova upotreba nije bez rizika, uglavnom vezana za održivost šumskih sistema i njihove proizvodnje, što šumarsku struku dovodi u poziciju da strogo mora voditi računa o pravilnom korišćenu biomase i poštovanju definisanog sečivog etata.*

*Ovaj rad razmatra stanje u oblasti biomase za energiju, njihovu procenu svojstava kao goriva,očuvanje trajnosti prirasta biomase kroz očuvanje šumskih ekosistema i svih pozitivnih funkcija šume kao opšte korisnih dobara.*

**Ključne reči:** biomasa, energija, etat, zapremina, uzgoj, procena, toplotna moć, obnovljivi izvori energije

## 1. INTRODUCTION

Energy has been obtained from forests for thousands of years. Forests have been one of the most important contributors to biomass production (The WBA Global Bioenergy Statistics Stockholm, 2017). Most of today's production of solid biomass for energy occurs in non-OECD countries (83.7% in 2015) where it is widely used for traditional heating and cooking. The traditional use of biomass is not efficient and it can have serious adverse effects on human health caused by combustion smoke (Hanna, R. et al, 2016). Excessive use of biomass is often associated with local deforestation and degradation of high forests into devastated forests, which consequently leads to soil erosion and endangerment of entire forest ecosystems. The modern use of biomass in the twenty-first century is characterized by cleaner and more efficient heating technologies.

The use of biomass is also associated with some controversy over the sustainability issues. In developed countries, the reason for the increasing interest in bioenergy lies in the necessity to pursue greenhouse gas mitigation policies. Wood biomass is a renewable source of energy which is considered to decrease the anthropogenic $CO_2$ emissions.

Due to the shrinkage of forest areas and the shortage of timber products, as well as the increasing inability to ensure forest and ecosystem sustainability, monitoring, estimation and regulation of forests have become a pressing need, all with the aim to determine the biomass volume, its increment within a given forest area or in a given period of time. This is important if we want to determine the allowable cut which will guarantee the sustainable growth of forest stands. In this sense, the forest inventory of the MU “Crni Vrh-Deževski” provided data on the biomass volume classified by tree species. Combined with the data on the allowable cut, they reveal the total energy value of the management unit, its energy value by tree species, as well as the energy value of the allowable cut in the course of a ten-year-long forest management plan.

The obtained data prove that the volume of the biomass harvested in a given stand in a defined study period should not be greater than the biomass produced in the same area in the same period. This is the only way to achieve sustainable forest management for biomass.

The forest biomass should be clearly distinguished from the agricultural biomass. The major difference lies in the time of biomass collection. Agricultural biomass is generated annually as a by-product of harvesting, while it takes much longer for the forest biomass to be collected in natural forest stands. Sometimes it can take more than 100 years to collect all the biomass present in a stand. Meanwhile, through thinnings, we harvest only as much biomass as can be produced, following the allowable cut prescribed for each management unit.

One of the advantages of biomass compared to other renewable energy sources is its versatility. Biomass in general, and forest biomass in particular can be converted into electricity, heat or transportation fuels. In practice, though, forest biomass is mainly used for the production of heat and electricity (Ge, X. et al., 2016). The conversion of forest biomass into biofuels that can be used in the transport sector still faces various challenges which have impeded its commercialization (Brown, R.C., 2011). Despite its advantages, and despite the fact that biomass is the most commonly used renewable energy source, the current share of bio-energy in the world is still limited. In 2015, bioenergy and renewable waste accounted for 9.4% of the world's energy supply (Hanna, R. et al, 2016). Of the various sources of biomass, solid biofuels accounted for 63.7% of the global supply of renewable sources (liquid biofuels, biogas and renewable municipal waste amounted to 4.3, 1.7 and 0.9% respectively, while other renewable energy sources accounted for the rest of the percentage). In OECD countries, biomass is mainly used in modern systems. Therefore the share of biomass and renewable waste is even lower. There the fuels accounted for 5.2% of total primary energy in 2015, while solid biomass accounted for 36.1% of the renewable energy supply. Solid biofuels, which are almost entirely composed of wood, wood residues and wood fuels, are used to generate electricity and heat. Direct heat is undoubtedly the most common application of solid biomass. In this case, biomass is used directly by end users (e.g. residential, industrial, commercial or agricultural users) rather than by the energy transformation sector (e.g. power plants, combined heat and power plants or heat plants). The prevailing use of solid biomass for heating purposes is largely justified by its traditional use for heating and cooking in African and Asian countries (WBA Global Bioenergy Statistics Stockholm, 2017).

The situation in Europe is different. Here, solid biomass has a higher energy value in the energy transformation sector due to the modern methods of biomass utilization (http://ec.europa.eu/eurostat/data/database). In total, the European energy transformation sector accounts for 30% of the solid biomass consumption while the global average, on the other hand, amounts to 9%.

In order to make the use of biomass economically justified and acceptable, it is necessary to use biomass with as low moisture content as possible. It is well-known that the drying and combustion processes, as well as the heat value of wood, depend on the density of wood. Hard and dense woods have higher calorific values and burn more slowly and thus produce a higher amount of heat. We cannot directly change wood density, but we can certainly change the percentage of moisture content in biomass.

It is best to harvest biomass during the resting period and taking into account the effects of climate factors to choose the period when the humidity is as low as possible.

## 2. MATERIJAL AND METHODS

This paper studies the state of the forest biomass potential in the MU "Crni Vrh Deževski" for the 2004-2014 forest management plan period. The total felling volume projected to be harvested over the period of ten years was smaller than the total tree increment assessed in the area of the MU "Crni Vrh Deževski", which indicates that this management unit had been properly managed taking into account its sustainability. This data was obtained in the new forest inventory of the management unit, designed for the period 2015-2024.

Our goal is to show the energy value of biomass as a renewable energy source and to point out that although it is renewable it is still a limited resource. Therefore, the amount of biomass harvested must not be larger than the projected biomass. The amount of biomass should not be increased by cutting trees for energy, but by increasing the area under forest. These new areas should be established by taking into account their ecological characteristics and selecting those tree species that are valuable for energy production.

We started from the assumption that the entire allowable cut is intended for biomass, although in practice, this is often not the case, because part of it is always used for timber which is more commercial than biomass.

Since we know the quantities (allowable cut) that can be harvested this MU by tree species, we used data on the density of wood for each tree species, as well as the energy value of raw and dried wood to determine the differences between different tree species.

## 3. DISCUSSION

Acording Forest management plan for the Gornjeibarsko forest area, "Crni Vrh-Deževski" management unit occupies an area of 2805.74 ha, a large part of which is under forest (2206.99 ha). Forest plantations occupies 123.02 ha, forest unstocked land 401.84 ha, barrens 44.35 ha and the rest 29.54 ha. There is evidently a lot of forest land that is suitable for afforestation which should be done as soon as possible. A total of 401.84 hectares (14.32%) should be successfully restocked so that this area can be used for biomass production.

The total volume of this MU is 233621 $m^3$. Broadleaved species account for 222159 $m^3$ or 95.10% of it. The most common tree species are beech, sessile oak, Turkey oak and hornbeam, while other broadleaves have an insignificant share. Coniferous species that make 4.90% include Norway spruce, Scots pine and Austrian pine. The total biomass accounts for 15% of the allowable cut and it is harvested in approximately equal quantities over a period of ten years through care and thinning measures.

**Table 1.** *The state of biomass in the MU "Crni Vrh-Deževski" in the 2004-2014 forest management plan period (Data on the weight of wood and the combustion heat were obtained from the following source – Vojcijehovski, 1961, Nikolić, 1990)*

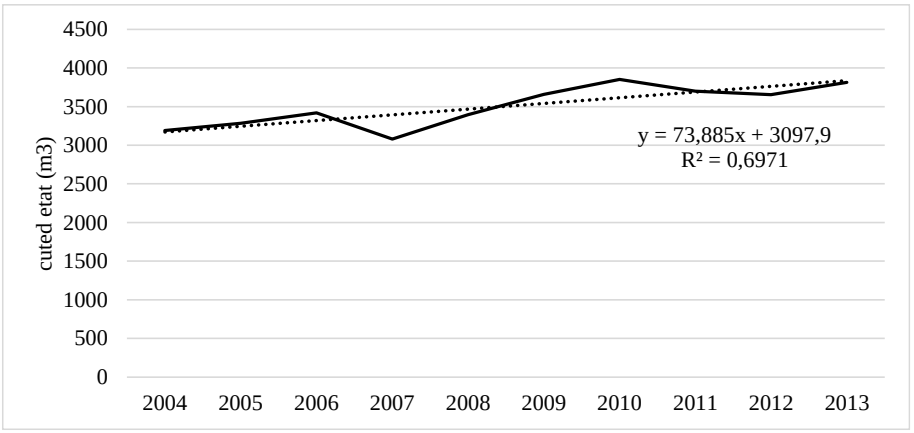
| Tree species | Volume $m^3$ | Wood weight $kg/m^3$ | Allowable cut $m^3$ | Combustion heat kj/kg | | Total $kj/m^3$ | Total $кj/m^3$ |
|---|---|---|---|---|---|---|---|
| | | | | Oven-dry | Dried | Oven-dry | Dried |
| Beech | 183292.0 | 680 | 27493.8 | 18816 | 14843 | 12794.88 | 10093.24 |
| Sessile oak | 20772.8 | 660 | 3115.92 | 18381 | 14455 | | 9540.30 |
| Turkey oak | 10610.2 | 670 | 1591.53 | 18381 | 14455 | 12315.27 | 9684.85 |
| Hornbeam | 3343.1 | 690 | 501.465 | 17008 | 13315 | 11735.52 | 9187.35 |
| Other hard broad.sp. | 1572.3 | 675 | 235.845 | 17996 | 14098 | 12147.3 | 9516.15 |
| Maple | 1282.9 | 590 | 192.435 | 17996 | 14098 | 10617.64 | 8317.82 |
| Field maple | 547.0 | 590 | 82.05 | 17996 | 14098 | 10617.64 | 8317.82 |
| Hop hornbeam | 356.3 | 690 | 53445 | 17008 | 13315 | 11735.52 | 9187.35 |
| Aspen | 230.9 | 410 | 34635 | 17996 | 14098 | 7378.36 | 5780.18 |
| Birch | 58.7 | 610 | 8.805 | 1949 | 15429 | 11888.9 | 9411.69 |
| Flowering ash | 61.2 | 650 | 9.18 | 17816 | 13984 | 11580.4 | 9163.70 |
| Other soft broad. sp. | 33.9 | 630 | 5.085 | 17996 | 14098 | 11337.48 | 8881.74 |
| Oriental hornbeam | 4.5 | 690 | 0.675 | 17008 | 13315 | 11735.52 | 9187.35 |
| **Total broadleaves** | 222159.0 | | 33323.85 | | | | |
| Norway spruce | 7507.9 | 430 | 1126.185 | 19662 | 15596 | 8454.66 | 6706.28 |
| Scots pine | 2274.3 | 490 | 341.115 | 21211 | 16957 | 10393.39 | 8308.93 |
| Austrian pine | 1679.8 | 580 | 251.97 | 21211 | 16957 | 12302.38 | 9857.1 |
| **Total conifers** | 11462.0 | | 1719.255 | | | | |
| **Total for the MU** | 233621.0 | | 35043.15 | | | | |

There is a clear difference in the energy value between oven-dry and partially dried wood in all tree species. The difference is so significant that it is recommended to oven-dry biomass before it is used for heating purposes. The allowable cut of this management unit is 35043.15 $m^3$, which is the amount of biomass that can be harvested from the forest in a period of 10 years, i.e., the annual allowable cut is about 3500 $m^3$. From the records of the FMP for the MU "Crni Vrh-Deževski", we can see the trends in the allowable cut by study year. The data are presented in Table 2.

**Table 2.** Allowable cut by study year

| **year** | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Vol.** $^3$ | 3189,1 | 3285,1 | 3417,2 | 3080,1 | 3396,2 | 3658 | 3850.15 | 3698.2 | 3655.10 | 3814 |

The data are used to present the linear regression of the biomass use.

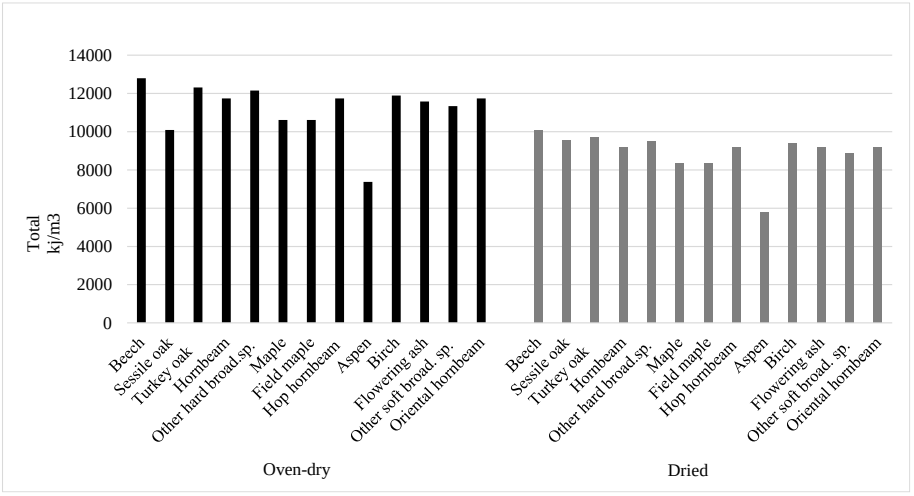



**Graph 1.** Linear regression of the biomass use in the observed period

The annual felled volume of oven-dry biomass has a 21% higher energy value. For instance, the felled volume of 3500 $m^3$ of oven-dry biomass has an energy value that equals 4235 $m^3$ of partially dry biomass. It follows that the process of biomass drying increases energy efficiency and thus reduces tree cutting.

This proves again that wood biomass should be used in a dry state.

The differences in the energy value between tree species are clear. In the future, certain tree species are expected to be favoured in the afforestation of barren land and establishment of plantations for energy purposes due to their high energy value.




**Graph 2**. Differences in the energy value of oven-dry and partially dry wood

Underused and unstocked areas should be afforested and if the conditions allow, fast-growing tree species should be introduced (i.e., plantations for energy purposes should be established). They will increase the allowable cut of this management unit and help derive other multiple forest benefits (Hadrović S, 2015).

The total energy value of biomass should be reduced by the fraction of the fossil fuel energy used in cutting, wood assortment production, skidding of biomass from the felling site to the haul road, and transporting it to the place of use.

Biomass should certainly be used as a renewable energy source, but not at the expense of other forest benefits. Clear-cutting should not be allowed on large surface areas as it can cause soil removal and erosion (Hadrović, S, Stević, S., 2017, Brašanac-Bosanac, Lj. et al., 2018).

Forest biomass is mostly used as raw material and it is rarely subjected to the upgrading processes. However, the use of upgraded biomass has been growing in importance. For instance, pellets are one of the fastest-growing bioenergy carriers. One of the benefits of upgraded forest biomass over raw biomass is the fact that it is more uniform and convenient to be used, particularly when it is used at a site away from the production site. A disadvantage is its higher cost compared to the correspondent raw biomass fuel. Untreated wood is characterized by low carbon content and high content of volatile matter and oxygen compared to solid fossil fuels. This leads to the lower heating values of wood, which combined with its low density results in low values of energy density. In practice, wood is often not oven-dried and contains a certain amount of water. The moisture content of green timber typically ranges from 50 to 60%, while the timber stored for summer or several years has the moisture content of 15-25%. The lower heating value of wood fuels is largely due to the content of water in the fuel. The higher the content of water in wood, the lower is its energy content. Another convenient characteristic of biomass is the low content of ash. However, it can be significantly higher in the bark, especially of oak trees.

## 4. CONCLUSIONS

The production of energy in the world has been increasingly focusing on renewable sources. Biomass is one of the major renewable sources. The most important reasons for its use lie in the fact that fossil fuels are exhaustible and the emissions from their combustion contribute to the global warming of the Earth. Therefore, the laws of most countries require a constant increase in primary energy production from renewable energy sources. The modern way of life is a dangerous "pollutant". Therefore, it is necessary to raise environmental awareness and develop new cleaner methods and technologies. It should be noted that biomass has its shortcomings. First of all, it can be a pollutant. Certain amounts of carbon dioxide and other gases are certain to be released into the atmosphere. It can also be unprofitable for an area. Therefore, when selecting the source of energy to be used, it is necessary to consider all the circumstances and to choose the most appropriate solution. The production of energy from biomass has the following advantages: we can store energy sources so that there is no need for energy reserves, which is a significant advantage over all other renewable energy sources. The optimum use of biomass promotes regional development and creates new job opportunities in the domestic industry, forestry and agriculture, which is of particular importance to the community.

Every year, power plants and cars burn an amount of fossil fuel that took about 500000 years to produce. This produces 24 billion tons of carbon dioxide ($CO_2$) which is assumed to have increased the $CO_2$ levels by 27% over the past 100

years. Combustion of wood doesn`t contribute to this increase because the same amount of $CO_2$ would be produced if the wood was left to decompose in the soil. However, as trees grow, they bind carbon and thus stop their contribution to the negative effects of $CO_2$ that would otherwise arise. Therefore, the environment can be significantly improved with greater afforestation and the use of wood in the construction of residential and commercial buildings or as an environmentally-friendly packaging material to substitute for the synthetic ones. A particularly large contribution to the environment can be given by using wood instead of other types of fuel because it is carbon-neutral fuel, unlike oil and coal. The wood is also a renewable material, and unlike fossil fuels, it is a renewable fuel as well. The following facts best illustrate the role and importance of wood in the efforts to preserve the environment and mitigate climate change in the world:

- to produce $1m^3$ of wood, trees require 1 ton of $CO_2$ which they take from the atmosphere;
- $1m^3$ of wood volume of a standing tree contains about 250 kg of carbon stored in wood fibers and about 750 kg of oxygen released into the atmosphere during the process of photosynthesis;
- European forests absorb about 140 million tons of carbon a year from the atmosphere during the process of photosynthesis;
- An area of 150 $m^2$ of forests releases an annual amount of oxygen that meets the needs of one person;
- a sixty-year-old beech tree provides oxygen for more than 10 people;
- a sixty-year-old beech tree can absorb $CO_2$ released into the atmosphere by 6 people.

Wood is the cleanest and safest fuel available today, especially compared to petroleum products and nuclear fuel. It is also the fuel with low nitrogen and sulfur content. The use of wood for heating, instead of oil, coal and natural gas, surely entails greenhouse gas emissions, but sustainable forestry can compensate for these emissions by planting new forests. Planting a large number of trees in deserts could yield excellent results. German experts conducted experiments with a special tree species (*Jatropha curcas* L.) which they planted in trial plots in Egypt and the Negev Desert. This tree species can survive adverse conditions and a hectare of this plant absorbs about 25 tons of carbon dioxide. It further increases biomass as a renewable energy source.

The same amount of felled volume has a 21% higher energy value if it is in a dry state. For instance, the felled volume of 3500 $m^3$ of oven-dry biomass has an energy value that equals 4235 $m^3$ of partially dry biomass. It follows that the process of biomass drying increases energy efficiency and thus reduces tree cutting. This proves again that wood biomass should be used in a dry state.

Underused and unstocked areas should be afforested and if the conditions allow, fast-growing tree species should be introduced (i.e., plantations for energy purposes should be established). They will increase the allowable cut of this management unit and help derive other multiple forest benefits.

The total energy value of biomass should be reduced by the fraction of the fossil fuel energy used in cutting, wood assortment production, skidding of biomass from the felling site to the haul road, and transporting it to the place of use.

Biomass should certainly be used as a renewable energy source, but not at the expense of other forest benefits. Clear-cutting should not be allowed on large surface areas as it can cause soil removal and erosion.

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# THE VALUE OF BIOMASS ENERGY – THE CASE STUDY OF "CRNI VRH-DEŽEVSKI" IN THE GORNJEIBARSKO FOREST AREA

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## Sumary

Of all terrestrial ecosystems, forests are the most important carbon reservoirs. Therefore they deserve special care and protection. They are also an irreplaceable source of biomass for energy. Forest biomass has been used as a fuel since the earliest times, and since the late twentieth century, there has been a renewed interest in its use for the production of heat and electricity. Forest biomass has become interesting as a source of energy due to some of its characteristics, above all its availability and uniformity around the world, which implies that both developing and less developed countries can use biomass as a renewable source of energy. Furthermore, biomass fuel is considered to be $CO_2$ neutral. However, its use is not risk-free. The risks are mainly related to the sustainability of forest systems and their productivity. Therefore, the forestry profession must be extremely cautious in using forest biomass and follow the prescribed allowable cut.

Energy has been obtained from forests for thousands of years. Forests have been one of the most important contributors to biomass production (WBA Global Bioenergy Statistics Stockholm, 2017). Most of today's production of solid biomass for energy occurs in non-OECD countries (83.7% in 2015) where it is widely used for traditional heating and cooking. The traditional use of biomass is not efficient and it can have serious adverse effects on human health caused by combustion smoke (Hanna, R. et al., 2016). Excessive use of biomass is often associated with local deforestation and degradation of high forests into devastated forests, which consequently leads to soil erosion and endangerment of entire forest ecosystems.

One of the advantages of biomass compared to other renewable energy sources is its versatility. Biomass in general, and forest biomass in particular can be converted into electricity, heat or transportation fuels. In practice, though, forest biomass is mainly used for the production of heat and electricity. (Ge, X. et al., 2016). The conversion of forest biomass into biofuels that can be used in the transport sector still faces various challenges which have impeded its commercialization ((Brown, R.C., 2011). Despite its advantages, and despite the fact that biomass is the most commonly used renewable energy source, the current share of bio-energy in the world is still limited. In 2015, bioenergy and renewable waste accounted for 9.4% of the world's energy supply (Hanna, R. et al, 2016). Of the various sources of biomass, solid biofuels accounted for 63.7% of the global supply of renewable sources (liquid biofuels, biogas and renewable municipal waste amounted to 4.3, 1.7 and 0.9% respectively, while other renewable energy sources accounted for the rest of the percentage). In OECD countries, biomass is mainly used in modern systems. Therefore the share of biomass and renewable waste is even lower. There the fuels accounted for 5.2% of total primary energy in 2015, while solid biomass accounted for 36.1% of the renewable energy supply. Solid biofuels, which are almost entirely composed of wood, wood residues and wood fuels, are used to generate electricity and heat. Direct heat is undoubtedly the most common application of solid biomass. In this case, biomass is used directly by end users (e.g. residential, industrial, commercial or agricultural users) rather than by the energy transformation sector (e.g. power plants, combined heat and power plants or heat plants). The prevailing use of solid biomass for heating purposes is largely justified by its traditional use for heating and cooking in African and Asian countries (WBA Global Bioenergy Statistics Stockholm, 2017).

The situation in Europe is different. Here, solid biomass has a higher energy value in the energy transformation sector due to the modern methods of biomass utilization (http://ec.europa.eu/eurostat/data/database). In total, the European energy transformation sector accounts for 30% of the solid biomass consumption while the global average, on the other hand, amounts to 9%.

In order to make the use of biomass economically justified and acceptable, it is necessary to use biomass with as low moisture content as possible. It is well-known that the drying and combustion processes, as well as the heat value of wood, depend on the density of wood. Hard and dense woods have higher calorific values and burn more slowly and thus produce a higher amount of heat. We cannot directly change wood density, but we can certainly change the percentage of moisture content in biomass.

It is best to harvest biomass during the resting period and taking into account the effects of climate factors to choose the period when the humidity is as low as possible.

## ENERGETSKA VREDNOST BIOMASE NA PRIMERU GJ „CRNI VRH-DEŽEVSKI“ U GORNJEIBARSKOM ŠUMSKOM PODRUČJU

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### Rezime

Od sih kopnenih ekosistemima, šume su najvažniji rezervari skladišta ugljenika,pa samim tim zaslužuju posebnu negu i zaštitu. Shodno tome, oni su i nezamenljiv izvor biomase za energiju. Šumska biomasa je korišćena kao gorivo iz ranih vremena, a od kraja dvadesetog veka nadalje, došlo je do obnavljanja interesa za njegovu upotrebu za proizvodnju toplote i električne energije. Interesovanje šumske biomase kao izvora energije odnosi se na neke od njegovih karakteristika, kao što su relativna brojnost i ujednačenost širom sveta te tako i zemlje u razvoju i manje razvijene zemlje imaju pristup biomasi kao obnovljivom izvoru energije.Takođe se biomasa smatra kao neutralno gorivo u emisiji SO2. Ipak, njegova upotreba nije bez rizika, uglavnom vezana za održivost šumskih sistema i njihove proizvodnje, što šumarsku struku dovodi u poziciju da strogo mora voditi računa o pravilnom korišćenu biomase i poštovanju definisanog sečivog etata.

Energija je dobijena iz šuma hiljadama godina, šume su najveći doprinos dale između ostalog u proizvodnji (WBA Global Bioenergy Statistics Stockholm, 2017). Većina današnje proizvodnje čvrste biomase za energiju javlja se u zemljama koje nisu članice Organizacija za ekonomsku saradnju i razvoj (OECD) (u 2015. godini 83,7%) i široko se koristi za tradicionalno grijanje i kuvanje. Tradicionalna upotreba biomase je neefikasna i karakteriše je ozbiljan negativan uticaj na ljudsko zdravlje usled dimnog sagorevanja (Hanna, R. et al, 2016). Preterana upotreba biomase je povezana sa lokalnim krčenjem šuma i prevođenja visokih šuma u devastirane i izraubovane šume gde posle toga dolazi do spiranja erozije zemljišta i ugrožava se celokupni šumski ekosistem.

Jedna od bitnih karakteristika biomase u dvadesetiprvom veku je čistija i efikasnija tehnologija za grijanje Drvna biomasa je obnovljivi izvor energije i smatra se da doprinosi smanjenju antropogenih emisija $CO_2$. Zbog smanjenja šumskih površina i nedostatka drvnih proizvoda, kao i garantovanja održivosti šuma i ekosistema, javila se potreba procene, praćenja i regulacije šuma kako bi se znala zapremina biomase , prirast na određenoj površini i u određenom vremenskom periodu da bi na osnovu toga mogli da odredimo sečivi etat uz garanciju trajne održivosti sastojine. Tako smo na osnovu podataka o inventuri šuma došli do količine zapremina za GJ „Crni Vrh- Deževski“razvrstanih po zastupnjenim vrstama drveća, i uz podatak o secivom etatu možemo uporediti ukupnu energetsku vrednost

gazdinske jednice, kao i vrednost za svaku vrstu drveta kao i energetsku vrednost za godišnji sečivi etat u periodu važenja osnove od deset godina.

Na ovaj način dokazujemo da količina zapremine koja se kroz proces seče uzme iz jedne sastojine za posmatrani period ne sme da bude veća od prirasta biomase na istoj površini za isti posmatrani period. Samo kroz tako gazdovanje možemo obezbediti trajnost biomase. Jedna od prednosti biomase u odnosu na druge obnovljive izvore energije je njegova svestranost. Biomasa uopšte, a posebno šumska biomasa, može se pretvoriti u električnu, toplotnu ili transportnu energiju. U praksi, međutim, šumska biomasa se uglavnom koristi za proizvodnju toplotne i električne energije (Ge, X. et al., 2016). Transformacija šumske biomase u biogoriva koja se mogu koristiti u sektoru transporta i dalje se suočava sa različitim izazovima, koji su ometali njegovu komercijalizaciju (Brown, R.C., 2011). Uprkos svojim prednostima i uprkos tome što je najčešće korišćeni obnovljivi izvor energije, sadašnji udeo bioenergije u svetu je još uveek vrlo ograničen. U 2015. godini bioenergija i obnovljivi otpad činili su 9,4% svjetske energetske ponude (Hanna, R. et al, 2016). Među različitim izvorima biomase, čvrsta biogoriva su činila 63,7% globalnog snabdevanja obnovljivim izvorima (tečna biogoriva, biogas i obnovljivi komunalni otpad su iznosili 4,3, 1,7 i 0,9%, a ostali obnovljivi izvori energije za ostatak) U zemljama OECD-a, gdje se biomasa uglavnom koristi u modernim sistemima, udio biomase i obnovljivog otpada je još niži, s tim da ta goriva čine 5,2% ukupne primarne energije u 2015. godini, a čvrsta biomasa čini 36,1% obnovljive energije snabdevanje . Čvrsta biogoriva, koja se gotovo u potpunosti sastoje od drveta, drvnih ostataka i drvnih goriva, koriste se za proizvodnju električne energije i topline. Direktna toplota je daleko najčešća primena čvrste biomase. U ovom slučaju, biomasa se koristi direktno od strane krajnjih korisnika (npr. Stambenih, industrijskih, komercijalnih, poljoprivrednih), a ne od strane sektora za transformaciju energije (npr. Elektrane, postrojenja za kombinovanu proizvodnju toplotne i električne energije ili toplane). Dominacija upotrebe čvrste biomase za potrebe grejanja uglavnom je opravdana tradicionalnom upotrebom u zemljama Afrike i Azije za grejanje i kuvanje (WBA Global Bioenergy Statistics Stockholm, 2017).

Da bi biomasa bila ekonomski opravdana i prihvatljiva za upotrebu , neophodno je da se ista koristi sa što manjim sadržajem vlage. Poznato je da proces sušenja ,kao i proces sagorevanja i toplotna vrednost drveta zavise od gustine drveta. Tvrđa drva sa većom gustinom imaju veću kalorisku vrednost, sporije sagorevaju te će na taj način proizvesti i veću količinu toplotne energije.Na gustinu drveta nemožemo direktno da utičemo, ali svakako možemo da utićemo na procenat sadržaja vode u biomasi.

Potrebno je da se biomasa priprema tako što će se seći u periodu mirovanja vegetacije,potom da se vodi računa i o utičaju klimatskih faktora da seča bude u periodu kada je vlažnost vazduha što niža.

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# POTENTIALS OF THE ASSESSMENT OF THE WOOD QUALITY IN STANDING TREES BY APPLYING ACOUSTIC METHODS

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**Abstract:** *Based on literature sources, the stress wave and ultrasound methods and tools designed for the evaluation of the effects of decay on wood are discussed in this paper. To make a review of the results obtained in numerous studies, the analytic-synthetic method was used and the evaluation of data was conducted. The results revealed high correlations between the measured properties and the actual wood quality. A number of studies show that the acoustic wave velocities correlate well to wood density and other wood properties. Changes in the acoustic velocity and wood density variations caused by decay have also been detected successfully using the ultrasonic tools. This means that wood quality can be assessed in situ and that the methods and devices in question can help us make the right decisions. Still, it must be pointed out that all the methods and devices used are only measuring and quantifying tools, and practical human experience cannot be replaced by any measuring tools.*

**Keywords:** acoustic methods, wood properties, wood quality, non-destructive wood investigation, wood production

# MOGUĆNOSTI PROCENE KVALITETA DRVETA DUBEĆIH STABALA PRIMENOM AKUSTIČNIH METODA

**Izvod:** *Na osnovu literaturnih izvora, u radu su razmatrane akustična tomografija i ultrazvučna metoda, kao i sprave koje su namenjene ispitivanju efekata koje trulež ima na*

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*svojstva drveta. Kako bi se načinio pregled rezultata dobijenih u brojnim istraživanjima, primenjen je analitičko-sintetički metod sa procenom podataka. Rezultati pokazuju dobru korelisanost između analiziranih svojstava drveta i njegovog kvaliteta. Tako, mnoga istraživanja pokazuju dobru korelisanost između brzine zvučnih talasa i gustine drveta, kao i ostalih njegovih svojstava. Promene u brzini zvučnih talasa i varijacije u gustini drveta koje su izazvane truležima su isto tako uspešno detektovane primenom ultrazvučnih instrumenata. Ovo znači da se kvalitet drveta može proceniti in situ i da opisane metode i sprave mogu doprineti boljem odlučivanju u praksi. Ipak, neophodno je istaći da sve metode i sprave predstavljaju samo pomagala za merenje i ispitivanje svojstava drveta i da se praktično iskustvo stručnjaka ne može nadomestiti nikakvim mernim istrumentima.*

**Ključne reči:** akustične metode, svojstva drveta, kvalitet drveta, nedestruktivno ispitivanje drveta, prerada drveta

## 1. INTRODUCTION

As a natural material, wood has been used for different purposes since ancient times. At present, wood is utilized as a raw material in the industry of different products (e.g., furniture, structure timber for buildings, various wood-based panels, pulp, and paper), being an irreplaceable raw material for some of these products. According to Marković *et al.* (2015) development of the wood processing industry is causing a growing demand for high-quality wood raw materials. In fact, due to its organic origin and renewability, wood is one of the most sought-after natural materials today (Živanović *et al.*, 2019).

Owing to its natural origin, wood shows a large variation in properties that mostly depend on the cellular, anatomical, and chemical characteristics of wood (Šoškić, 2002). The properties of wood highly condition the application of wood final products, as well as their economic value. This is the prime reason for the grading of wood based on its properties. In most cases, sorted wood is graded visually, with no science background. However, this method of wood property assessment is not always acceptable, due to its unreliability and subjectivity. Much more reliable methods should be used to assess the properties of wood, especially those properties reflecting the interior structure of wood which is difficult to assess visually. In recent years, great efforts were made in wood science and technology to develop non-destructive methods and tools for a more accurate assessment of wood properties of standing trees (Živanović *et al.*, 2019). Mechanical, acoustic, and radiation methods have been developed for this purpose. These methods investigate properties of wood *in situ*, without destruction. This way, science and practice are provided by significant data regarding the properties and quality of wood, while the wood consumption is minimized (Todorović, 2014).

The paper presents two acoustic methods for the assessment of wood quality in standing trees. The stress wave and ultrasound methods, as well as tools designed for the evaluation of the effects of decay on wood, based on wood acoustic properties, are discussed thoroughly in the paper from the point of view of cost-efficient production in wood-processing.

Acoustics is a popular way to estimate stiffness in standing trees with simple, compact, and easy to use devices (Dickson *et al.*, 2004). Instruments for this purpose

usually measure the speed of waves or sound traveling through the wood. There are two ways for assessing the internal condition of wood using sound – by using ultrasound and sound waves. The main difference between them is that the ultrasonic wave is generated by sound pulses of known frequency, while the voltage of the sound wave is not known. Given that wood is a solid medium, the speed of the wave in it is much higher than in air and depends on the type of wave and the elasticity and density of the material. Damaged wood often results in a modified speed of propagation of the acoustic wave, so that the propagation time of the sound wave provides useful information about the mentioned properties of wood (Goh *et al.*, 2018).

## 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 methods studied. The evaluation of literature data collected was based on simple, practical, but also some complex indicators. The purpose of the paper was to make a review of the results obtained in numerous papers.

The collected literature data, related to the potentials for applying acoustic methods and tools for the assessment of the wood quality in standing trees, have been carefully studied and classified into several groups:

1. Literature data related to the theoretical definitions, purpose, and practical application of the methods and tools;
2. Literature data comprising comparative tests with other non-destructive methods for the evaluation of the quality of wood in standing trees;
3. Literature data comprising the results of the same methods applied to different tree species.

## 3. RESULTS AND DISCUSSION

In order to promote timber value, it is fundamentally important to study the characteristics of forest management options in more detail. To avoid unintentional loss of wood quality when selecting trees for high productivity in tree breeding programs, acoustic methods are among the most useful methods for efficient and reliable assessment of wood quality in standing trees. This is demonstrated by the results obtained in numerous studies. The results of the studies that are considered the most notable are presented in Table 1.

Mahon (2007) obtained acoustic velocities from 100 standing loblolly pine (*Pinus taeda* L.) trees with the transmitting and receiving probes placed on the same-face and opposite-faces, and by comparing the results using FAKOPP's TreeSonic. In this study, significant differences in velocity between the two methods were found. Variation in velocities from hit-to-hit was 62% less using the opposite-face method compared to the same-face method. In addition to felled tree acoustic velocities, standing tree acoustic velocities were calculated for all six flight paths for

79 loblolly trees. The author found that acoustic velocity, both in standing and felled trees, increased with age.

**Table 1.** *Selected wood property investigations conducted using acoustic and other non-destructive methods*

| N° | Method used | Tree species | Correlation (*r*) | Property analyzed | Reference |
|---|---|---|---|---|---|
| 1. | Acoustic waves | *Pinus taeda* | Strong | Density | Mahon (2007) |
| 2. | Acoustic waves | *Cunninghamia lanceolata* | 0.77<br>0.57<br>0.45 | Various | Yin *et al*. (2010) |
| 3. | Acoustic waves | *Pinus radiata* | Strong negative | Longitudinal shrinkage | Chauhan *et al*. (2013) |
| 4. | Acoustic waves<br>Pylodin penetration | *Picea abies* | -0.96<br>-0.94<br>0.99 | Density<br>Microfibril angle<br>Modulus of elasticity | Chen *et al*. (2015) |
| 5. | Acoustic waves (SWV)<br>Pylodin penetration (PP) | *Larix decidua* | 0.56 (SWV)<br>0.32–0.61 (PP) | Modulus of elasticity | Škorpík *et al*. (2018) |
| 6. | Ultrasonic method | *Pinus caribea*<br>*Eucalyptus citriodora*<br>*E. grandis*<br>*Goupia glabra*<br>*Hymenaea* sp. | Strong | Density | Oliveira and Sales (2006) |
| 7. | Ultrasonic method | *Picea abies*<br>*Pinus sylvestris* | 0.663<br>0.796<br><br>0.588<br>0.5139 | Bending strength<br><br>Compressive strength | Dzbeński and Wiktorski (2007) |
| 8. | Ultrasonic method | *Fagus orientalis* | Strong | Decay | Kazemi-Najafi *et al.* (2009) |
| 9. | Ultrasonic method<br>X-ray | *Picea abies*<br>*Populus deltoides* | Strong | Reaction wood | Brancheriau *et al*. (2012) |

Yin *et al.* (2010) attempted to establish the method for evaluating wood mechanical properties by acoustic non-destructive testing in standing trees and logs of a Chinese fir (*Cunninghamia lanceolata* /Lamb./ Hook.) plantation. In addition, they compared three acoustic non-destructive methods for evaluating the static bending modulus of elasticity (MOE), modulus of rupture (MOR), and compressive strength parallel-to-grain ($\sigma$c) of plantation wood. Static bending tests were then performed to determine the bending MOE and MOR, and compressive tests parallel-to-grain were made to determine $\sigma$c. As determined by the three acoustic methods, the differences between the bending MOE and dynamic MOE of logs were statistically significant ($p$>0.001). Good correlations ($r$=0.77, 0.57, and 0.45) between dynamic modulus of elasticity (DMOE) of a log determined based on stress wave, DMOE of a log determined based on longitudinal vibration, and DMOE of a

log determined based on the ultrasonic wave, and static MOE, respectively, were obtained ($p$>0.001). The authors concluded that longitudinal vibration may be the most precise and reliable technique for the evaluation of the mechanical properties of logs among the three acoustic non-destructive methods analyzed. Moreover, the results of the study indicated that stress wave technology would be an effective method for evaluating wood mechanical properties both in logs and standing trees.

El-Kassaby *et al.* (2011) assessed the genetic control and phenotypic and genotypic correlations among wood density, MOE, height, diameter, and volume for Douglas-fir full-sib families using comparable test sites. They observed significant differences in wood density using two *in situ* methods (drilling resistance and acoustic velocity). The reliability of the *in situ* assessments was verified through cumulative pith-to-bark wood density assessment, resulting in inconsistent genetic and phenotypic correlations for early growth years. The latter findings of the study imply that caution should be used in employing these *in situ* techniques as early screening tools in breeding programs. The authors concluded that significant and consistent genetic correlations between the *in situ* methods and wood density and stiffness support their use as a non-destructive and economic assessment approach.

Morrow *et al.* (2013) took standing stress wave measurements from 274 small-diameter Douglas-fir trees in western Montana. Stand, site, and soil measurements were made in this study, and DMOE was determined with a stress wave timer. Several theoretical and logical models were developed to predict DMOE. The authors realized that soil basic density may not be a universally important predictor of wood quality, but future research should consider tree–soil interactions for broad-scale wood quality models.

In the study by Chauhan *at al.* (2013), opposite wood and compression wood were isolated from the leaning stems and tested for DMOE, density, longitudinal shrinkage, volumetric shrinkage and compression wood area for nursery seedlings of clones of radiata pine (*Pinus radiata* D. Don) using automated image analysis method and acoustic velocity. Acoustic velocity in opposite wood had a strong negative association with longitudinal shrinkage. Based on the results of the study, the authors concluded that the opposite wood of the clone with the lowest DMOE exhibited the highest longitudinal shrinkage.

Baar *et al.* (2015) analyzed five tropical hardwoods (*Afzelia bipindensis* Harms, *Intsia bijuga* /Colebr./ Kuntze, *Millettia laurentii* August & De Wildeman, *Astronium graveolens* Jacq. and *Microberlinia brazzavillensis* A. Chev.) of different grain using three non-destructive techniques – longitudinal and flexural resonance method and ultrasound method. The results of their study provided higher values of MOE than the static bending test, but a close correlation was observed between these variables. The weakest correlation was found for the ultrasound method. The authors concluded that the prediction of MOR is less accurate when DMOE is compared with the static MOE. On the other hand, it was still a good prediction in comparison with the density model, and almost all of the correlation coefficients showed the lowest values, although the prediction of MOR by non-destructive techniques was unsatisfactory.

Chen *et al.* (2015) evaluated the suitability of using Pilodyn penetration (PP) and acoustic velocity to assess wood density, microfibril angle, and MOE of Norway spruce (*Picea abies* /L./ H. Karst). Strong correlations between Pilodyn

measurement and wood density ($r$=−0.96), and between acoustic velocity and microfibril angle ($r$=−0.94), were detected in this study. The authors found that PP and acoustic velocity measurements from standing trees can provide a reliable prediction of the stiffness of Norway spruce for breeding selection. They realized that traditional methods for the estimation of solid wood quality traits of standing trees, such as wood density, microfibril angle, and MOE, are time-consuming and expensive, which render them unsuitable for rapid screening of a large number of trees in tree breeding programs. The main conclusion of the study was that a combination of PP with Hitman acoustic velocity provides very high selection efficiency for the three most important quality traits of wood mechanical properties of Norway spruce.

Legg and Bradley (2016) made a review on the use of acoustics to measure the stiffness of standing trees, stems and logs. In addition, they reviewed studies that have used acoustic tools to investigate factors that influence the stiffness of trees. These factors included different silvicultural practices, geographic and environmental conditions, and genetics. According to this review, studies using acoustic tools have reported that the initial planting spacing can affect stiffness. The geographic location appeared to play a role in the properties of wood, as well. Genetics also plays a large part in the properties of wood, such as stiffness. The authors concluded that it would be beneficial if any future studies on this topic include more comparisons with other techniques (such as static bending tests) and make a comparison with resonance and stress wave methods.

Dahle *et al.* (2016) used standard methods to determine static flexural modulus (ES) of elasticity and conducted acoustic testing to estimate DMOE by measuring the speed of sound through a sample of wood without the need to remove any wood samples from northern red oak (*Quercus rubra* L.). The research investigated whether acoustic testing can be used to accurately estimate MOE of green wood. The authors determined strong correlation coefficient (0.42) between ES and DMOE. DMOE was found to be slightly higher than ES, but simple regression can be developed to predict ES from DMOE for a given species of interest. They concluded that a portable acoustic stress wave system can be used to rapidly estimate DMOE in standing trees.

Proto *et al.* (2017) used the acoustic velocity time of flight tool to estimate the influence of four thinning treatments performed in Southern Italy. The objective of the study was to determine whether the effects of silvicultural practices on wood quality of Calabrian pine (*Pinus nigra* Arnold subsp. *calabrica*) can be identified using the acoustic measurement of DMOE from standing trees. The results showed that tree diameter has a significant influence on acoustic wave measurements and that a valid relationship exists between diameter at breast height and tree velocity. The results proved that the stress wave technique can be successfully applied to standing trees.

Škorpík *et al.* (2018) tested and applied PP and measured stress wave velocity (SWV) from trees within a European larch (*Larix decidua* Mill.) breeding program. They found a significant variation of PP and SWV among forest stands, single trees, and even within trees if measured on opposite sides in mountainous terrain. Both measurements exhibited a high degree of genetic determination, i.e., repeatability was 0.32–0.61 for PP and 0.56 for SWV. The results of the study

demonstrated that the integration of wood quality parameters into larch breeding programs is highly recommended and that reliable tools are available.

Russo *et al.* (2019) hypothesized that the tree stand density could influence DMOE and, thus, the future wood quality. They derived DMOE values from data obtained by the acoustic velocity measured with the stress wave timer from Calabrian pine (*Pinus brutia* Tenore). In this study, a strong positive correlation was observed between the acoustic velocity, the thinning treatments and the diameter at breast height. The thinning realized at 25% induced better tree wood quality. The authors also analyzed the best predictors for DMOE estimation, using variables easily measurable in the field, such as tree diameter, tree height, or their transformations (number of trees per hectare and basal area per hectare). The results presented a useful tool for predicting the wood stiffness in relation to stand parameters that are easily measurable in forest inventories.

In the research by Llana *et al.* (2020), acoustic velocity was used to measure 38 standing trees and resonance velocity was recorded in green logs made from the trees. The logs were then dried and tested in bending. In addition, estimation models to predict mechanical properties from non-destructive testing measurements were developed. In this study, large differences between velocities obtained by acoustic and resonance techniques were found. Models based on both non-destructive testing velocities together with a species factor were well correlated with bending MOE, while models including tree diameter were moderately correlated with bending strength. The inclusion of density in the models did not improve the estimation. The authors concluded that models based on acoustic measurements from standing trees or resonance from green logs, together with tree species and diameter, provide reliable estimates of mechanical properties of round timber from hardwood thinnings and that the methodology can be easily used for pre-sorting material in forests. For instance, mechanical properties of small-diameter round timber from hardwood thinnings of common alder (*Alnus glutinosa* /L./ Gaertn.), European ash (*Fraxinus excelsior* L.), European birch (*Betula pendula* Roth. and *B. pubescens* Ehrh.), and sycamore (*Acer pseudoplatanus* L.) can be evaluated by non-destructive testing in either standing trees or green logs, without wood density determination. Moreover, the authors stated that velocity differences between acoustic and resonance methods are influenced by tree species and age and that the tree diameter improves the estimation of bending strength but not of stiffness.

Oliveira and Sales (2006) investigated the effect of density on the velocity of an ultrasonic wave in wood of Caribbean pine (*Pinus caribea* Morelet), lemon-scented gum (*Eucalyptus citriodora* /Hook./ K. D. Hill & L. A. S. Johnson), flooded gum (*Eucalyptus grandis* W. Hill), kabukalli (*Goupia glabra* Aubl.) and jatobá (*Hymenaea* sp.). The study aimed to analyze the influence of density on the longitudinal velocity of an ultrasonic wave, propagated in the longitudinal direction. The relationship between density and velocity was analyzed in two different manners – between and within species. The results obtained between species indicated that ultrasonic velocity tends to increase with increasing density. The results obtained within species also showed an increasing trend in ultrasonic velocity as density increases, but the relationship was not as significant as it was for between species.

Dzbeński and Wiktorski (2007) demonstrated that ultrasonic measurements made both from sawn timber and from standing trees produce satisfactory results in

predicting certain mechanical properties of sawn timber obtained from the analyzed raw material. In this study, the highest correlation (0.65) was observed between the velocity of ultrasounds along trunks and MOE of sawn timber obtained from them. A similar correlation (0.60) with the bending strength was also satisfactory. Very strong correlations were achieved between longitudinal wave velocity ($r$=0.87) and transverse wave velocity ($r$=0.71) in standing trees trunks, and MOE of sawn timber; and parallel correlation coefficients relating to bending strength (r=0.66; $r$=0.80), and compressive strength ($r$=0.59; $r$=0.51). In addition, a very strong correlation ($r$=0.84, $p$>0.001) between longitudinal ultrasonic velocity in standing tree trunks and sawn timber obtained from same trees provided the basis for the mentioned correlations. The authors concluded that the velocity of ultrasonic wave propagation in coniferous standing tree trunks (pine and spruce) is a good indicator of mechanical properties of sawn timber obtained from them. To ensure the correct interpretation of the results, they recommended that studies should be conducted to detect and locate inner rot in standing tree trunks. They also suggested that the studies could be performed by taking measurements of ultrasonic wave propagation transversely in trunks in a potentially defected area and an area free from defects.

Kazemi-Najafi *et al.* (2009) used ultrasonic wave timing inspection to detect the internal decay in standing Iranian beech trees (*Fagus orientalis* Lipsky). The results of this study showed that ultrasonic wave velocity linearly and significantly decreased by increasing hole dimensions, and the location of holes did not influence the extent and trend of velocity decrease. Although slots covered a small volume fraction of disks, they had a great effect on ultrasonic velocity reduction as compared with circular holes.

Brancheriau *et al.* (2012) studied the effect of reaction wood on ultrasonic wave propagation using tomographic imaging. Reaction wood forms when part of a tree is subjected to mechanical stress and helps to bring parts of the plant into an optimal position. The ultrasonic emission was a pulse train of square waves. Two logs of poplar (*Populus deltoides* W. Bartram ex Marshall) and Norway spruce were tested because of the presence of different types of reaction wood (tension wood for poplar and compression wood for spruce). In addition to ultrasonic tests, X-ray imaging in transmission was used. The ultrasonic maps were analyzed to highlight the differences between normal wood and observed reaction zones. The X-ray images were also compared to ultrasonic maps. Significant differences were found between normal and reaction wood for both the slowness and the attenuation. Furthermore, poplar and spruce had opposite behaviors. The anatomical and chemical key traits of reaction wood explained these observations. The interaction between moisture content and density highly influenced the ultrasounds/X-rays relationship. The difference of density and moisture content between tension and normal wood did not separate the two groups for poplar. In the case of spruce, the relationships between ultrasonic tomography and X-rays radiography were due to the differences between compression wood and normal wood.

The studies discussed in the present paper revealed high correlations between the measured properties and the actual wood quality. The results show that the acoustic wave velocities correlate well to the density of wood and other wood properties. Changes in the acoustic velocity and wood density variations caused by decay have also been detected successfully using the ultrasonic tools. Similar results

have also been obtained in our research regarding the use of resistograph and fractometer in wood processing (Živanović *et al.*, 2019).

## 4. CONCLUSION

The present paper aimed to point out the importance of two methods (acoustic and ultrasound) as reliable ways for the assessment of wood defects and quality. Using these methods, decay in wood is discovered *in situ*. Thus, the methods discussed are recommended for measuring the propagation of acoustic waves through wood of standing trees considering the fact the wave velocity is higher in healthy wood.

Studies discussed in the paper indicate high correlations between the measured properties (MOE, DMOE, Es and $\sigma$c) and the actual wood quality. This means that the quality of wood can be predicted *in situ* and that the methods described in the paper can help us make the right decisions. This way, science and practice are provided by significant data on the properties and quality of wood, while wood consumption is minimized.

Still, it must be pointed out that all the methods and devices used, including the stress wave timer and ultrasonic tomograph, are only measuring and quantifying tools. The most important of all is the practical experience of the researcher and this will not change in the future because human expertise cannot be replaced by any measuring tools.

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## POTENTIALS OF THE ASSESSMENT OF THE WOOD QUALITY IN STANDING TREES BY APPLYING ACOUSTIC METHODS

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### Summary

At present, wood is an irreplaceable raw material for many products. The properties of wood highly condition the application of wood final products, as well as their economic value. In most cases, sorted wood is graded visually, with no science background. Thus, more reliable methods should be used to assess the properties of wood, especially those properties reflecting the interior structure of wood which is difficult to assess visually. Great efforts have been made in wood science and technology to develop non-destructive methods and tools for the assessment of wood properties in standing trees.

In this paper, two methods (stress wave and ultrasound) and tools designed for the evaluation of the effects of decay on wood, based on wood acoustic properties, are discussed. In order to make a review of the results obtained in numerous studies, the analytic-synthetic method was used and the evaluation of literature data was conducted.

The results discussed in the reviewed studies show that the acoustic wave velocities correlate well to wood density and other wood properties. Changes in the acoustic velocity and wood density variations caused by decay have also been detected successfully using the ultrasonic tools. This way, science and practice are provided by significant data on the properties and quality of wood, while its consumption is minimized.

Still, it must be pointed out that all the methods and devices used, including the stress wave timer and ultrasonic tomograph, 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 and this will not change in the future because human expertise cannot be replaced by any measuring tools.

# MOGUĆNOSTI PROCENE KVALITETA DRVETA DUBEĆIH STABALA PRIMENOM AKUSTIČNIH METODA

*Ivana ŽIVANOVIĆ, Nebojša TODOROVIĆ, Ljubinko RAKONJAC,Filip JOVANOVIĆ*

## Rezime

Drvo je danas nezamenljiva sirovina za mnoge proizvode, pri čemu svojstva drveta znatno uslovljavaju primenu finalnih drvnih proizvoda, kao i njihovu ekonomsku vrednost. U većini slučajeva, sortimenti se ocenjuju vizuelno, bez naučne osnove. Stoga je potrebno primeniti pouzdanije metode za procenu svojstava drveta, posebno onih svojstava koja se odnose na unutrašnju građu drveta, koju je teško proceniti spolja. U drvnoprerađivačkoj nauci i tehnologiji uloženi su veliki napori kako bi se razvili postupci i uređaji za određivanje svojstava drveta dubećih stabala na nedestruktivan način.

U ovom radu su razmatrane akustična tomografija i ultrazvučna metoda, kao i sprave koje su konstruisane da utvrde efekte koje trulež ima na svojstva drveta. Da bi se načinio prikaz rezultata koji su dobijeni u brojnim istraživanjima, primenjen je analitičko-sintetički metod i izvršena je procena podataka iz literature.

Rezultati koji su predstavljeni u analiziranim radovima pokazuju dobru korelisanost između brzine zvučnih talasa i gustine drveta, kao i ostalih njegovih svojstava. Promene u brzini zvučnih talasa i varijacije u gustini drveta koje su izazvane truležima su takođe uspešno detektovane ultrazvučnim instrumentima. Na ovaj način, nauka i praksa dobijaju značajne podatke o svojstvima i kvalitetu drveta, a utrošak materijala se minimalizuje.

Ipak, neophodno je istaći da sve metode i sprave koje se koriste za opisanu namenu, uključujući akustični tajmer i ultrazvučni tomograf, predstavljaju samo pomagala za merenje i ispitivanje onoga što je čovek već uočio. Stoga, praktično iskustvo stručnjaka ostaje nezamenljivo, što se u budućnosti neće promeniti jer se stručnost istraživača ne može nadomestiti nikakvim mernim instrumentima.

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# ENVIRONMENTAL ASPECTS OF BIOLOGICAL WASTEWATER TREATMENT BY DIFFERENT METHODS AND MICROORGANISMS

*Tatjana VIJATOV[1], Gordana DRAŽIĆ[1], Filip JOVANOVIĆ[2]*

**Abstract:** *The biological treatment of wastewaters (municipal and industrial) is an important topic in the field of biochemistry and biotechnology, as well as in the field of environmental engineering. It has many advantages, such as the simple operation of the basic bioreactor, the potential for the production of valuable bioproducts and efficient wastewater treatment in a short time. However, the biological wastewater treatment also has certain downsides, such as air pollution in places which are near bio-lagoons, and endangering the health of personnel involved in this process. By studying and analyzing data from the reference literature, this paper provides a comprehensive overview of information on microorganisms involved in the wastewater treatment process, the factors with a negative effect on their development, as well as the negative effects of these microorganisms and the biological wastewater treatment process on the environment.*

**Key words**: biological wastewater treatment, oleaginous microorganisms, environmental protection, air pollution, health risks

# EKOLOŠKI ASPEKTI BIOLOŠKOG PREČIŠĆAVANjA OTPADNIH VODA RAZLIČITIM POSTUPCIMA I MIKROORGANIZMIMA

**Izvod:** *Biološko prečišćavanje otpadnih voda (komunalnih i industrijskih) značajna je tema u oblasti biohemije i biotehnike, kao i na polju inženjerstva zaštite životne sredine. Ono ima niz prednosti, poput jednostavnog rada osnovnog bioreaktora, potencijala za proizvodnju vrednih bioproizvoda i efikasnog tretmana otpadnih voda u kratkom roku. Međutim, biološko prečišćavanje voda poseduje i određene negativne osobenosti, kao što su*

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*zagađenje okoline na mestima neposredno oko biolaguna i ugrožavanje zdravlja osoblja koje je uključeno u ovaj proces. Pregledom i analizom podataka iz literature, u ovom radu se daje iscrpan pregled informacija o mikroorganizmima koji su zastupljeni u procesu prečišćavanja voda, faktorima koji negativno utiču na njihov razvoj, kao i negativnim efektima ovih mikroorganizama i biološkog prečišćavanja otpadnih voda na životnu sredinu.*

**Ključne reči**: biološko prečišćavanje voda, eleaginozni mikroorganizmi, zaštita životne sredine, zagađenje vazduha, zdravstveni rizici

## 1. INTRODUCTION

Wastewaters are one of the critical problems of industrial production and urban organization.

There are various kinds of biological systems that can help us restore and maintain the physical, chemical and biological properties of water (Čule *et al.*, 2017). For the biological wastewater treatment, using aerobic and anaerobic microorganisms for water purification are two technologies that have been around for a long time and are still used today. Three types of wastewater that can be treated by oleaginous microorganisms are (1) wastewater from the food industry, (2) municipal wastewater (sludge), (3) wastewater from the fermentation industry (Chan *et al.*, 2009). The core of anaerobic-aerobic treatment of organic wastewater is usually activated sludge, which does not involve the activity of only one microorganism, but a complex microbial population consisting of bacteria, fungi, protozoa, metazoa, etc. (Eckenfelder, 1998; Sevior and Blackall, 2012).

The wastewater treatment plant (WWTP) has a bioreactor composed of a single chamber in which the processes of biological removal of organic pollutants take place, together with biological nitrification and denitrification. The sewer is aerated using membrane diffusers that are delivered through separate rotary air blowers. The air is supplied to the grilles by rotary blowers, which are characterized by minimal service time and provide high reliability. The stabilization of excess sludge oxygen leads to the removal of odors and the creation of conditions necessary to achieve a high rate of dehydration of sludge. Next, the sewage with activated sludge flows to the vertical secondary sedimentation tanks, located inside the bioreactor. The treated wastewater is then gravitationally discharged through a flow meter and a collection pipe to the treated wastewater outlet, as well as the receiving water body, which is usually a drainage ditch directed towards a river (Korzeniewska *et al.*, 2009).

These technologies are an important issue for science and practical application since the decomposition of pollutants with the use of indigenous microorganisms in conventional systems for wastewater treatment is not always efficient enough. Thus, the aim of this paper is to identify and present diverse populations of microorganisms used in various industries for the process of biological wastewater treatment, and to assess the extent of dispersion of potential pathogens, their negative impact on the environment and the health risks to the personnel engaged in the implementation of the process.

## 2. MATERIAL AND METHODS

The paper deals with the issue of biological treatment of three basic types of wastewater, as well as the issue of technologies that have been developed for this purpose. In order to make a comprehensive review of the results obtained in numerous studies – the most relevant literature sources on the researched topic were collected, evaluated, systematized, selected and analyzed. The analytical-synthetic research method was applied to process and present the collected data.

Based on the literature on microbiological air pollution caused by the operation of WWTP, an assessment was made of the dispersion of potential pathogens in terms of negative aspects to the environment and the health status of personnel engaged in the process of biological wastewater treatment.

## 3. RESULTS AND DISCUSSION

### 3.1. Oleaginous microorganisms used for biological wastewater treatment

The treatment of wastewater by oleaginous microorganisms has attracted much attention from many researchers due to its many benefits. Namely, this technology can be carried out in a basic bioreactor and fermenter (which can be used for conventional fermentation), so it does not require much financing in advance. Furthermore, this technology can not only effectively treat wastewater in a short time but can also create certain valuable bioproducts (Huang *et al.*, 2017).

In municipal wastewater, the oleaginous yeast *Lipomyces starkeyi* was used to remediate sewage sludge, by accumulating lipids, with the lipid content reaching 68% (Angerbauer *et al.*, 2008). In addition to sewage sludge, it has been determined that the sludge from paper mills can be converted into neutral lipids by the activity of one oleaginous yeast for biodiesel production – *Cryptococcus vishniaccii* (Deeba *et al.*, 2016). Oleaginous yeast *Rhodosporidium kratochvilovae* was used as a model organism for its unique ability to utilize pulp and paper industry effluent as a culture medium and to accumulate high quantity of triacylglycerol or neutral lipids as large size lipid droplets ($4.56 \pm 0.24$ μm) within its cellular compartment. The process showed a significant reduction in effluent toxic components, i.e. color (89%), lignin (94.27%), phenol (99.6%), total dissolved solids (84.59%), biological oxygen demand (BOD) (77.36%), and chemical oxygen demand (COD) removal (94.22%) (Patel *et al.*, 2017). Oleaginous yeasts, such as *Rhodotorula glutinis*, *Rhodosporidium toruloides* and *Criptococcus curvatus*, could also be used to treat municipal wastewater (Pirozzi *et al.*, 2013). Another effective strategy for municipal wastewater treatment could be the application of a common culture of different microorganisms, such as oleaginous yeast and algae (Chi *et al.*, 2011). Using the raw biomass gasification wastewater, the bacterium *Rhodococcus opacus* accumulated 54.3% of lipids with a wastewater COD removal efficiency of 64%. Moreover, these values were further enhanced to 62.8% and 74%, respectively, following supplementation of the wastewater with mineral salt media in the ratio 4:1 (Goswami *et al.*, 2017). Raw refinery wastewater was also utilized by the same oleaginous bacterium for converting it into bio-oil via hydrothermal liquefaction of the lipid-

rich biomass produced during the treatment process. Among the different strategies, the continuous cell recycle system proved efficient in terms of complete removal of COD (99%) and high lipid production (86%) at a hydraulic retention time of 16 h (dilution rate of 0.06 $h^{-1}$) (Paul *et al.*, 2019). In summary, according to Hall *et al.* (2011) and Huang *et al.* (2017), a total of nine oleaginous yeasts and one oleaginous bacterium have been used to treat municipal wastewater so far.

**Table 1**. *Biological treatment of different wastewaters by oleaginous microorganisms*

| Wastewater | Microorganisms | COD removal (%) | Source |
|---|---|---|---|
| Food industry wastewater | | | |
| Wastewater from the monosodium glutamate industry | *Rhodotorula glutinis* | 85.51 | Xue *et al.* (2006) |
| Olive oil mill wastewater | *Lipomyces starkeyi* | NA | Yousuf *et al.* (2010) |
| Wastewater generated by potato processing | *Aspergillus orizae* | 74.2 | Muniraj *et al.* (2013) |
| Wastewater generated by soybean processing | *Chlorella pyrenoidosa* | 77.8 | Hongyang *et al.* (2011) |
| Soybean oil refinery wastewater | *Trichosporon fermentans* | 55 | Qiao *et al.* (2019) |
| Wastewater from the starch industry | *Rhodotorula glutinis* | 80 | Xue *et al.* (2010) |
| Municipal wastewater or sludge | | | |
| Sewage sludge | *Lipomyces starkeyi* | NA | Angerbauer *et al.* (2008) |
| Sludge from paper mills | *Cryptococcus vishniaccii* | NA | Deeba *et al.* (2016) |
| Wastewater from the pulp and paper industry | *Rhodosporidium kratochvilovae* | 77.36 | Patel *et al.* (2017) |
| Municipal wastewater | *Rhodotorula glutinis, Rhorosporidium toruloides, Cryptococcus curvatus* | NA | Pirozzi *et al.* (2013) |
| | A co-culture of oleaginous yeasts and algae | 88 | Chi *et al.* (2011) |
| | Oleaginous consortium (yeasts and bacteria) | 81 | Hall *et al.* (2011) |
| Wastewaters from refineries and biomass gasification industries | *Rhodococcus opacus* | 74 | Goswami *et al.* (2017) |
| | | 99 | Paul *et al.* (2019) |
| Fermentation wastewater | | | |
| Brewery effluent | *Rhodotorula glutinis* | NA | Schneider *et al.* (2013) |
| Wastewater from the bioethanol industry | *Rhodosporidium toruloides* | 72.3 | Zhou *et al.* (2013) |
| Cellulosic ethanol wastewater | *Oleaginous yeasts and activated sludge* | 83.15 | Zhang *et al.* (2018) |
| Distillery wastewater | *Cryptococcus curvatus* | 80 | Gonzales-Garcia *et al.* (2013) |
| | *Rhodotorula glutinis* | 84 | |
| Wastewater from ABE fermentation | *Trichosporon coremiiforme* | 68.0 | Chen *et al.* (2012) |
| | *Trichosporon dermatis* | 68.2 | Peng *et al.* (2013) |
| | *Trichosporon cutaneum* | 68.0 | Xiong *et al.* (2015) |
| Riboflavin (B2) fermentation waste | *Chlorella pyrenoidosa* | 89.2 | Sun *et al.* (2013) |

The food industry is very important in modern society. Many branches of the processing industry, such as the olive oil industry, the starch industry (Field *et al.*, 1987), and the monosodium glutamate industry (Liu *et al.*, 2007), generate large

amounts of wastewater. As a rule, the wastewater from the food industry has a high ratio of BOD5 and COD, which indicates high fermentability, so it is possible to treat them by conventional anaerobic digestion (Hassan and Nelson, 2012). Many studies show that oleaginous microorganisms can also be used to purify wastewater from the food industry. For example, the oleaginous yeast *R. glutinis* was used to produce microbiological oil in wastewater generated by the production of monosodium glutamate, with COD removal reaching as high as 85.51%, but the lipid yield was low (less than 0.25 g/l) (Xue *et al.*, 2006). Still, the lipid yield can be significantly increased by adding glucose to the process (Xue *et al.*, 2008). On the other hand, the oleaginous yeast *L. starkeyi* has been used to purify the wastewater generated in the olive oil mill, with the formation of lipids suitable for biodiesel production (Yousuf *et al.*, 2010). The oleaginous fungus *Aspergillus orizae* was used to treat the wastewater generated by potato processing, with the COD removal accounting for 74.2% (Muniraj *et al.*, 2013). In addition, it has been found that the wastewater from soybean processing can be used to cultivate the oleaginous microalga *Chlorella pirenoidosa*, so that the COD removal amounts to almost 80% (Hongiang *et al.*, 2011). The wastewater from the starch industry was used in one study as a feedstock for microbiological lipid production, by means of yeast *R. glutinis*, with the results indicating the possibility of industrial application of oleaginous microorganisms for wastewater treatment (Xue *et al.*, 2010). Finally, a fungus from the genus *Paecilomyces* with high flocculating activity, that can flocculate the oleaginous yeast *Trichosporon fermentans*, was used to reduce the organic matter in SOR (standard oxygen requirement) wastewater and to produce microbial oil. Under the optimum conditions, the flocculation percentage of *Paecilomyces* sp. against *T. fermentans* from SOR wastewater reached 95% and the removal of COD and oil content in the fermented SOR wastewater reached 55% and 53%, respectively (Qiao *et al.*, 2019).

Large amounts of wastewater are also generated after fermentation. In the biological wastewater treatment in the fermentation industry, the anaerobic-aerobic method based on activated sludge is usually used with the implementation of special equipment (Lu *et al.*, 1999; Pant and Andoleya, 2007). Recently, it has been established that oleaginous microorganisms can be used to treat wastewater from various fermentation industries. Thus, the waste from the brewery was used as a fermentation substrate for the simultaneous accumulation of microbiological oil and carotenoids, by means of the oleaginous yeast *Rhodotorula glutinis* (Schneider *et al.*, 2013). In addition, oleaginous yeast *Rhodosporidium toruloides* was used to treat bioethanol wastewater, with the COD removal, yeast biomass and lipid content 72.3%, 3.8 g/l, and 34.9%, respectively (Zhou *et al.*, 2013). Oleaginous yeasts *R. glutinis* and *Cryptococcus curvatus* were used to treat wastewater from distilleries, with the COD removal accounting for about 80% (Gonzales-Garcia *et al.*, 2013). Similar to ethanol fermentation, ABE (acetone-butanol-ethanol) fermentation also generates a significant amount of wastewater after treatment. It has been found that oleaginous microorganisms can treat wastewater of ABE fermentation so that the removal of COD amounts to almost 70% (Chen *et al.*, 2012; Peng *et al.*, 2013; Xiong *et al.*, 2015). Other wastewaters from the fermentation process can also be treated using oleaginous microorganisms. For instance, the oleaginous microalga *C. pirenoidosa* was used for the remediation of fermentation eluates of riboflavin (B2),

with the COD removal being as high as almost 90% (Sun *et al.*, 2013, In: Huang *et al.*, 2017). Finally, a strategy for lipid production through coupling oleaginous yeasts and activated sludge biological methods by the cultivation of *R. glutinis* in cellulosic ethanol wastewater was also used. Under optimal conditions in wastewater medium (dilution ratio of 1:2 and glucose supplement of 40 g/l), the maximum biomass and lipid content, as well as the lipid yield, reached 11.31 g/l, 18.35%, and 2.08 g/l, with the associated removal rates of COD, total organic carbon (TOC), $NH_4^+$-N, total nitrogen (TN) and total phosphorous (TP) reaching 83.15%, 81.81%, 85.49%, 70.52%, and 67.46%, respectively. In contrast, cellulosic ethanol wastewater treated by the anaerobic-aerobic biological process resulted in the removal of COD, $NH_4^+$-N, TP, and TN reaching 67.55%, 94.17%, 90.16%, and 48.89%, respectively (Zhang *et al.*, 2018).

An overview of oleaginous microorganisms, used for the treatment of industrial and municipal wastewater, is shown in Table 1.

From the discussion above, it is clear that conventional anaerobic-aerobic biological treatment has a great total removal of COD from industrial and municipal wastewaters (greater than 80%, and sometimes even 90%). In contrast, in the case of biological wastewater treatment by oleaginous microorganisms, the removal of COD is usually relatively low – less than 80%. As a result, these technologies are considered less competitive with other technologies that have industrial applications. Therefore, in order to achieve the industrialization of wastewater treatment by oleaginous microorganisms, the most important task these technologies are facing is to increase the efficiency of COD removal to meet water quality standards.

### 3.2. Inoculated microorganisms

The results of many studies in the literature suggest that, in the activated sludge systems, bioaugmentation can improve the performance of contaminated water treatment by adding external microorganisms with a high degradation capacity of specific pollutants (e.g., Van Limbergen *et al.*, 1998; Yu and Mohn, 2002; El Fantroussi and Agathos, 2005). However, the ecological background (different natural life forms living in communities within a biotope inoculated with an exogenous inoculum) is a major obstacle to the successful performance of bioremediation with such inoculum. In terms of survival, activity, and migration, the relationship of the inoculated microorganism with new biotic and abiotic environments may be crucial to the outcome of any bioaugmentation strategy. There is an increasing amount of information in the literature that the best way to overcome such environmental barriers is to identify microorganisms from the same ecological niche with those present in the contaminated area that is being treated (e.g., El Fantroussi and Agathos, 2005; Thompson *et al.*, 2005).

The design of a single inoculum of the bioaugmentation strategy involves isolation of individual strains of controlled origin, in order to determine which of them show special abilities of decomposition of various pollutants in wastewater. However, the decomposition ability of the whole microbial consortium is usually greater than the ability of any strain in it, because it often depends on the mutual interaction that takes place in microbial consortia (Huban and Plowman, 1997). Microorganisms selected for inoculum formation should be able not only to break

down the target pollutants, but also to be competitive with other microorganisms, compatible with the indigenous microbial community, and complementary and/or synergistic for the degradation of effluents (Yu and Mohn, 2002).

### 3.3. Assessment of the degree of microbiological air pollution in WWTPs

The number of microorganisms in the air is one of the basic indicators of atmospheric pollution. The character and effect of microorganisms on the environment depend on their initial concentration in the sewage, development phase, emission threshold, wastewater treatment technology, aeration techniques and meteorological and environmental conditions. Microorganisms, which are transferred from the sewer to the air, by aerosol, are subjected to certain conditions that can prevent their development. Some of them die quickly, mainly from drying out or from exposure to excessively high or low temperatures and/or solar radiation. However, other microorganisms are equipped with specific mechanisms that allow them to fight against adverse environmental conditions that inhibit their biological activity (Andersen and Frisvad, 2002; Agranovski *et al.*, 2003).

To assess microbiological air contamination in WWTPs, and the potential exposure hazard to workers and people living in their immediate surroundings, many authors have studied the bioaerosols in and/or near these plants.

In Poland, Filipkowska *et al.* (2000) studied the emission levels of microbiological pollutants from the wastewater treatment plant in Bartoszyce. The results of the study showed that aeration tanks constitute a significant source of biological aerosol emissions. However, considerably smaller amounts of microorganisms were emitted into the atmosphere from wastewater-collection posts and secondary settling tanks. In addition to this study, Breza-Boruta and Paluszak (2007) carried out microbiological research of bioaerosols in the Municipal Sewage Treatment Plant in Toruń. The concentration of selected bacteria, fungi and actinomycetes in the atmospheric air was estimated in the vicinity of sand catchers, aeration chambers and maturing compost piles, as well as 100 m beyond the treatment plant. It was found that the air at the test stands showed different degrees of microbiological pollution. The largest bioaerosol emission sources were the sand catcher and the maturing compost storage facility. Specifically, the total number of bacteria and fungi amounted to a maximum of 104 CFU/$m^3$, and of actinomycetes – 103 CFU/$m^3$. The bacteria of the genus *Pseudomonas* (fluorescent subgroup) occurred at all the stands throughout the study except December. The number of *Escherichia coli* and bacteria of the genera *Enterococcus* and *Salmonella* remained at the very low level of about 101 CFU/$m^3$, and of all these bacteria only faecal streptococci D-type were isolated beyond the treatment plant.

The study done by Michałkiewicz *et al.* (2011) dealt with microbiological air pollution around wastewater treatment plants in Słupca, Kostrzyń, and Września, and the Complex Wastewater Treatment and Wastes Composting Plant in Grodzisk Mazowiecki. The results showed that the largest group of microorganisms in the monitored air were psychrophilic and mesophilic bacteria and microscopic fungi. The number of psychrophilic bacteria ranged from 78 to 225,000 CFU/$m^3$, the number of mesophilic bacteria varied in the range from 0 to 195,000 CFU/$m^3$, and

the fungi from 0 to 65,700 CFU/$m^3$ of air. The number of other bacteria (*Staphylococcus*, *Pseudomonas fluorescens*, and coliforms) ranged from 0 to 87,500 CFU/$m^3$. The authors detected a great number of bacteria and fungi near sewage aeration tanks, places of sludge disposal, and grit chambers. A change in air pollution has been noted depending on the season and climatic conditions (wind strength in particular).

The most notable study was conducted by Korzeniewska *et al.* (2009). The authors collected air samples at five locations in the WWTP area, and at five locations around the plant, and at one control location. The sampling sites were selected where the emission of bacterial aerosol and dust was potentially the highest, taking into account the wind direction (sampling along the wind direction), as well as the distance from the plant fence. In this study, special attention was paid to faecal bacteria from the family Enterobacteriaceae, because they represent a typical sewage microflora. The results of the study showed that the largest number of bacteria from this family is found in the air sampled inside the bioreactor. The great diversity of bacteria in the sewage during the wastewater treatment phase was then reflected in the air samples collected inside the bioreactor, outside the bioreactor (under the roof), as well as at the outlet of the treated sewage leading into the drainage ditch. Species belonging to the genera *Pantoea* and *Serratia* were predominant on the fence, and near the plant, while *Escherichia vulneris, Enterobacter sakazakii* and *Klebsiell* sp. were found further from the WWTP. However, no mannitol positive bacteria of the genus *Staphylococcus* were observed in the analyzed sewage and air samples. The results of mycological analyzes of the air samples collected within the WWTP indicated a higher number of mold species than it was the case with yeasts and filamentous fungi. Numerous fungi, which could be harmful in the natural human environment, were sporadically discovered during the summer, near the bioreactor. Namely, species of the genera *Alternaria, Aspergillus, Cladosporium, Mucor, Oidium, Penicillium, Absidia, Actinomucor* and *Botritis* have been identified in the WWTP area, as well as in its surroundings. Among the yeasts that predominated in sewage were species of the genera *Candida, Cryptococcus,* and *Rhodotorula,* isolated mainly from air sampled near the grate chamber and within the bioreactor itself. The genera *Candida* and *Cryptococcus* were also present in the vicinity of the WWTP. The significant statistical differences in the number of investigated groups of microorganisms were observed between air samples collected in summer and during autumn in relation to those obtained in winter and spring. Their highest mean number was determined in air sampled in summer (except actinomycetes, psychrotrophic and hemolytic bacteria, which were most abundant in spring, as well as yeasts and molds that were most abundant in autumn), while the lowest number was recorded in winter and/or in spring. No significant statistical differences in the number of these microorganisms were detected between the air samples collected from different locations. As already mentioned, the highest concentrations of bacteria from the Enterobacteriaceae family, which ranged from $2.0x10^5$ to $4.0x10^7$ CFU/$cm^3$, were found in the air inside the bioreactor, its vicinity, as well as near the grate chamber. The high diversity of bacteria from this family (including *Shigella* spp., *Iersinia enterocolitica*, *Escherichia coli* and *Clebsiella pneumoniae ozaenae*) may indicate a health risk for plant personnel in case of prolonged exposure time. However, no increased emissions of the analyzed groups

of microorganisms were found outside the WWTP, which also applied to faecal bacteria (*Escherichia coli* and *Clebsiella pneumoniae ozaenae*). Purified sewage water was dominated by yeasts and yeast-like fungi.

A quantitative and qualitative analysis of airborne microorganisms near a WWTP was also conducted by Grisoli *et al.* (2009) in Italy. Six sites were selected as air sampling sites. Near the facilities, mesophilic bacteria, psychrophilic bacteria and microfungi showed the highest median concentrations of 307.5, 327.5, and 257.5 CFU/$m^3$, respectively. The contamination index – global index of microbial contamination (GIMC/$m^3$) showed mean values of 4058.9 in summer and 439.7 in winter and the contamination index – amplification index showed values of 4.5 and 1.1 in the same seasons, respectively. Controlling the seasonal effect, mesophilic bacteria, *Pseudomonas* spp. and Enterobacteriaceae showed a significant decline in concentration with respect to upwind air samples and with increasing distance.

In China, Yang *et al.* (2019) collected air samples from various treatment facilities of a typical WWTP. Concentrations of airborne bacteria varied in a wide range (23–4878 CFU/$m^3$). It was found that the main emission sources of airborne bacteria were treatment facilities with aeration, mechanical agitation, and located indoors. For treatment facilities located indoors, higher percentages of airborne bacteria were associated with wastewater and sludge, while more airborne bacteria were originated from the ambient air for outdoor installations. Opportunistic pathogens (e.g., *Micrococcus*, *Bacteroides*, *Chryseobacterium*, *Pseudomonas* and *Acinetobacter*) were detected in airborne bacteria.

Based on the analyzed data from the literature, it may be argued that the studied facilities do not pose a hazard in respect of the tested bacteria emissions (Breza-Boruta and Paluszak, 2007). However, even if these plants do not represent a potential risk for nearby populations, they may pose a potential health risk for workers (Grisoli *et al.*, 2009). According to Yang *et al.* (2019), inhalation is the main pathway for on-site exposure of workers to airborne bacteria. Thus, due to the presence of opportunistic pathogens, strict control measures should be employed in WWTPs to reduce infection risks. Research data have shown that coliform bacteria represent a good indicator of microorganisms' emissions from sewage into the air (Michałkiewicz *et al.*, 2011). In relation to this, Korzeniewska *et al.* (2009) stated that covering the aeration chambers significantly reduces the formation of aerosols and the number of microorganisms that is present in the air inside the plant and in its surroundings.

## 4. CONCLUSION

Based on the data from the reference literature, the following conclusions can be drawn:

- The usual solution for the wastewater problem is to use the so-called co-cultures of microorganisms. Activated sludge is one such example of a natural population of microorganisms. Biodegradation of organic materials can also be achieved by the co-culture method. Another way to overcome this environmental problem is to identify microorganisms from the same ecological niche as those that exist in the contaminated area which is being treated;
- With conventional anaerobic-aerobic biological treatment, the total

removal of COD from industrial and municipal wastewaters can be greater than 80%, and even 90%. In contrast, in the case of biological wastewater treatment by oleaginous microorganisms, we have relatively low removal of COD – usually less than 80%. For this reason, these technologies are less competitive with other technologies with industrial applications. Thus, to achieve the industrialization of wastewater treatment using oleaginous microorganisms, the most important task these technologies are facing is to increase the efficiency of COD removal in order to meet the standards for water quality.

- The degree of air pollution in WWTPs, as well as their surroundings, is reflected by faecal bacteria from the family Enterobacteriaceae, which represent the typical sewage microflora. Thus, their number should be monitored in order to accurately determine the effects of the plant on the natural environment and human health;

- The main sources of bioaerosol emissions in the area of a WWTP are the bioreactor and the grate. The great diversity of species and the increased number of bacteria of the Enterobacteriaceae family, including pathogenic and opportunistic bacteria, found in the air emitted in the bioreactor, may mean that the health of the personnel spending longer periods in or near the bioreactor could be at risk. Still, covering the aeration chambers significantly reduces the formation of aerosols and the number of microorganisms present in the air of the plant and its surroundings;

Future research should focus on the development of the wastewater treatment technologies using the co-culture methods, a combination of chemical or physical treatments, control and adaptation of the fermentation processes, as well as by other methods.

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## ENVIRONMENTAL ASPECTS OF BIOLOGICAL WASTEWATER TREATMENT BY DIFFERENT METHODS AND MICROORGANISMS

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### Summary

Wastewaters are one of the critical problems of industrial production and urban organization. Biological wastewater treatment has many advantages, such as the simple operation of bioreactors, potential for the production of valuable bioproducts and the efficiency of the treatment itself. However, it also has certain downsides, such as environmental pollution and endangering the health of the working personnel. For this reason, this paper provides a comprehensive overview of information on microorganisms involved in the wastewater treatment process, the factors that negatively affect their development and the negative effects of these microorganisms on the environment.

For processing and presentation of collected data from numerous reference sources, the analytical-synthetic method was applied. The results related to the issue of the impact of the wastewater treatment plant (WWTP) on the environment and the personnel engaged in this process are considered.

The results of the research show that by using the conventional anaerobic-aerobic biological treatment, the total removal of COD (chemical oxygen demand) from industrial and municipal wastewater reaches a value of near 90%. In contrast, in the case of biological wastewater treatment by oleaginous microorganisms, there is usually a relatively low removal of COD (<80%). Undoubtedly, this makes the technologies in question less competitive with other industrial technologies. To implement the treatment of wastewater by oleaginous microorganisms on an industrial level, it is necessary to increase its efficiency to remove COD.

In the context of possible air pollution in the area of WWTP, the main sources of bioaerosol emissions are the bioreactor and the grate. The great diversity of species and the increased number of genera of bacteria from the family Enterobacteriaceae indicate that the health of personnel who stay longer in and/or near the bioreactor could be endangered. However, covering the aeration chambers significantly reduces the formation of aerosols, as well as the number of microorganisms present in the air in the closed area of the WWTP and its surroundings.

Future research should focus on the development of wastewater treatment technologies using the co-culture methods, a combination of chemical and physical treatments, as well as by controlling and modifying this process.

## EKOLOŠKI ASPEKTI BIOLOŠKOG PREČIŠĆAVANjA OTPADNIH VODA RAZLIČITIM POSTUPCIMA I MIKROORGANIZMIMA

*Tatjana VIJATOV, Gordana DRAŽIĆ, Filip JOVANOVIĆ*

### Rezime

Otpadne vode su jedan od kritičnih problema industrijske proizvodnje i gradske organizacije. Biološko prečišćavanje voda ima niz prednosti, poput jednostavnog rada bioreaktora, potencijala za proizvodnju vrednih bioproizvoda i efikasnosti samog tretmana. No, ono poseduje i određene negativne karakteristike, kao što su zagađenje okoline i ugrožavanje zdravlja angažovanog osoblja. Iz tog razloga, u ovom radu se daje iscrpan pregled informacija o mikroorganizmima zastupljenim u procesu prečišćavanja voda,

faktorima koji negativno utiču na njihov razvoj i negativnim efektima ovih mikroorganizama na životnu sredinu.

Za obradu i prikaz prikupljenih podataka iz brojnih literaturnih izvora, primenjen je analitičko-sintetički metod. Sagledani su rezultati koji se odnose na problem uticaja postrojenja za prečišćavanje otpadnih voda (PPOV) na okolinu i osoblje koje je angažovano u ovom procesu.

Rezultati istraživanja pokazuju da konvencionalnim anaerobno-aerobnim biološkim tretmanom, ukupno uklanjanje HPK (hemijska potrošnja kiseonika) iz industrijskih i komunalnih otpadnih voda dostiže vrednost od 90%. Nasuprot tome, u slučaju biološkog tretmana otpadnih voda oleaginoznim mikroorganizmima imamo relativno nisko uklanjanje HPK (<80%). Nesumnjivo, to ove tehnologije čini manje konkurentnim drugim industrijskim tehnologijama. Da bi se ostvario tretman otpadnih voda oleaginoznim mikroorganizmima na industrijskom nivou, potrebno je povećati njegovu moć uklanjanja HPK.

Kada je reč o potencijalnom zagađenju vazduha oko PPOV, utvrđeno je da su glavni izvori emisije bioaerosola na području PPOV bioreaktor i rešetka. Veća raznolikost vrsta i povećan broj rodova bakterija iz porodice Enterobacteriaceae ukazuju na to da bi zdravlje osoblja koje duže boravi u bioreaktoru ili u njegovoj blizini moglo biti ugroženo. No, pokrivanje aeracionih komora značajno smanjuje stvaranje aerosola, kao i broj mikroorganizama prisutnih u vazduhu u zatvorenom području PPOV i njegovoj okolini.

Buduća istraživanja treba usmeriti ka razvoju tehnologija prečišćavanja otpadnih voda metodama zajedničke kulture, kombinacije hemijskog i fizičkog tretmana, kao i putem kontrole i prilagođavanja ovog procesa.

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# GUIDELINES FOR THE INTRODUCTION OF BIOLOGICAL SYSTEMS FOR REVITALIZATION OF POLLUTED WATER AND WASTEWATER TREATMENT IN STRATEGIC DOCUMENTS IN SERBIA

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**Abstract**: *Long-term courses of water protection and management are based on the fact that Serbia belongs to the region of UNECE countries (UN Economic Commission for Europe) while most of its territory belongs to the Danube River Basin where countries have established multilateral coordination and cooperation in water management. Since the Republic of Serbia is currently in the process of joining the EU, it is obliged to gradually align its strategic decisions in the field of water to the documents that apply to EU member states. The degree of the state's readiness to join the EU will be assessed based on the adequate introduction of internationally accepted principles of water management into the strategic documents and their establishment and implementation at the state level and within international cooperation in this area. Serbia will not be granted EU membership unless it invests significant funds in wastewater and polluted water treatment, as this is one of the priorities in meeting the criteria to open Chapter 27. The introduction of biological systems into the standard water treatment infrastructure provides higher levels of environmental protection and contributes to the integration of environmental requirements, opinions and principles into the plans and programs that encourage and promote sustainable development. The paper will present the current level of alignment between EU and Serbian water-related legislation and propose specific guidelines for the introduction of biological systems for the treatment of polluted water in strategic documents in Serbia.*

**Keywords***:* revitalization of polluted water, wastewater treatment, EU strategic documents, biological water-treatment systems, guidelines, Serbia.

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# SMERNICE ZA UVOĐENJE BIOLOŠKIH SISTEMA ZA REVITALIZACIJU ZAGAĐENIH I PREČIŠĆAVANJE OTPADNIH VODA U STRATEŠKA DOKUMENTA U SRBIJI

**Izvod:** *Dugoročni pravci zaštite i upravljanja vodama zasnovani su na činjenici da Srbija pripada regionu zemalja UNECE (Ekonomska komisija UN za Evropu) i najvećim delom teritorije slivu Dunava na kome su države uspostavile multilateralnu koordinaciju i saradnju u upravljanju vodama. Pošto se Republika Srbija trenutno nalazi u procesu pridruživanja EU, sledi i obaveza da svoje strateške odluke u oblasti voda postepeno prilagođava dokumentima koji važe za države članice EU. Od adekvatnog uvođenja međunarodno prihvaćenih principa upravljanja vodama u strateška dokumenta i uspostavljanja i njihovog sprovođenja na državnom nivou i u okviru međunarodne saradnje u ovoj oblasti, zavisiće i opšta ocena stepena spremnosti države za priključenje EU. Srbija neće moći da pristupi Evropskoj uniji ukoliko ne uloži značajna sredstva u prečišćavanje otpadnih i zagađenih voda, jer je to jedan od prioriteta u ispunjavanju kriterijuma za poglavlje 27. Uvođenje bioloških sistema u standardu infrastrukturu za prečišćavanje zagađenih voda u direktnoj je vezi sa obezbeđivanjem višeg nivoa zaštite životne sredine i integracije ekoloških zahteva, mišljenja i načela u planove i programe u cilju podsticanja i unapređenja održivog razvoja. U radu će se prikazati dosadašnji stepen usaglašenosti vodnog zakonodavstva EU i Srbije i predložiti konkretne smernice za uvođenje bioloških sistema za prečišćavanje zagađenih voda u strateška dokumenta u Srbiji.*

**Ključne reči:** revitalizacija zagađenih voda, prečišćavanje otpadnih voda, strateška dokumenta EU, biološki sistemi za prečišćavanje voda, smernice, Srbija.

## 1. INTRODUCTION

Biological systems as a type of green technology enable the removal of different categories of pollutants from polluted water and wastewater with great efficiency. It is done in a completely natural way, without the use of chemicals or additional energy, and thanks to symbiotic relationships between its main components (plants, microorganisms, algae, substrate, and water) (Čule *et al*., 2017).

**Figure 1.** *A biological system, 2020 (Orig.)*

Despite their innovativeness, biological systems have not been recognized in the laws related to environmental protection, nature protection, water management and other relevant regulations of the Republic of Serbia yet. However, it is encouraging that the current legislation makes provision for the introduction of various biological water treatment systems in Serbia, either as an independent process in some areas or as a supplement to conventional treatment systems.

In the sector of environmental protection, i.e., in the field of water protection, the basic requirements set by the European Union to its potential members are: improvement and expansion of the water supply network; improvement and expansion of the sewerage network; construction of wastewater treatment facilities; cleaning of contaminated soil and polluted watercourses with unsatisfactory water quality; protection of (aquatic) ecosystems, habitats and protected species from economic and environmental pressures; prevention of further pollution of both surface water and groundwater, etc. (Stevanović-Čarapina, 2005).

EU candidate countries, including Serbia, need to harmonize their regulations with those of EU legislation related to water, which includes various and numerous directives, regulations, decisions, and resolutions. The group of water-related EU regulations includes regulations related to integrated pollution prevention and control (IPPC), regulations governing the field of environmental impact assessment (EIA), strategic environmental assessment (SEA), regulations governing the public access to environmental information, public participation in decision-making on environmental issues, waste management, as well as numerous regulations governing the protection of other aspects of the environment (soil, air, biodiversity) and others.

Having recognized the aspirations of an environmentally conscious society to acknowledge water management and protection as one of its main tasks, the Secretariat for Environmental Protection of the City of Belgrade and the Institute of Forestry, Belgrade set up the project "Revitalization of the Topčiderska River using biological systems for the treatment of polluted waters" in 2014, and then in 2016 the project "Revitalization of the lake at the locality of Trešnja by the system of Floating Islands".

In both projects, special attention was paid to the harmonization of EU and Serbian water legislation and the proposal of measures that need to be implemented in order to integrate biological systems into the standard infrastructure for the revitalization of polluted water and treatment of wastewater and introduce them into the strategic documents in Serbia. This paper gives a brief overview of the results that have been achieved in this field.

## 2. METHODOLOGY

The study was performed using the method of analysis with elements of generalization and inductive-deductive approaches. The method of generalization "... forms general attitudes on the basis of individual ones“ (Miljević, 2007). The method of induction "… derives general attitudes from several special ones" (Milosavljević, Radosavljević, 2008), while the method of deduction, which "…

represents a form of inference", acquires special knowledge on the basis of "… general legal understanding" (Miljević, 2007). Of the basic scientific methods, a comparative method was used, the subject of which is "… identity, similarity and diversity of the same phenomenon at different times and in different spaces determined by adequate measures, identical or diverse phenomena in a defined space and time" (Miljević, 2007). To study the content of documents, content analysis was applied as a kind of partial analysis (Milosavljević, Radosavljević, 2008).

The data on EU and Serbian Water Law was analyzed by comparing different international declarations, legal regulations and acts in the European Union and Serbia in the field of water and environmental protection. The data on biological systems for the treatment of polluted water and wastewater was analyzed on the basis of collected literature data and previous knowledge of researchers engaged in both projects.

## 3. RESULTS AND DISCUSSION

The European Union does not compel any country on how to organize its legislation. The approximation of law is a joint obligation to be fulfilled to gain membership in the European Union. It means that countries aspiring to join the European Union must align their national laws, rules, and procedures to enable efficient transposition of the overall legal structure of the EU (Brašanac-Bosanac, Lj., 2014). As the obligation to approximate continues after accession, the pre-accession approximation process becomes an opportunity for a country to organize its institutions and procedures and to train its staff for daily tasks and responsibilities of European Union law-making, implementation, and enforcement.

Within the group of EU regulations related to the environment, there are many regulations applicable to issues of water protection and water management. According to Todić, D. and Isoski, Z. (2005), these include, before anything else, all those regulations that refer to integrated pollution prevention and control (IPPC). Then, there are the regulations that relate to the field of environmental impact assessment (EIA), strategic environmental assessment (SEA), or the public access to environmental information. They also include numerous regulations governing the protection of other aspects of the environment (soil, air, biodiversity), waste management, and others.

The field of water protection and water management is regulated by 17 directives. The WFD is an “umbrella” directive that includes and links other important directives that directly or indirectly relate to the field of water. European Union water legislation is of paramount importance not only for the Member States but also for all countries that intend to cooperate or become members of the Union. The most important act in the field of water is the Water Framework Directive (WFD). It is an operational tool to achieve the key goal of European water policy, which is "comprehensive protection of all water bodies, taking into account the natural interaction between them in quantitative and qualitative terms, with the application of the principle of integrated water resources management ". The concept of integration of all relevant segments (water resources at the basin level, environmental protection, water use, legislation, decision-making levels, water

management of transboundary basins through international cooperation, etc.) is the only key to achieving the set goals. With the adoption of the Water Framework Directive, water resources in the EU have become a concern of the whole Union, which implies the obligation of each Member State to harmonize the legislative, and technical and economic approach to water management and ensure a coherent water management strategy. Countries that are on their way to becoming EU members also have this obligation.

***Introduction of biological systems into the standard infrastructure for the revitalization of polluted water and treatment of wastewater***

- ✓ In order to introduce a biological system for the revitalization of polluted water and treatment of wastewater into the standard infrastructure, which is prescribed by appropriate legislation, certain by-laws, and standard planning documentation, it is necessary to conduct preliminary, comprehensive research at a particular location and polluted watercourse or water surface.
- ✓ If the results of research at a particular location indicate that the applied biological treatment can reduce the content of different categories of pollutants that are parameters for assessing the ecological status of water, the data can be used as a direct indicator of the efficiency of biological systems for the revitalization of polluted water and treatment of wastewater and allow their introduction into appropriate strategies, programs, and plans.
- ✓ It is necessary to determine the limiting concentrations of pollutants and percentages of pollution reduction after biological wastewater treatment.
- ✓ Bearing in mind that there are significant differences between rural and urban areas regarding the indicators of development such as demographic characteristics (population and population density), type of economic activity (dominant industrial or agricultural activity), income (higher or lower revenues), existing communal infrastructure (developed or poorly developed water supply and sewerage network, the presence of septic tanks), it is necessary to adjust the relevant by-laws to these conditions.
- ✓ The concept of the rural system for wastewater collection and treatment needs to be adapted to the specific area and the primary goal is to protect water from pollution (especially drinking water sources of local water supply systems) and thus protect human and livestock health.
- ✓ In order to improve the condition of the communal infrastructure in rural areas, when planning and building biological systems for wastewater collection and treatment, it is necessary to prescribe precise and concrete rules of conduct for individuals, legal entities, and competent local self-government bodies. The technical conditions of the by-law would refer to the design, construction, construction supervision, use, and maintenance of facilities and devices for wastewater collection and treatment in rural areas where technical, economic, and organizational requirements for a public sewerage system cannot be met. The conditions would refer to natural and legal persons who, as owners or users, build or already have residential, sports, educational, or tourism facilities.

- ✓ Local self-government bodies are obliged to develop an implementation program and submit its draft to the Ministry in charge of water management and environment to assess its content.
- ✓ Besides the by-law that serves as a planning act in the field of planning and construction, it is necessary to adopt special by-laws related to environmental protection.
- ✓ In dispersed rural settlements, there is a possibility that users are not willing to accept the new concept, which calls for a previous education campaign. Before the implementation, a pilot system must be developed and by-laws made in different environments.
- ✓ Regardless of the type of water supply and the size of the biological system, when introducing biological systems into the standard infrastructure for the treatment of polluted water, all principles of risk management in regular and emergency situations must be applied, so that measures for the remediation of the state resulting from extreme events are of smaller extent but more effective.

**Figure 2**. *A floating island after the first year of revitalization, 2019 (Orig.)*

## 4. CONCLUSIONS

The harmonization of EU and Serbian water legislation is a long-term process, which implies the joint engagement of all relevant actors, both the state and the business, academic, and scientific community and international organizations. It is extremely important that the Republic of Serbia is actively involved in EU development programs, because it takes many years for the prescribed and foreseen innovations and guidelines to be applied in practice. In recent years, the Republic of Serbia has largely harmonized its water legislation with the EU Water Framework Directive and accompanying regulations (2010a, 2010b, 2011, 2015). In order to adequately and timely react and establish more successful cooperation with the countries of the European Union in the coming period, it will be necessary:

- ✓ to continue the process of integration, multilateral and bilateral cooperation following the recommendations of the European Directive in the field of EU water policy WFD/2000/60, Directive 2007/60 EC on flood risk assessment and management and other EU directives in the field of water (1998, 2000, 2009) .
- ✓ to conduct water quality monitoring and prevent and sanction hazardous situations and negligence of individuals;
- ✓ to conceptualize an adequate state response to the consequences;
- ✓ to promote biological systems for the revitalization of polluted and treatment of wastewater and introduce them into standard infrastructure through national strategic documents and action plans wherever previous research shows that it will be possible and efficient.

In order to preserve and improve water resources in the Republic of Serbia, it is necessary to establish such social relations in which the use and protection of the quality of water and environment in riparian areas becomes a concern of each and every individual. Such a goal requires education and participation of the scientific and professional public and incentives based on economic relations and public awareness.

The introduction of biological systems in the standard infrastructure for the revitalization of polluted water and treatment of wastewater is an important instrument of the general, strategic, and previously harmonized environmental and development interests of Serbia. Their implementation is directly related to ensuring a higher level of environmental protection and the integration of environmental requirements, opinions, and principles into plans and programs to encourage and promote sustainable development.

**Note:** *The paper is the result of research within the projects: "Revitalization of Topčiderska River using biological systems for the treatment of polluted water" (Contract No. V-01 401.1-83) and "Revitalization of the lake at the locality of Trešnja by the System of Floating Islands" (Contract No. V-01 401.1-50), funded by the Secretariat for Environmental Protection of the City of Belgrade.*

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## GUIDELINES FOR THE INTRODUCTION OF BIOLOGICAL SYSTEMS FOR REVITALIZATION OF POLLUTED WATER AND WASTEWATER TREATMENT IN STRATEGIC DOCUMENTS IN SERBIA

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### Summary

Despite their innovativeness, biological systems for revitalization of polluted water and wastewater treatment, have not been recognized in the laws related to environmental protection, nature protection, water management and other relevant regulations of the Republic of Serbia yet. EU candidate countries, including Serbia, need to harmonize their regulations with those of EU legislation related to water, which includes various and numerous directives, regulations, decisions, and resolutions. In order to introduce a biological system for the revitalization of polluted water and treatment of wastewater into the standard infrastructure, which is prescribed by appropriate legislation, certain by-laws, and standard planning documentation, it is necessary to conduct preliminary, comprehensive research at a particular location and polluted watercourse or water surface. The introduction of biological systems in the standard infrastructure for the revitalization of polluted water and treatment of wastewater is an important instrument of the general, strategic, and previously harmonized environmental and development interests of Serbia.

## SMERNICE ZA UVOĐENJE BIOLOŠKIH SISTEMA ZA REVITALIZACIJU ZAGAĐENIH I PREČIŠĆAVANJE OTPADNIH VODA U STRATEŠKA DOKUMENTA U SRBIJI

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### Rezime

Iako predstavljaju inovativnu tehnologiju, biološki sistemi za revitalizaciju zagađenih i prečišćavanje otpadnih voda još uvek nisu prepoznati u zakonima koji regulišu oblasti zaštite životne sredine, zaštite prirode, vode i drugim relevantnim propisima Republike Srbije. Zemlje kandidati za ulazak u EU, uključujući i Srbiju moraju da usklade svoje propise sa onim što obuhvata legislativa EU u oblasti vodnog prava u koju spadaju različite i brojne direktive, uredbe, odluke i rezolucije. Da bi se biološki sistem za revitalizaciju zagađenih i prečišćavanje otpadnih voda uveo u standardnu infrastrukturu, koju propisuje odgovarajuća zakonska regulativa, pojedini podzakonski akti i standardna planska dokumentacija, neophodno je sprovesti preliminarna, sveobuhvatna istraživanja na određenoj lokaciji i zagađenom vodotoku ili vodenoj površini. Uvođenje bioloških sistema u standardu infrastrukturu za revitalizaciju zagađenih i prečišćavanje otpadnih voda predstavlja značajan instrument generalnih, strateških i prethodnog usaglašenih ekoloških i razvojnih interesa Srbije.

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# HUNTERS IN EUROPE
# WHAT DOES IT MEAN „THE HUNTERS POPULATION“ IN EUROPE?

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**Abstract:** *According to FACE (The European Federation of Associations for Hunting) approximately 7 million hunters are registered in Europe. Throughout the year they work in nature, in the hunting ground, or organize work of supporting teams and individuals on development of habitats with different kinds of animals, of which only some are hunted or listed as game. By using methods of positive selection and care in order to increase quality and quantity of the habitat itself, is maintained and permanently increased biological diversity of plant populations and whole ecosystem same as animal populations, including game. Disappearance of certain animal species in certain parts of Europe surely is not caused by game management, but is a result of rapid urbanization and development of urban and rural areas with all the supporting infrastructure. Human overpopulation parallel brought to reduction of habitat areas for numerous animal and game species. It's therefore required to establish balance between humans and other beings on a certain space, which therefore requires good management. The most competent members of human community which can manage wild animals and game in the most competent way are certainly hunters. In every community mutual understanding and cooperation of all other stakeholders and ecosystem beneficiaries is key. We should not forget that a human is part of natural ecosystem and a hunter is the most competent person who understands habits and life of game animals and therefore can manage it in the best way. Due to this reason game, hunter and hunters population take care of the game animals survival, their overall food chain their development*

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*and relative relationship in order to avoid deterioration and favoring of certain species over the other, increasing biological diversity of game animals and habitat which they inhabit; of overall and particular individual health state, of active and passive protection defining and implementing regulations important for behavior and management, on the basis of good management and good will in this way actively and significantly contributing to development of environmental protection.*

**Key words:** game animal's protection, biodiversity, rural development, game tourism, weapon, game management

## 1. INTRODUCTION

One of the oldest human activities or work is certainly hunting. Through hundreds and thousands of years, animal hunting has gone through considerable transformation. Transformation in sense of a need for hunting, ways of hunting, game breeds, hunting weapons and tools, areas on Earth where people hunt, number of hunted game, number of hunters. The most considerable changes in game hunting happened when hunting, from ultimate need for surviving and ensuring of meat food for survival of tribe, family and human race, grew into a kind of fun and hobby (More, 1973; Potter et al,. 1973; Stankey et al. 1973; Hende, 1974; Kellert, 1978; Hautaluoma and Brown, 1979). But the secondary reason was still considerable and important need for ensuring food (Robinson and Redford, 1991; Muchaal and Ngandjui 1999) and regulating the wildlife population (Brown et al., 2000; Di Minin et al., 2016). Another considerable change appeared with inventing of firearms and guns that made hunting much easier and considerably changed the way and methods of game hunting. With time, number of hunters in population grew smaller in relation to other activities. Also, involvement of hunters because of dire need for surviving became ever smaller in relation to hunting for pleasure, fun, hobby or trophy selling (Lewis and Alpert 1997). But still, even today, in some parts of the world, hunting game for food and survival of communities where hunters live is very much present.

Looking from today's aspect and time where developed population in Europe lives, a question that arises is this: is hunting only fun, which is how many hunting circles are trying to present it and all that at the expense and harm of animals.

Also, another question is: in society, what is the significance of hunter population, if that is how we can call all those who practice hunting, in wider or narrower area.

According to data of FACE (The European Federation of Associations for Hunting) there are about 7 million hunters registered in Europe. That is a very respectable number which, by its scope, excels entire population of some countries in Europe. Especially because it is a known fact that, in spite of all cultural, historical, linguistic and economic differences between countries and hunters themselves, all those hunters work, speak and think in their unique "hunting way". Through the whole year, all those hunters work in nature, hunting grounds, or they organize work of service teams and individuals on development of habitats, where all kinds of different animals, of which only a part is intended for hunting or declared as game, habit, live and move about. With methods of positive selection and care for

increasing of quality and quantity of habitats, biological diversity of plants groups of the whole ecosystem, as well as animal population, is being preserved and continually increased. Disappearance of particular animal breeds in particular parts of Europe surely isn't prompted because of hunting and hunters, but it is a result of implacable urbanization and development of both urban and rural areas, with all their infrastructural facilities (network of roads, railways, canals, industrial objects...). Nowhere in Europe have the hunters been a cause for decreasing or disappearing of animals that are intended for hunting or not. They could only be their caretakers and protectors. If we can recall, about ten years ago there was a story about a popular bear they named Bruno, who was trying to run away between Germany, France and Switzerland, desperately looking for his habitat. With human overpopulation, the areas for animal living have been decreased. That is why it is necessary to find balance between people and other living beings in particular narrow or wide areas and it is necessary to run it well.

The most competent members of humane society, who will manage to take care of wild animals and game in the best possible way with the best quality, are certainly hunters. All that in mutual understanding, together with all the other participants and users of ecosystem. Hunter is the most competent and skilled person that understands behavior and life of game and that is why he takes the best care of it.

For that reason, hunters and hunter population manage game survival, their whole food chain (of plant and animal sources), their development and mutual influences, so that there wouldn't be any violation/endangering at one side, or leniency of one species above the other. Also, they are involved in increasing of biological diversity of game and their habitat, about altogether and individual health condition, about active and passive protection by creating and implementing regulations and rules of behavior and managing, and all that based on good mastering and good faith, so that they actively and considerably influence survival and development of environmental protection.

Indirectly, although often directly, they influence development of rural areas, considerably contribute to growth of hunting tourism, which becomes more and more the unavoidable part of general progress of tourist offering. As a by product of hunting activities it certainly needs to be mentioned that all amount of game meat is being secured in different forms of high quality, naturally grown food, which daily enhances the need of gastronomic culture in particular areas.

Finally, we should mention that 7 million hunters skillfully manage firearms and cold weapons (rifles, guns, pistols, knives, bows and arrows), and that way they also contribute to development of particular sporting, recreational, military, competitive, safety skills, which greatly enrich society development, and also, technological development of particular tools and equipment. If we also add factors of relaxation, vacation and rest, enjoyment of nature and company, especially today when there is so much stress in everything, which causes a greater risk of illnesses, we have to ask ourselves seriously about the nature and importance of hunter's population and their influence on our community and the whole society?

Research goal here is to collect and investigate data about a total number of hunters in Europe, with a special emphasis on Southeast Europe (SEE) countries.

Assigned data should be mutually compared, and the relations between hunters in Eastern Europe and other parts of Europe should be particularly researched.

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

Research has been conducted by collecting data published in all relevant professional literature and official reports of hunters associations, international associations or statistical institutes of particular European countries. Collected in one place and elaborated in specific way, it gives us plenty of information that offer answers to relevant and everyday questions of the entire population that lives in Europe.

Part of the research has been conducted for the area of SEE, of which some countries are already members of the European Union, some are still in a waiting process or in the process of adjustment, and some are still in negotiations about becoming members of the EU. All those countries are in one of the phases of transitional changes, considering that for several decades they had lived in a socialist regime. For that reason, this research has an additional character of comparing condition and possible changes in society, observed through the aspect of researching and investigating hunter's population and its social importance. From the basic scientific methods, a comparative method was used, which subject is "… identity, similarity and diversity of the same phenomenon at different times and in different spaces determined by adequate measures, identical or diverse phenomena in a defined space and time" (Miljević, 2007). To study the content of documents, content analysis was applied as a kind of partial analysis (Milosavljević and 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

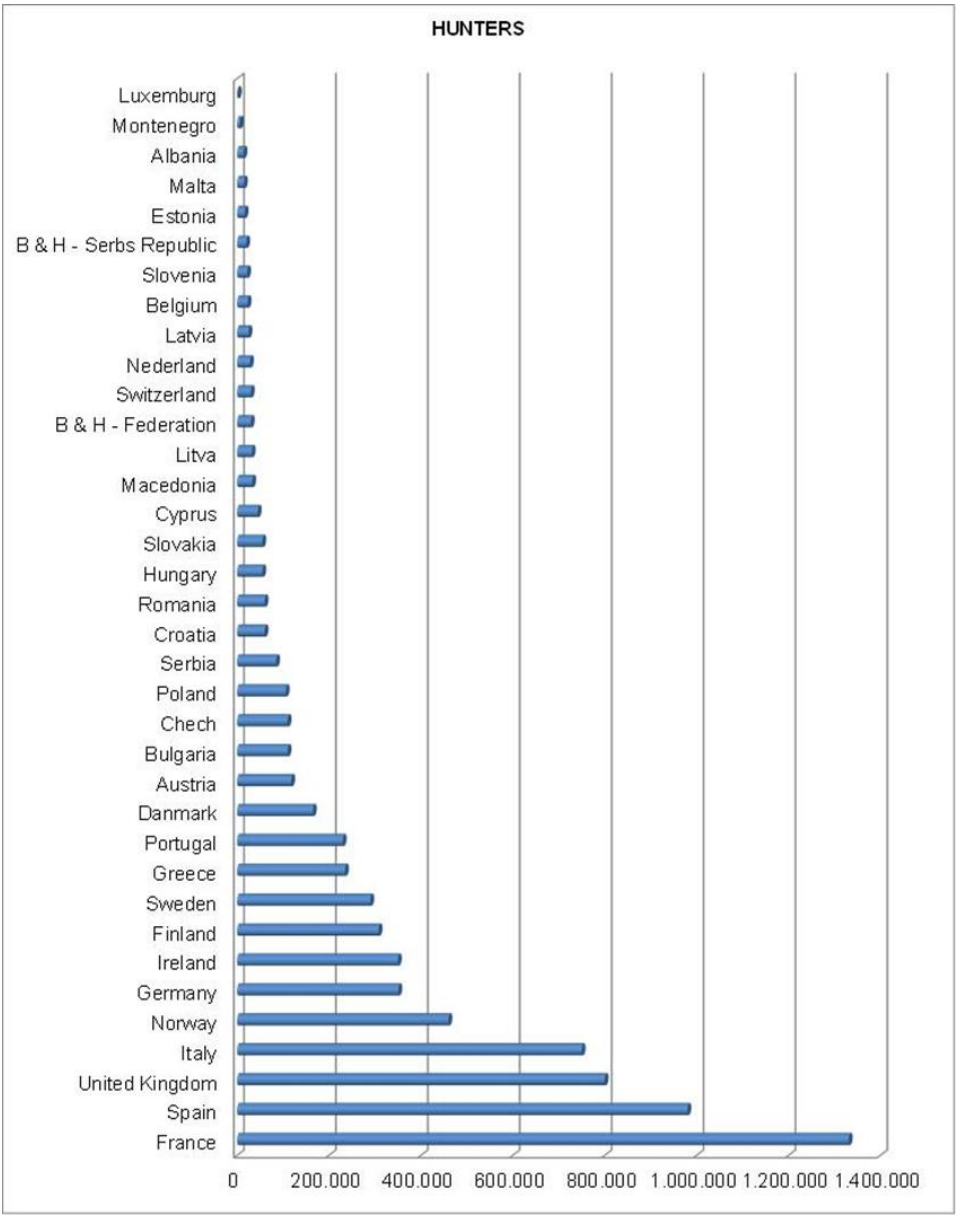
### Europe

**Table 1.** *Data about hunters in Europe*

| HUNTERS IN EUROPE | | | | | | |
|---|---|---|---|---|---|---|
| | COUNTRY | HUNTERS | % | RELATIO | | INHABITANTS |
| 1. | Albania | 14.000 | 0,2 | 226 | 0,39 | 3.600.000 |
| 2. | Austria | 118.000 | 1,6 | 70 | 1,43 | 8.260.000 |
| 3. | Belgium | 23.000 | 0,3 | 452 | 0,22 | 10.396.000 |
| 4. | B & H - Federation | 30.000 | 0,4 | 90 | 1,11 | 2.700.000 |
| 5. | B & H - Serbs Republic | 20.000 | 0,3 | 65 | 1,54 | 1.300.000 |
| 6. | Bulgaria | 110.000 | 1,5 | 70 | 1,43 | 7.700.000 |
| 7. | Chech | 110.000 | 1,5 | 93 | 1,08 | 10.230.000 |
| 8. | Croatia | 60.000 | 0,8 | 73 | 1,33 | 4.500.000 |
| 9. | Cyprus | 45.000 | 0,6 | 17 | 5,88 | 765.000 |
| 10. | Danmark | 165.000 | 2,2 | 33 | 3,03 | 5.445.000 |
| 11. | Estonia | 16.600 | 0,2 | 78 | 1,28 | 1.294.800 |
| 12. | Finland | 308.000 | 4,2 | 17 | 5,88 | 5.236.000 |
| 13. | France | 1.331.000 | 18,1 | 48 | 2,08 | 63.888.000 |
| 14. | Germany | 351.000 | 4,8 | 233 | 0,43 | 81.783.000 |
| 15. | Greece | 235.000 | 3,2 | 45 | 2,22 | 10.575.000 |
| 16. | Hungary | 55.000 | 0,7 | 190 | 0,53 | 10.450.000 |
| 17. | Ireland | 350.000 | 4,8 | 12 | 8,33 | 4.200.000 |
| 18. | Italy | 750.000 | 10,2 | 77 | 1,30 | 57.750.000 |
| 19. | Latvia | 25.000 | 0,3 | 92 | 1,09 | 2.300.000 |
| 20. | Litva | 32.000 | 0,4 | 112 | 0,89 | 3.584.000 |
| 21. | Luxemburg | 2.000 | 0,0 | 250 | 0,40 | 500.000 |
| 22. | Macedonia | 33.000 | 0,4 | 64 | 1,57 | 2.100.000 |
| 23. | Malta | 15.000 | 0,2 | 27 | 3,70 | 405.000 |
| 24. | Montenegro | 6.000 | 0,1 | 103 | 0,97 | 620.000 |
| 25. | Nederland | 28.170 | 0,4 | 618 | 0,16 | 17.409.060 |
| 26. | Norway | 460.000 | 6,3 | 11 | 9,16 | 5.020.000 |
| 27. | Poland | 106.000 | 1,4 | 363 | 0,28 | 38.478.000 |
| 28. | Portugal | 230.000 | 3,1 | 46 | 2,17 | 10.580.000 |
| 29. | Romania | 60.000 | 0,8 | 361 | 0,28 | 21.700.000 |
| 30. | Serbia | 85.000 | 1,2 | 85 | 1,18 | 7.200.000 |
| 31. | Slovakia | 55.000 | 0,7 | 98 | 1,02 | 5.390.000 |
| 32. | Slovenia | 22.000 | 0,3 | 91 | 1,10 | 2.000.000 |
| 33. | Spain | 980.000 | 13,3 | 41 | 2,44 | 40.180.000 |
| 34. | Sweden | 290.000 | 3,9 | 31 | 3,23 | 8.990.000 |
| 35. | Switzerland | 30.000 | 0,4 | 267 | 0,38 | 8.000.000 |
| 36. | United Kingdom | 800.000 | 10,9 | 76 | 1,32 | 60.800.000 |
| **37.** | **TOTAL** | **7.350.770** | **100,0** | **71** | **1,40** | **525.328.860** |

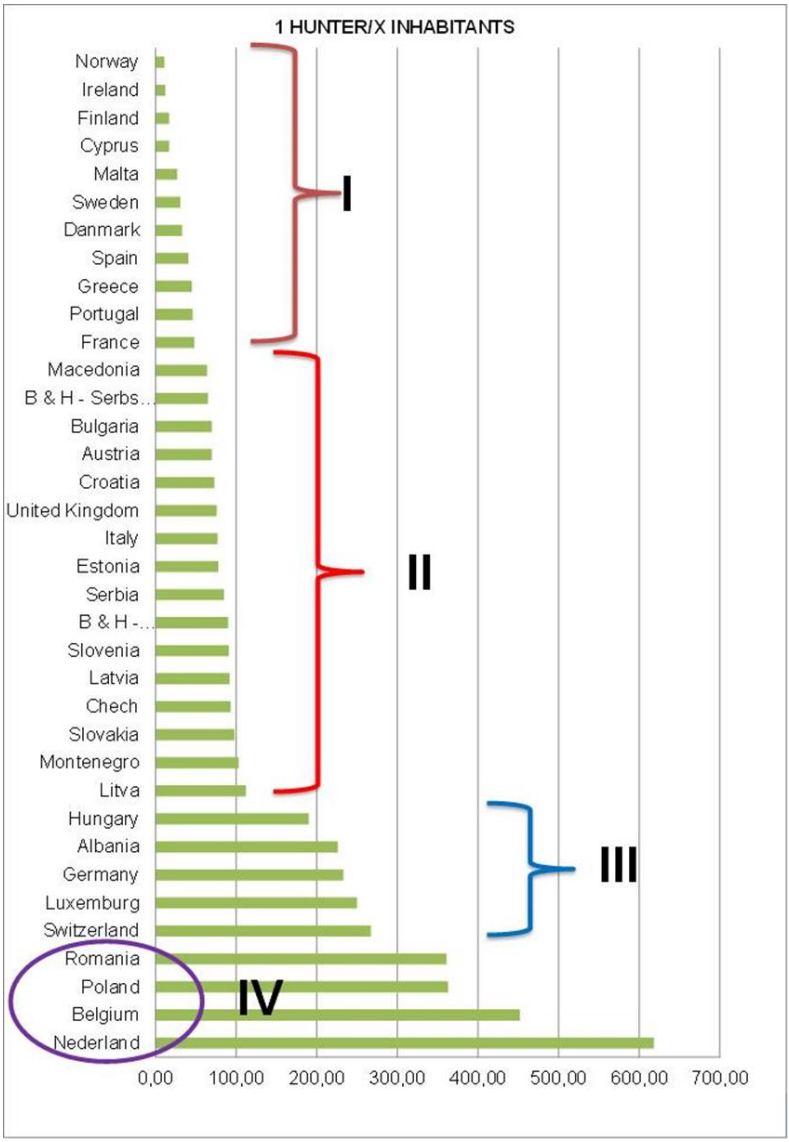
Hunters population in Europe is 1.4 % of total number of citizens. It is organized in associations (FACE) and it is the biggest NGO in Europe. Also, it is bigger than 19 countries and the number of their citizens. More than 7 million people take care about preservation of nature and wildlife, health and well-being of wild animals, biodiversity, firearms and about their own and total safety. More than 7

million people enjoy nature, recreation and sport activities, in different landscapes, from cold Nordic to warm, southern Mediterranean, from 0 to 5.000 meters altitude.



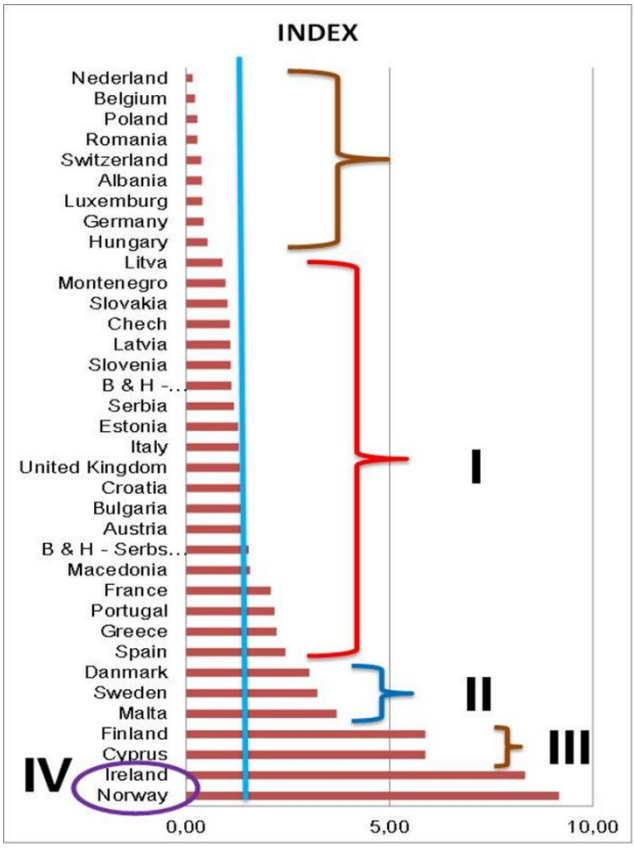

**Picture 1.** *Number of hunters in Europe*

Number of hunters in each country is considerable, but it is not in correlation with the area, nor with the number of citizens. Most hunters live in France (1.3 mil).



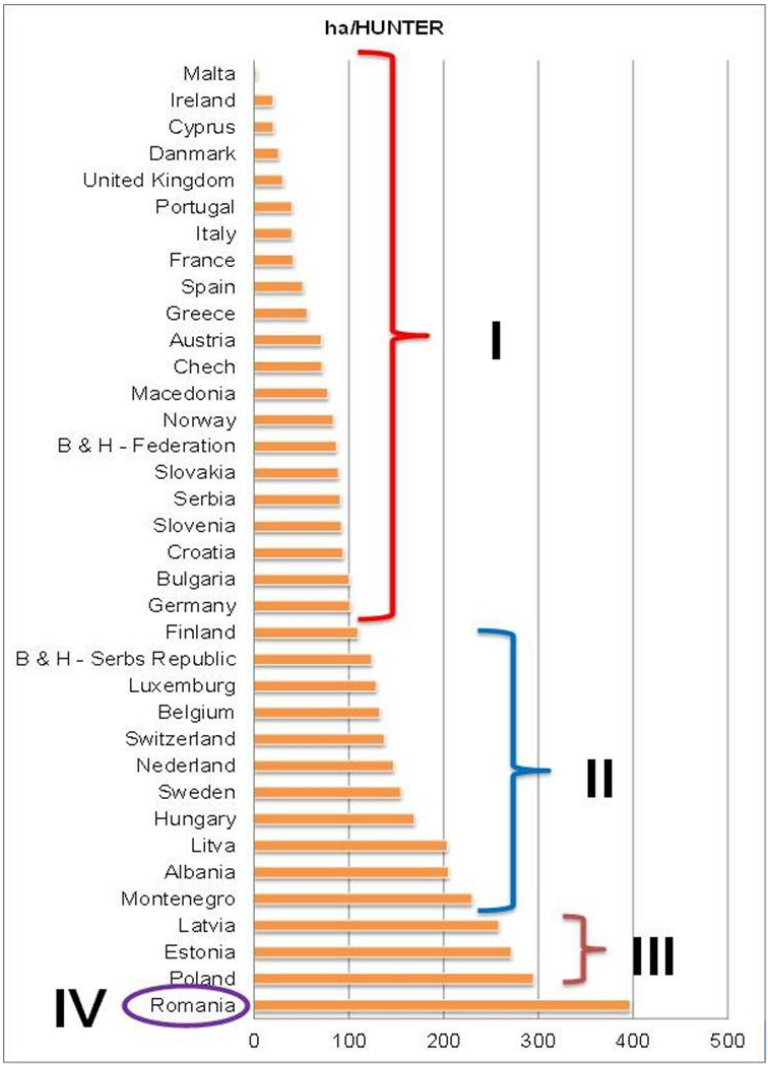

**Picture 2.** *Relation: 1 hunter to X citizens of Europe*

In picture 2 it can be seen per how many citizens there is one hunter. There are four groups. In the first group there are 11 countries, where one hunter comes to 50 citizens. In second group there are 16 countries, where one hunter comes to approximately 100 citizens. In third group there are 5 countries, where one hunter comes to approximately 200 citizens. In the fourth group there are 4 countries, where one hunter comes to more than 350 citizens. In Netherlands even more than 600. Average value (71) of this relation is not an adequate indicator in our case.




**Picture 3.** *Relation (index) in Europe*

In picture 3 it can be seen how many hunters come to 100 citizens in each country. Differences are large; from 0.16 to 9.16. In only 11 countries index is bigger than 2.0 and in only 4 countries it is between 6 and 9.




**Picture 4.** *Relation of surface area in hectares per 1 hunter in Europe*

In picture 4 it can be seen how many hectares of total area is covered by one hunter. There are four groups. In first group there are 21 countries, where one hunter covers approximately 100 hectares. In second group there are 11 countries, where one hunter covers approximately between 100 and 200 hectares. In third group there are 3 countries, where one hunter covers approximately between 250 and 300 hectares. In Romania one hunter covers approximately 400 hectares of the total area (fourth group).

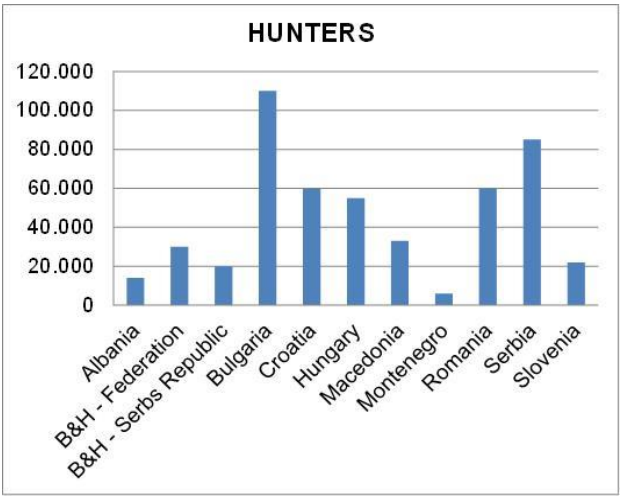
**Table 2.** *Data about hunters in SEE*

| HUNTERS IN SEE | | | | | | |
|---|---|---|---|---|---|---|
| | COUNTRY | HUNTERS | % | RELATIO | | INHABITANTS |
| 1. | Bulgaria | 110.000 | 22 | 70 | 1,43 | 7.700.000 |
| 2. | Serbia | 85.000 | 17 | 85 | 1,18 | 7.200.000 |
| 3. | Croatia | 60.000 | 12 | 73 | 1,33 | 4.500.000 |
| 4. | Romania | 60.000 | 12 | 361 | 0,28 | 21.700.000 |
| 5. | Hungary | 55.000 | 11 | 190 | 0,53 | 10.450.000 |
| 6. | Macedonia | 33.000 | 7 | 64 | 1,57 | 2.100.000 |
| 7. | B&H - Federation | 30.000 | 6 | 90 | 1,11 | 2.700.000 |
| 8. | Slovenia | 22.000 | 4 | 91 | 1,10 | 2.000.000 |
| 9. | B&H - Serbs Republic | 20.000 | 4 | 65 | 1,54 | 1.300.000 |
| 10. | Albania | 14.000 | 3 | 226 | 0,39 | 3.600.000 |
| 11. | Montenegro | 6.000 | 1 | 103 | 0,97 | 620.000 |
| 12. | **TOTAL** | **495.000** | 100 | **129** | **0,78** | **63.870.000** |

In SEE lives 12.2 % of all Europe's population and 7.7 % are hunters from European hunters population. It means that a part of hunter's population of this region is lower than the European average. The reason lies in the fact that all those countries used to have a socialist regime and today they are all in a transitional period. In general, economic standard in all those countries is lower than in other parts of developing Europe. In the past, in some of those countries it was not possible to possess firearms due to high prices and special state regulations.

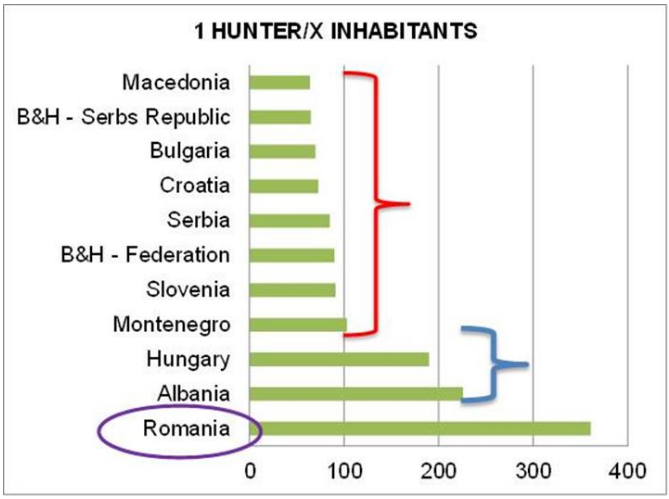
Hunters population in SEE is 7.7 %, which is less than hunter population in Europe 14.0 %. That means this region has large possibilities for development of national and international hunting. Particularly if we know how attractive and appropriate wildlife is in this area. It is also important for hunting tourism, as well as other ways of earning money.

Largest hunters population (110 000) is in Bulgaria (Table 2, Picture 5), which is, for example, twice as much as in Romania (60 000), that has three times more inhabitants (21.7 compared to 7.7 mil). Political and economic statuses are equal in both countries.



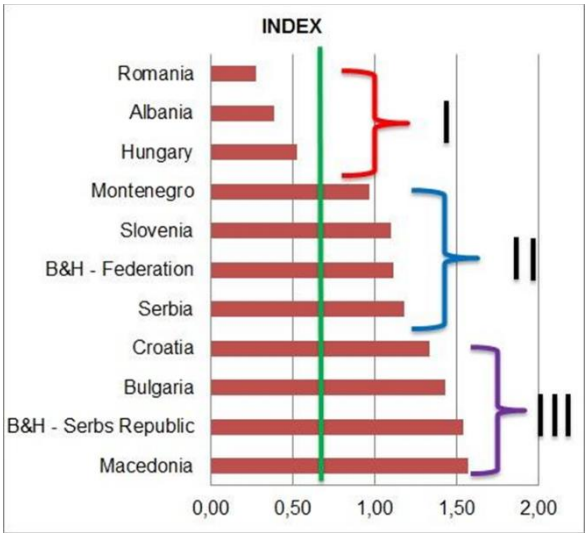

**Picture 5**. *Number of hunters in SEE*

Number of hunters in SEE varies considerably from one country to another, but it is not closely related to the area or population. As it was mentioned most hunters live in Bulgaria (110 000), even though the country doesn't have the largest surface area or the number of citizens.



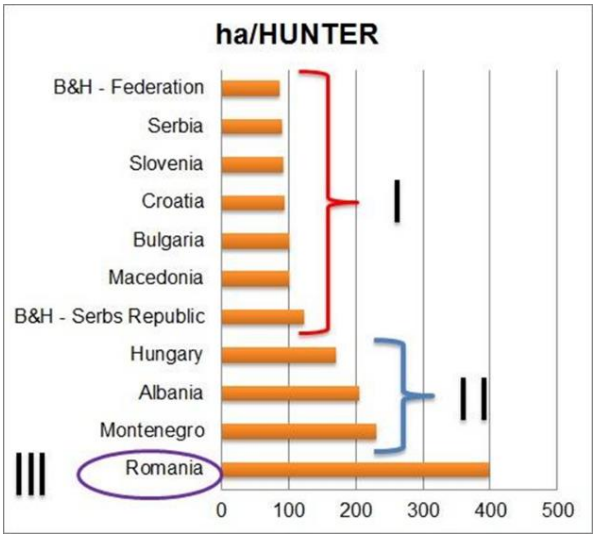

**Picture 6.** *Relation: 1 hunter to X citizens in SEE*

In picture 6 it can be seen per how many citizens there is one hunter. There are three groups. In first group there are 8 countries, where one hunter comes to 60 to 100 citizens. In second group there are only two countries (Albania and Hungary), where one hunter comes to approximately 200 citizens. In Romania, one hunter comes to approximately more than 300 citizens (third group). That means 4 to 5 times more than in countries of the first group. Average value (129) of this relation is not an adequate indicator in our case.




**Picture 7.** *Relation (index) in SEE*

In picture 7 it can be seen how many hunters comes to 100 citizens in each country. In Albania, Hungary and Romania (~ 0.4) three times less than in Bosnia and Herzegovina, Serbia, Bulgaria, Croatia and Macedonia (~ 1.5).




**Picture 8.** *Relation of surface area in hectares per 1 hunter in Europe*

In picture 8 it can be seen how many hectares of the total area one hunter covers. There are three groups. In first group there are 7 countries, where one hunter covers approximately 100 hectares. In second group there are only three countries (Albania, Hungary and Montenegro), where one hunter covers approximately 200 hectares. In Romania one hunter covers approximately 400 hectares of the total area (third group). That is four times more than in countries of the first group.

## 4. DISCUSSION

Hunter's population is one of the largest international NGO s in Europe. With its important and unselfish activity, it is a considerable factor in preservation and protection of environment, micro and macro spaces at all altitudes of our continent (FACE, 2013). Also, with assurance of respectable 10 billion euros and engaging approximately 100.000 workplaces, they are a considerable factor in social community at all levels of social activities. With positive selection and with strictly controlled rules of game managing, they considerably contribute to increasing of quality and preservation of biodiversity (FACE, 2006).

This research observed 35 European countries, from the north in Scandinavia to the south in the Mediterranean, from 0 to 5.000 meters altitude (FACE, 2013). Individually, 19 countries have fewer inhabitants than the altogether hunter's population of 7 million. Particular relations have been divided into logical groups, so that it would be easier to present interrelations, by using different indicators (indexes). Grouping of countries is not in correlation with their size, number of citizens, hunters, cultural or political commitment, nor with their standard (GDP). That means there are other factors to be considered. Bearing in mind that

there are considerable differences between countries, but observing the number of hunters and their relations, we obtain a picture about a large mixture of results, which doesn't influence common divisions: west east; EU non-EU; developed less developed.

For that reason, the whole hunter's population is like a large compliant family and because of that, hunters throughout the continent understand each other very well and they successfully communicate. At the same time, that leads to quality exchange of experiences and knowledge and also to development of mutual hunting tourism at the highest quality and quantity level. Their positive attitude has a good influence on the field of game breeding, game protection and protection of their habitat, protection of the entire ecosystem, preservation and development of biodiversity, safety, ballistics, optical industry, cynology, quality nourishment of humans and animals, tourism, industry and other service and supporting industry.

The ten observed countries of SEE, don't derogate from European criteria. Even though they are on the considerably lower level of GDP and in the long-term transitional process, with their culture and professionalism they don't lag behind other parts of Europe. There are even some advances that are noted because of the quantity and quality of game and because of the attractive and intact nature. All these are good preconditions for development of an even better mutual collaboration in that part of Europe, as well as with the whole continent. At the same time, that creates new space for total traffic of goods and services in hunting (over 10 billion Euros), and potential job openings on both sides. That is why the role of FACE is becoming more important and it is an unavoidable factor in creating hunting policy and the future of a new hunting wave in the areas of SEE, particularly today, in times of a hard financial crisis.

## 5. CONCLUSION

In the SEE, in ten observed countries, presented data and obtained mutual relations don't differ considerably from European data. Although the GDP in those countries is considerably lower, hunting activities are very much present, and with the game resources are very attractive for an even larger development of hunting tourism.

Hunters in Europe have never been a cause of disappearance of any game species in a particular area. Moreover, their care about professional breeding and sometimes even re-introduction of already disappeared species, whilst investing a huge amount of their own assets and their maximum engagement, has prompted the increasing of the species number and rising of health and condition altogether. Indirectly, hunters have influenced preservation and improvement of biodiversity of the entire ecosystem.

They manage firearms and cold weapons professionally and adeptly, which has an indirect influence on the culture of recreational and sportive shooting development. With that, hunters are qualified for using of firearms for the purposes of defense, protection and safety of citizens, individuals and community. Handling, using and behavior with firearms are at the highest professional and ethic level. All 7 million hunters use highly sophisticated, maintained and registered firearms with their maximum care, so that health and lives of hunters are not endangered, as well

as their community and lives of others around them. Criminal and deviant behavior of individuals and groups in society doesn't have any base or contacts with hunters.

With their activities, they contribute considerably to the development of hunting tourism, gastronomic offer, and enrichment of human nourishment with highly nutritional values. Also, through their active participating and professional breeding of dogs, they contribute considerably to the development of cynology altogether, particularly hunting cynology. Hounds are used more and more for non-hunting purposes, because of their refined values and skills.

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## HUNTERS IN EUROPE
## WHAT DOES IT MEAN „THE HUNTERS POPULATION" IN EUROPE?

*Miroslav BENKO, András NÁHLIK, Kristijan TOMLJANOVIĆ*

### Summary

The most competent members of the human community who can manage wild animals and wildlife in a sustainable way are certainly hunters. Mutual understanding and cooperation of all stakeholders and ecosystem users is crucial for the implementation of hunting activities. Hunters care about the survival of wildlife, their overall food chain, their development and relative relationship to avoid deterioration and favoring of certain species over others, increasing the biodiversity of wildlife and the habitats they inhabit. The most significant changes in game hunting occurred when hunting, from the extreme need to survive and provide food for the survival of tribes, families and the human race, grew into a kind of entertainment and hobby. Looking from today's aspect and time where developed population in Europe lives, a question that arises is this: is hunting only fun, which is how many hunting circles are trying to present it and all that at the expense and harm of animals. This research includes the application of basic methods of document analysis and existing reports related to the number of hunters in Europe. In Southeast Europe, the presented data and the obtained mutual relations in the ten observed countries do not differ significantly from the European data. Although the gross domestic product in these countries is much lower, hunting activities are very present, and game resources are very attractive for even greater development of hunting tourism.

# LOVCI U EUROPI
# ŠTO ZNAČI „LOVAČKA POPULACIJA" U EUROPI?

*Miroslav BENKO, András NÁHLIK, Kristijan TOMLJANOVIĆ*

## Rezime

Najkompetentniji članovi ljudske zajednice koji mogu na održiv način da upravljaju divljim životinjama i divljači su svakako lovci. Za sprovođenje aktivnosti u lovu ključno je međusobno razumevanje i saradnja svih zainteresovanih strana i korisnika ekosistema. Lovci brinu o preživljavanju divljači, njihovom ukupnom lancu ishrane, njihovom razvoju i relativnom odnosu kako bi se izbeglo pogoršanje i favorizovanje određenih vrsta u odnosu na druge, povećavajući biološku raznolikost divljači i staništa koja naseljavaju. Najznačajnije promene u lovu na divljač dogodile su se kada je lov, od krajnje potrebe za preživljavanjem i osiguranja hrane za opstanak plemena, porodice i ljudske rase, prerastao u neku vrstu zabave i hobija. Gledajući sa današnjeg aspekta i vremena u kojem živi razvijena populacija u Evropi, postavlja se sledeće pitanje: da li je lov samo zabava, to jest koliko lovačkih krugova pokušava da ga predstavi i sve to na štetu životinja. Ovo istraživanje uključuje primenu osnovnih metoda analize dokumenata i postojećih izveštaja vezanih za brojnost lovaca u Evropi. U jugoistočnoj Evropi, predstavljeni podaci i dobijeni međusobni odnosi u deset posmatranih zemalja ne razlikuju se znatno od evropskih podataka. Iako je bruto domaći proizvod u tim zemljama znatno niži, lovne aktivnosti su itekako prisutne, a resursi divljači veoma su atraktivni za još veći razvoj lovnog turizma.

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**SUSTAINABLE FORESTRY** **ODRŽIVO ŠUMARSTVO**
COLLECTION 81-82, 2020 ZBORNIK RADOVA 81-82, 2020

UDK 528.88:630*587.7(497.11 Stara planina)=111
Preliminary Communication

# APPLICATION OF MULTISPECTRAL SENSORS AND UNMANNED AERIAL SYSTEM IN STARA PLANINA REGION

*Nenad ŠURJANAC[1], Marija MILOSAVLJEVIĆ[1], Mara TABAKOVIĆ-TOŠIĆ[1], Miroslava MARKOVIĆ[1]*

**Abstract**: *In the area of Stara Planina mountain, a multispectral survey of forest vegetation was performed. Data acquisition was done with unmanned aerial system DJI Phantom 4 Pro, equipped with integrated RGB 20Mpix sensor, and MicaSense RedEdge M, 5-channel narrowband multispectral sensor. Data was collected in the form of images, and 4 composite orthomosaics were produced – broadband visible RGB, narrowband visible RGB, and with vegetation indices applied NDVI and NDRE. RGB orthomosaic showed no significant changes in canopies apart from the variability of levels of green. Orthomosaics with vegetation indices applied showed changes in the level of physiological activities of leaves. NDVI map showed the negative changes of the top of the canopies, while NDRE map showed more dramatic changes within the canopy as well. Besides the map, 5 polygons with different NDRE values were selected and their respective spectral signature graphs were produced. The areas with the lowest NDRE values had the highest reflectance values in all wavelengths, while the absorption of light is much higher in physiologically active vegetation. Values of NDRE lower than 0.479 were inspected from the ground. This kind of ground-truth provided evidence that the areas coded in red were with lower physiological activity due to the infestation by beech leaf-mining weevil Orchestes fagi L. Another interesting finding was that both NDVI and NDRE values were higher in the areas not directly exposed to the sunlight. The areas shaded by surrounding canopies received only diffuse light but it showed a more positive ratio between absorbed and reflected wavelength which could be characteristic of the* Fagus Sylvatica *species. The findings in this study showed a strong correlation between low values NDRE vegetation index and negative changes deep within the canopy of high vegetation, which can serve as an indicator of pest infestation in forestry*

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**Keywords***:* multispectral sensor, vegetation indices, forestry, remote sensing, leaf-mining weevil, MicaSense, drones, DJI Phantom, Metashape.

## PRIMENA MULTISPEKTRALNIH SENZORA I BESPILOTNIH LETELICA U REGIONU STARE PLANINE

**Izvod:** *U regionu Stare Planine izvršeno je snimanje šumske vegetacije multispektralnim senzorom. Prikupljanje podataka je urađeno bespilotnom letelicom DJI Phantom 4 Pro, opremljenom sa integrisanom RGB kamerom rezolucije 20 Mpix, i MicaSense RedEdge M uskokanalnom multispektralnom kamerom. Podaci su prikupljeni u obliku fotografija od kojih su proizvedeni 4 kompozitna ortomozaika – širokopojasni u vidljivom delu spektra, uskokanalni u vidljivom delu spektra, i 2 ortomozaika sa primenjenim vegetacijskim indeksima – NDVI i NDRE. RGB ortomozaici nisu pokazali značajne promene u krošnjama, osim očekivanih različitih nijansi zelene boje. Ortomozaici sa primenjenim vegetacijskim indeksima pokazali su promene u nivoima fiziološke aktivnosti listova. NDVI mape su pokazale negativne promena u najvišim delovima krošnje, dok su NDRE mape pokazale dramatičnije promene i dublje u krošnjama. Na mapama je izdvojeno 5 poligona sa različitim NDRE i NDVI vrednostima, na osnovu čijih vrednosti refleksije su izrađeni grafikoni spektralnih potpisa. Područja sa najnižim vrednostima NDRE su imale najviše vrednosti refleksije na svim talasnim dužinama, dok je absorpcija svetla mnogo viša u fiziološki aktivnoj vegetaciji. Biljke sa delovima koji su imali vrednosti NDRE indeksa manje od 0,479 su proverene sa zemlje. Ovakvo uzorkovanje i provera su pružili dokaze da su površine klasifikovane kao loše zaista bile lošeg zdravstvenog stanja usled infestacije bukvinim minerom (Orchestes fagi L). Interesantan nalaz je bila pojava da su vrednosti oba indeksa bile najviše u delovima krošnje koji su bili zaklonjeni od direktne sunčeve svetlosti. Delovi koji su bili u dubokoj senci su primali samo difuznu svetlost, ali su imali daleko pozitivniji odnos između absorbovane i reflektovane svetlosti, što može bi i spektralna karakteristika bukve kao vrste. Rezultati prikazani u ovom radu pokazali su snažnu povezanost između niskih vrednosti NDRE vegetacijskog indeksa i negativnih promena u krošnji visoke vegetacije, što se može koristiti kao indikator infestacija štetočinama u šumarstvu.*

**Ključne reči:** multispektralni senzor, vegetacijski indeksi, šumarstvo, daljinska detekcija, bukvin miner, MicaSense, dronovi, DJI Phantom, Metashape.

## 1. INTRODUCTION

Every surface, alive or dead, has certain spectral properties that are represented in certain spectral reflectance. Reflectance is a measure of how much energy a certain surface reflects at a specific wavelength (Humbolt State University, Introduction to Remote Sensing). The patterns of spectral reflectance belonging to certain surfaces are called spectral signatures. Every surface that reflects light, and therefore can be seen has a spectral signature. These signatures describe the underlying properties of the surfaces. Spectral reflectance signatures result from the presence or absence, as well as the position and shape of specific absorption features of the surface (Huete, 2004). When it comes to the vegetation the most important features that have an impact on the shape of the spectral reflectance curve, and the levels of reflectance of certain wavelengths are biochemical and biophysical

characteristics, 3D cellular organization (Ustin and Jacquemoud, 2020), and chlorophyll pigments. They dominate absorption and reflectance in the wavelength range between 400 and 700 nm (Huete, 2004). Chlorophyll-a and Chlorophyll-b absorb wavelengths between 400-500 nm and 600-700 nm for photosynthesis. Xanthophyll is blue leaf pigment, which strongly absorbs light of wavelengths between 400-500 nm, and alongside red pigment is responsible for colors of leaves in deciduous plants (Huete, 2004). Every vegetation undergoing the stress gives off a different spectral response – spectral signature under the effect of stress on leaf pigments.

Wavelengths between 780-900nm are not significantly absorbed by healthy leaves (Merzlyak et al, 2002). Near-Infrared (NIR) part of the spectrum, 700-1300 nm does not interact with leaf pigments. It goes through them and reflects most of the energy in a healthy and well-functioning leaf structure. Stressed plants reflect a lower amount of energy in NIR part of the spectrum, which in combination with a higher amount of energy in 400-700 nm parts of the spectrum is evidence of stress in plant (Huete, 2004).

Sharp rise between Red and NIR parts of the spectrum is called Red Edge, and the levels of reflected energy in that part of the spectrum is very suitable for the detection of stress in plants. Reflectance near 700nm is a very sensitive indicator of chlorophyll concentration (Gitelson et al., 1996).

Spectral reflectance signatures provide information about the state, geochemical composition, and structure of leaf and canopy (Huete, 2012).

The way to quantify the information on the physiological activity of plants is to use the spectral vegetation indices or simply vegetation indices. These indices represent the numerical values that are related to the amount of stress in the plants. There are various numerical ranges of those values, depending on the algorithm used.

Most often spectral indices use reflectance values of 2 contrasting wavelengths, one with high absorbance and the one with high reflectance. Such an example is the widely used NDVI – Normalized Difference Vegetation Index. That index shows the ratio between NIR, which has high reflectance, and Red wavelength which has high absorbance. Chlorophyll absorbs visible light, while the cellular structure of leaves reflects NIR light (NASA, Measuring Vegetation, NDVI and EVI indices).

Stress such as dehydration, pest or fungi infestation, or pathogen caused stress causes spongy layers of leaves to deteriorate (Slaton et al. 2001). This further causes absorption instead of reflectance of NIR light. At the same time reflectance of Red light increases. This affects the numerical values of NDVI to become low. This is a fairly good indicator of stress in plants. The limitation of this particular vegetation index is saturation which occurs once the canopies are fully developed or even earlier, depending on plant species. This can lead to results being falsely high.

To avoid this saturation, using the part of the spectrum that can "penetrate" the upper layers of the canopy, brings information from the depth of the canopy. The part of the spectrum that allows this is Red Edge. The ratio between NIR and Red Edge levels of reflectance gives more information about the whole plant instead of the top levels of the canopy.

## 2. LOCATION – STUDY AREA

Area of interest for this paper was mixed coniferous/broadleaf forest located at Stara Planina, in Eastern Serbia (image 1.). This was especially due to the presence of European Beech (*Fagus sylvatica* L.). Details on position and vegetation are presented in Table 1.

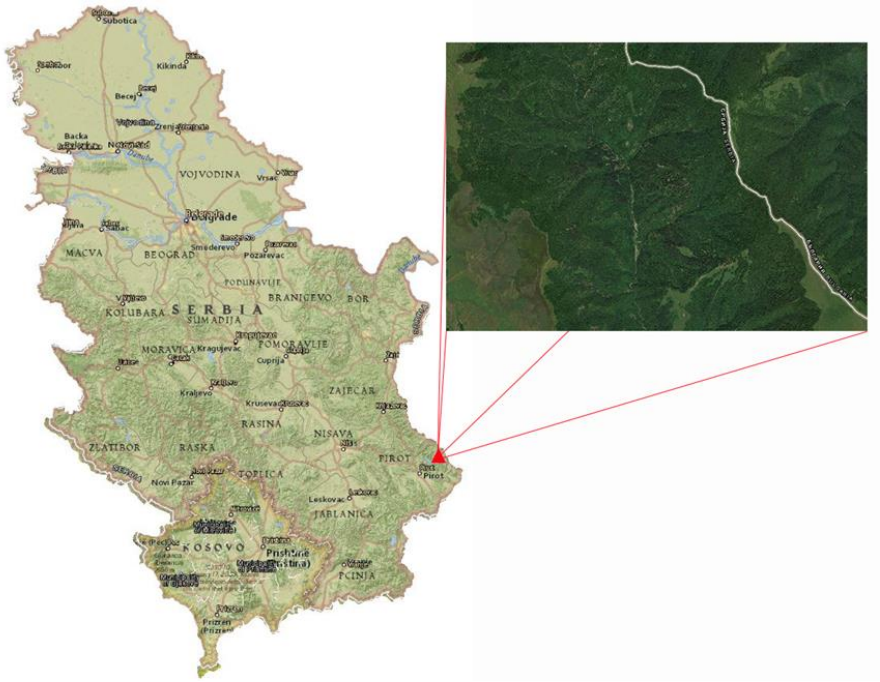



**Image 1.** *Study area location*

**Table 1.** *Location information*

| Plot | Forest Estate | Management unit | Forest Compartment | Coordinates WGS84 | Altitude | Type of soil | Type of forest |
|---|---|---|---|---|---|---|---|
| 1 | Pirot | Stara Planina / Široke Luke | 42 | N 43°15'32" E 22°50'45" | 1068 | Brown | Sessile Oak Forest - High |
| 2 | | | 43 | | | | |
| 3 | | | 44 | | | | |

## 3. MATERIAL AND METHODS

In the period from the 12th to the 17th of August 2020, preliminary screening of several areas located at the Stara Planina Mountain was performed.

Equipment used for data acquisition was unmanned aerial system (UAS) DJI Phantom 4 Pro, equipped with onboard 20 Megapixel RGB sensor, and narrowband multispectral sensor MicaSense RedEdge M.

Flight altitude was 100 meters above ground level. This ensured resolution of ~4cm/pixel for multispectral, and 2.5cm/pixel for RGB sensor.

Deployment of UAS is suitable for surveying hard-to-reach areas, it is fast and easy to deploy, it has a minimal impact on the environment, and it can cover large areas in short times (Šurjanac *et* al. 2019).

Collected data was in the form of individual overlapping images. Broadband RGB sensor collected 3-channel data in the visible range of wavelengths 400-700 nm. It consists of Red, Green, and Blue channels, each having 256 levels of intensity. Multispectral images come as 5-channel images consisting of visible range wavelengths - Red, Green, Blue, and non-visible range – Red Edge and Near-Infrared. Narrowband multispectral sensor has 5 individual sensors that collected images in separate bands. The sensitivity of every channel is represented with 65536 levels of intensity. This provides the ability to detect fine levels of stress and difference between various levels of physiological activities in plants.

Remotely sensed images can contain errors and noise due to the sensor construction and/or environmental conditions. Radiometric calibration is, therefore, a prerequisite in digital image processing, especially in biophysical analyses (Wang and Myint, 2015). To overcome different weather and light conditions before and after every imaging session calibration images were taken. Calibration images are 5-channel images of Calibrated Reflectance Panel, which has known values of different wavelengths. Calibration of images is of the utmost importance when working with spectral reflectance values. Poorly calibrated images will produce improper values of the reflectance which will lead to bad conclusions and decisions. This kind of problem is defined as GIGO – Garbage In - Garbage Out.

All images were gathered during the course of 10 minutes to prevent otherwise partially cloudy weather from impacting recorded reflectance values. RGB and multispectral images were collected simultaneously – the drone carried both sensors at the same time. The total amount of images from the multispectral camera was 2,415, which actually are 483 5-channel co-registered images. Co-registration is the process of fine matching the images taken with multisensory cameras of camera rigs. Without a proper co-registration process the multispectral images would end up blurry and useless. Co-registration is done automatically in the photogrammetric software. The software that was used for photogrammetric analyses of the images was Agisoft Metashape Professional 1.6.4. and Trimble eCognition for advanced object-based image analyses.

Initial analyses included co-registration of the images, production of a sparse and dense point cloud, production of digital elevation model, and orthomosaic, which consists of stitched and overlapped images.

The second level of analyses was performed in Trimble eCognition, which grouped pixels with similar properties throughout all channels and layers, and formed objects which are better representatives of properties than individual pixels. This allowed classification based on vegetation index values and better delineation of the various plants and multicriteria classification.

Final data analyses and presentation was performed in QGIS and MS Excel.

## 4. RESULTS AND DISCUSSION

The final product of initial processing and pixel-based analyses are composite orthomosaics in visible wavelengths and color-coded thematic maps with applied 2 vegetation indices – NDVI and NDRE.

Map created with NDVI index provided information about the conditions that are prevailing in the top levels of the canopies. There was no significant variation within deciduous species of trees. The variation of NDVI index was notable in various vegetation types and different cover types, such as road, and water surfaces.

NDRE index provided much more information valuable for differentiation of physiological activity of the plants and detection of areas with increased levels of stress in plants. This was used to detect the area of deciduous trees, between road and stream. This area had lower values of the index, which are an indicator of physiological stress.

The main three wavelength bands used as indicators were Red, Red Edge, and Near Infra-Red. The color-coded maps with the representation of the values of these 3 bands are shown in image 2, 3 and 4.

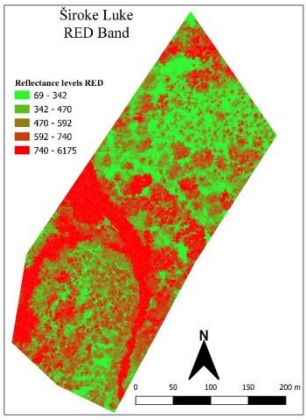



**Image 2**. *Reflectance Red band*

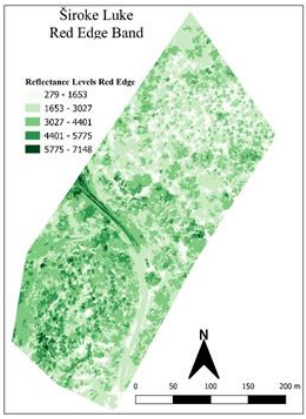



**Image 3.** *Reflectance Red Edge band*

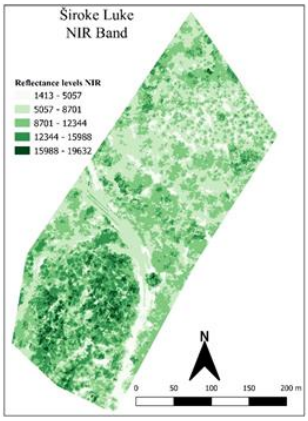



**Image 4.** *Reflectance Near Infra-Red*

Chlorophyll normally absorbs wavelengths corresponding with blue and red colors. High reflectance of the red band indicates potential issues of physiological activity (Image 2). However, the single band can't be used individually. The analyses of other bands such as Red Edge and NIR bands which are affected by spongy tissue in leaves also provide significant insight into the physiological activity of the plants.

Image 3. and Image 4. present color-coded values of Red Edge and NIR bands reflectance. In healthy plants, these values should be high. As the health deteriorates reflectance in these bands lowers.

But just like with the red band, the values of Red edge and NIR bands are not sufficient for a definite indication of plants' physiological activity. This is well presented in spectral signature graphs of the NDRE vegetation index. Here the parts of the image with the lowest values, which indicates the poorest health, have the highest reflectance values in each captured wavelength.

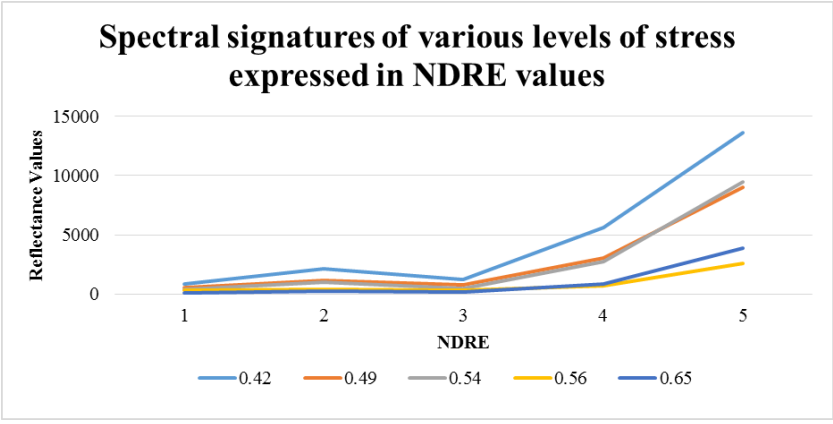
As stated above, a healthy plant will reflect more NIR energy than an unhealthy plant from the same amount of incoming light. In this image selected color-coding represents low NIR energy as pale green, while the strongest reflectance is colored dark green. The distribution of the color shows which areas have low reflectance which should indicate potential issues.

Here certain areas have very low Red Edge reflectance. From the terrain survey and from the digital surface model it can be seen that those areas belong to the lower parts of the canopies, thus receiving less direct sunlight. These parts of the canopy rely only on diffused light, thus having lower amounts of reflected energy.

A very similar distribution was noticed at the wavelengths in the NIR region. Again, very low reflectance in areas in lower parts of the canopy. Relying on this information "As Is" could lead to the conclusion that lower parts of the canopy have lower levels of activity. 1. Showes the dark blue line, with the NDRE value of 0.65 which actually belongs to the lowest parts of the canopy.

To get to the numerical values of health levels of physiological activity ratio of reflectance between at least 2 layers should be used. Each layer represents 1 discrete wavelength. These ratios are vegetation indices. To detect changes 2 vegetation indices were used – Normalized Difference Vegetation Index (NDVI), and Normalized Difference Red Edge index (NDRE).

NDVI values tend to saturate in closed canopies, which is why it has falsely high values. NDRE can bring out the data deeper from the canopies and provide more reliable data in closed canopies.

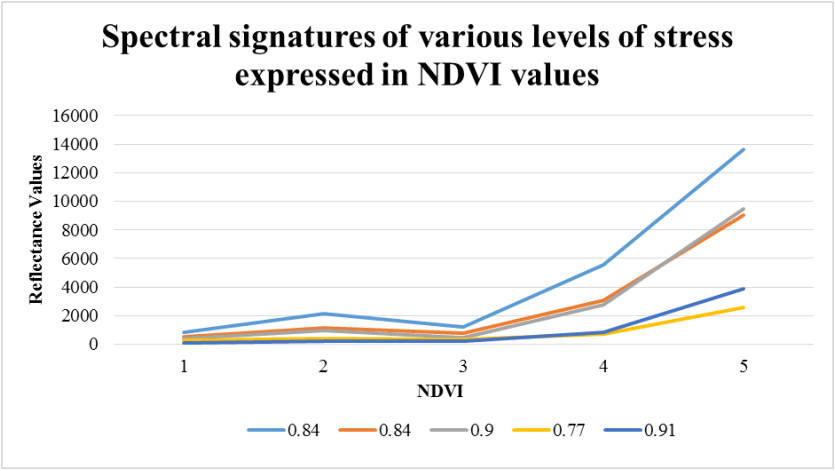



**Graph 1.** *Spectral signatures of 5 sample polygons with NDRE values*

Graph 1 and 2 show how the same spectral signatures produce very different values and trends in various vegetation indices, which further have different indications on vegetation health. Data for graphs were sampled from 5 different classes of vegetation index values.

NDVI showed mostly what was happening in the surface levels of the canopies of the deciduous trees. Data in graphs 2. showed how 5 samples produced values of NDVI from 0.77 to 0.91.

On the other hand, Graph 1. showed a wide range of NDRE index values from 0.42 to 0.65.




**Graph 2**. *Spectral signatures of 5 sample polygons with NDVI values*

Image 5. and image 6. shows the map in visible wavelength range, while image 7. and image 8. show maps with applied NDVI and NDRE vegetation indices.


**Image 5**. *RGB Broad band*

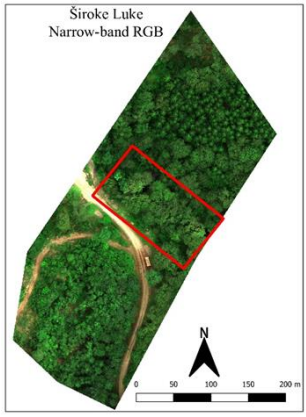



**Image 6.** *RGB Narrow band with sample area*

Images in RGB – visible range, made from the broad sensor and narrow band multispectral sensor, showed no significant differences between healthy and stressed vegetation. The broadband sensor provided high resolution, with a lot of detail, but still, no changes were visible on vegetation. Narrowband RGB had more contrast, and even though it provided more insight into subtle changes in color intensity, no index of negative changes in vegetation was observable.

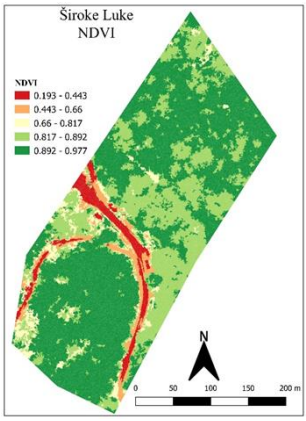



**Image 7.** *NDVI thematic map*

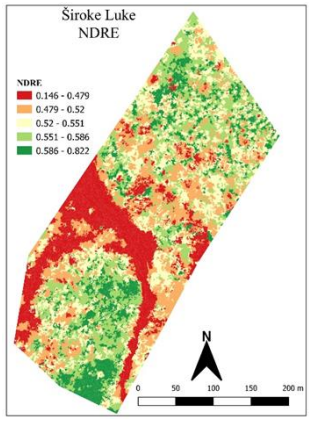



**Image 8.** *NDRE thematic map*

Maps with applied vegetation indices showed similar areas of interest. NDVI values showed that certain areas have lower levels of activity, but it was still very high activity according to the index values. This is very likely to be associated with the saturation of NDVI.

NDRE map pointed out areas with higher levels of stress. These areas are colored red, and even though there was some correlation with areas with lower NDVI values, the NDRE map provided more distinctive values for stress identification.

For the purpose of the ground truth, area just north of the road was inspected (Image 6). It was confirmed that the area detected the drone was infested with beech weevil *Orchestes fagi* L. (Coleoptera: Curculionidae: Curculioninae) (Image 8). The beech leaf-mining weevil (*Orchestes fagi* L.) is one of the most dangerous pests attacking the leaves of common beech (*Fagus sylvatica* L), (Miteva *et* al.). Larvae feed on the parenchyma tissue of the leaves destroying the most important part of the process of photosynthesis, leaving only the epidermis, which consequently diminishes the growth of the tree (Sweeney *et* al. 2012). The mine provides living and feeding quarters for the larva. In this area, over 80% of all beech trees were attacked by beech leaf-mining weevil.

**Image 9**. *The beech leaf-mining weevil (Orchestes fagi L.)*

The significance of *Orchestes fagi* L in the Beech forest of Serbia is important. The previous research has shown that within the framework of ICP Forest, In 51 out of 125 sample plots which were set (869 beech trees out of 2,860 trees), *Orchestes fagi* L was found on 21 out of 51 sample plots where beech presence was

recorded, i.e. on 93 out of 869 trees. The presence of this pest was reported on 10.7% of trees and on 41.2% of the sample plots (Radulović and Milanović, 2009).

## 5. CONCLUSION

Application of UAS and multispectral sensors in forestry had the purpose of providing a sufficient amount of data for pinpointing the areas affected by stress and/or pest infestation. The method has proven to be very successful for monitoring vitality and health status, as well as detecting possible causes of their disturbance. In the case of the beech weevil, it was proven that this group of plants had endangered health. The total range of the index is ranged from -0.3 to 0.7. The early detection of harmful organisms and categorization of bands from the multispectral camera which indicates that is a specific organism detect is a future study for forest monitoring. The especially positive result was the fact that data from over 1 hectare can be gathered for less than a minute, and detect early stress, which would lead to the protection of economically and environmentally valuable resources. Another aspect of the results was the detection of the various physiological activity of leaves on a single tree, depending on different exposure to sunlight.

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### Summary

Multispectral imaging provides information on the physiological activity of plants. Levels of reflectance in wavelengths in Near-Infrared and Red Edge parts of the spectrum are sensitive to chlorophyll content and molecular structure of leaves. Stress-induced changes in leaves strongly influence the levels of reflectance. In Stara Planina region, measurement of levels of reflectance in mixed forest stands was performed to test the ability of drone-borne multispectral sensors to detect subtle changes in reflectance caused by stress from pest infestation (*Orchestes Fagi* L) in European beech (*Fagus sylvatica* L). Data acquisition was performed with narrow-band multispectral sensor MicaSense RedEdge M, in 5 discrete channels, and RGB digital camera in 3-channel images. Data processing was done in professional photogrammetry, and GIS software. Even though inspection of invisible parts of the spectrum did not reveal any changes in vegetation, application of vegetation indices - NDVI and NDRE provided information not only which trees showed lower levels of physiological activities, but also indicated which parts of the trees had more or less stress. The finding from the drone was confirmed through ground-truthing (observation and sampling). This paper showed a positive correlation between the application of multispectral sensors for stress identification in forestry and observation from the ground which indicates that reliable results may be obtained in a fast and effective manner from the application of drones in forestry.

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*Mara TABAKOVIĆ-TOŠIĆ, Miroslava MARKOVIĆ*

## Rezime

Multispektralni snimci nam pružaju informacije o fiziološkoj aktivnosti biljaka. Intenziteti reflektovane svetlosti na talasnim dužinama koje pripadaju Blisko-Infracrvenom i Ivično-crvenom delu spektra su osetljivi na promene u koncentraciji hlorofila i molekularne strukture lista. Promene na listovima koje su uzrokovane stresom imaju jak uticaj na intenzitete reflektovane svetlosti. U regionu Stare Planine, izvršena su merenja intenziteta reflektovane svetlosti sa listova u mešovitoj šumi kako bi se utvrdila mogućnost primene multispektralnih senzora sa dronova. Od naročitog interesa je bila primena u detekciji finih promena u refleksiji na Evropskoj bukvi koja je izazvana štetočinama, konkretno bukvinim surlašem (*Orchestes Fagi* L). Prikupljanje podataka ja izvršeno uskokanalnom multispektralnom kamerom MicaSense RedEdge M i standardnom kamerom za snimanje u vidljivom delu spektra. Podaci su prikupljani u obliku 5-kanalnih i 3-kanalnih RGB fotografija, i obrađeni su profesionalnim fotogrametrijskim i GIS softverom. Iako pregledom podataka u vidljivom delu spektra nije bilo indikacija o stresu, primenom vegetacijskih indeksa - NDVI i NDRE ukazano je ne samo na stabla sa nižom fiziološkom aktivnošću, već su i detektovani delovi stabala sa većim ili manjim stresom. Svi nalazi dobijeni na osnovu podataka sa drona su provereni i potvrđeni na osnovu terenskih observacija i uzorkovanja. U ovom radu je prikazana pozitivna korelacija između informacija u šumarstvu dobijenih multispektralnim senszorom i terenskim observacijama, što ukazuje na mogućnost dobijanja pouzdanih podataka na brz i efikasan način primenom dronova u šumarstvu.

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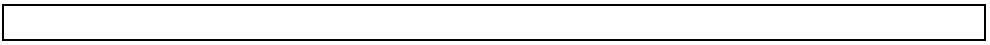

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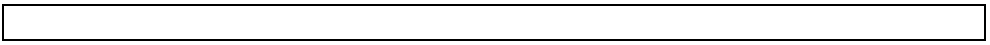

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Janković, Lj. (1958): Contribution to the knowledge of gypsy moth host plants in nature during the last outbreak, 1953-1957, Plant protection, 49-50: 36-39 (In original: *Janković, Lj. (1958): Prilog poznavanju biljaka hraniteljki gubara u prirodi u toku poslednje gradacije, 1953-1957. god. Zaštita bilja, 49-50: 36-39*)

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Roberts, G., Parrotta, J. and Wreford, A. (2009): *Current Adaptation Measures and Policies.* In: Risto Seppälä, Alexander Buck and Pia Katila. (eds.). Adaptation of Forests and People to Climate Change - A Global Assessment Report. IUFRO World SeriesVolume 22. Helsinki. 123-13311

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