FORS²D

FORESTRY SCIENCE FOR SUSTAINABLE DEVELOPMENT

BOOK OF ABSTRACTS

"Perspectives of forestry and related sectors as drivers of sustainable development in the post-Covid era"

Banja Luka, the Republic of Srpska / Bosnia and Herzegovina
29–30 September 2022

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Perspectives of forestry and related sectors as drivers of sustainable development in the post-Covid era

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FORESTRY SCIENCE FOR SUSTAINABLE DEVELOPMENT

"Perspectives of forestry and related sectors as drivers of sustainable development in the post-Covid era"

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Foreword

Dear participants and friends,

The International Scientific Conference "***Forestry science for sustainable development FORS²D – Perspectives of forestry and related sectors as drivers of sustainable development in the post-Covid era – FORS2D***" in Banja Luka is held on the occasion of important Jubilee (30 years) of the Faculty of Forestry, University of Banja Luka, and 30 years of PFE "Šume Republike Srpske" a.d. Sokolac, in cooperation with FAO (*United Nations Food and Agriculture Organization*). Considering global changes that we are facing, the importance of forests cannot be underestimated. We depend on forests for our survival, from the air we breathe to the wood we use, but without education and scientific research we cannot promise sustainable development or sustainable forestry. Besides basic functions of forests needed for humans, forests also offer climate change mitigation, watershed protection, prevent soil erosion and torrential floods that we are frequently facing in recent decades. Unfortunately, despite our dependence on forests, we are still allowing them to disappear.

This Conference will give an opportunity for participants to address important issues related to forestry, exchange recent research, knowledge and experiences in forestry and related fields, to establish functional international cooperation among institutions, to improve cooperation between forestry science and practice and finally to forestry as important sector for human well-being at local, national and global level.

The Conference is organized in nine sessions along different themes. Together there are five plenary lectures, 64 oral presentations and 64 poster contributions, with more than 120 participants.

As announced, authors, the reviewed and accepted papers are going to be published in the Bulletin of the Faculty of Forestry, University of Banja Luka (http://glasnik.sf.unibl.org).

We wish you a very successful Conference and pleasant stay in Banja Luka.

Chair of the Organization Committee

Marijana Kapovic Solomun

Predgovor

Dragi učesnici i prijatelji,

Međunarodna naučna konferencija „Šumarska nauka za održivi razvoj FORS^{2}D – Perspektive šumarstva i povezanih sektora kao pokretača održivog razvoja u post-kovid eri – FORS^{2}D" se održava u Banjoj Luci povodom značajnog jubileja (30 godina) Šumarskog fakulteta Univerziteta u banjoj Luci i 30 godina JPŠ "Šume Republike Srpske" a.d. Sokolac, u saradnji sa FAO (Organizacija Ujedinjenih nacija za hranu i poljoprivredu). Imajući u vidu globalne promjene kojima se suočavamo, značaj šuma mora biti posebno istaknut. Opstanak čovječanstva zavisi od šuma od vazduha koji udišemo do drveta koje koristimo kao materijal, ali bez obrazovanja i naučnog istraživanja ne možemo obećati održivi razvoj ili održivo šumarstvo. Pored osnovnih funkcija šuma potrebnih čoveku, šume takođe nude ublažavanje klimatskih promjena, zaštitu riječnih slivova, sprječavanje erozije zemljišta i bujičnih poplava sa kojima se često suočavamo poslednjih decenija. Nažalost, uprkos činjenici da zavisimo od šumskih ekosistema, mi i dalje dozvoljavamo da one nestaju.

Ova Konferencija će pružiti priliku učesnicima da se pozabave važnim pitanjima vezano za šumarstvo, razmijene novija istraživanja, znanja i iskustva u šumarstvu i srodnim oblastima, da uspostave funkcionalnu međunarodnu saradnju među institucijama, da unaprijede saradnju šumarske nauke i struke i konačno da istaknu šumarstvo kao važan sektor za ljudsko blagostanje na lokalnom, nacionalnom i globalnom nivou.

Konferencija je organizovana u devet sesija na različite teme. Učesnicima će se obratiti pet eminentnih plenarnih predavača, 64 usmenih izlaganja i 64 poster priloga, sa više preko 120 učesnika. Kako je najavljeno, recenzirani i prihvaćeni radovi biće objavljeni u Glasniku Šumarskog fakulteta Univerziteta u Banjoj Luci (http://glasnik.sf.unibl.org).

Želimo Vam uspješnu Konferenciju i ugodan boravak u Banja Luci.

Predsjednica Organizacionog odbora

Marijana Kapović Solomun

THEMATIC AREAS

1. Forest and sustainable development in light of climate change
2. Nature-based solutions
3. Let's green, be seen
4. A modern and competitive forestry sector
5. Innovative value chains and sociological aspects in forestry and related sectors

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УНИВЕРЗИТЕТ У БАЊОЈ ЛУЦИ
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NOWADAYS FORESTRY IN EUROPE: ITS CHALLENGES AND ITS PUBLIC PERCEPTION

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ABSTRACT

At European Union level, the recently adopted forest strategy aims to enhance the quantity and quality of forests, to reverse the negative trends and to adapt forests to the new socio-economic conditions, to extreme weather and the high uncertainty brought about by climate change, with the multi-functional role of forests at its core. The need to keep the ecological, social and economic roles of forestry balanced, in the present local, national and European context, entails specific challenges on sustainable forest management, which has to reflect the societal demands and expectations. The significant increase of public environmental and social awareness in the last decades in Europe has led to a clear shift of management objectives from the traditional, sustained yield to multiple purposes objectives. Several recent studies show that the general public in Europe consider the ecological value of forests to be of primary importance, while most forest owners are naturally in favour of the economic function of forests. In spite of the changes and adaptation in forest management in line with the societal needs, the image of forestry and foresters has been rather controversial in the last decades. The public perceives as the most negative issues only those that are negatively evaluated by the media. The fact that the majority of the public consider (mainly from media information) forestry operations and poor forest management to be the most frequent threats to forests might not reflect the reality. In this context, more efforts to improve the communication capacity and strategy of forest organisations are needed.

Key words: multi-functional, communication, multiple purposes objectives

FUTURE OF CLOSE-TO-NATURE SILVICULTURE IN BOSNIA AND HERZEGOVINA AND SLOVENIA

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ABSTRACT

A new forest management paradigm Closer-to-Nature Forest Management (CRNFM) was proposed in the EU Forest Strategy for 2030 with the aim to improve nature conservation and climate adaptation of European forests. Implementation guidelines have not yet been fully developed and will likely vary from country to country. In addition, some countries are already implementing many of the guidelines, while others with predominant industrial forestry are implementing fewer. The aim of this paper is to compare practices and strategies for future development of close-to-nature forestry in Bosnia and Herzegovina and Slovenia. In the analysis, we follow the general guidelines for the implementation of CRNFM in different geographical areas of Europe, developed by an international group of researchers (https://doi.org/10.36333/fs12). In the introductory part, a brief historical development of close-to-nature forestry in both countries is presented. This is followed by a comparison of selected indicators of existing conservation measures in tune with CRNFM, e.g. retention of biological legacies, microhabitats, conservation of special biotopes and patches affected by natural disturbances, and preservation of traditional management practices. This is followed by an analysis of existing and planned measures to adapt forests to stresses caused by global change. The final chapter presents the enablers, problems, and knowledge gaps for successful adoption of CRNFM in Slovenia, BiH, and Southeastern Europe. In general, CRNFM provides a good basis for the development of nature conservation, adaptation of forests to environmental changes and adjusting of variable forest management approaches in Europe. However, insufficient emphasis is placed on coordinating the economic and social roles of forests in both the new EU Forestry Strategy and national policies. In the future, the changing environment will require much greater coordination of sectoral policies at both international and national levels.

Key words: Closer-to-Nature Forest Management, EU Forest Strategy 2030, forest conservation measures, adaptation to climate change

SOIL CARBON SEQUESTRATION FOR FOOD AND CLIMATE SECURITY AND ADVANCING SUSTAINABLE DEVELOPMENT GOALS OF THE UNITED NATION

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ABSTRACT

World soils are the largest reservoir of carbon in the terrestrial biosphere. Soil C stock comprises of soil organic carbon(SOC) and soil inorganic carbon(SIC). Estimated to 1-m depth, the SOC stock is estimated at 1550 Pg and SIC stock at 750 (to 950). Thus , the total soil C stock of ~2300 Pg is 3.7 times that in all vegetation(620 Pg) and 2.6 times that in the atmosphere(880 Pg). The atmospheric stock is increasing at the rate of about 5.3 Pg C/yr. In general, SIC stock is more in soils of the arid and semi arid regions, SOC is more in soils of humid and sub-humid regions. There are two types of SIC: primary carbonates derived from the weathering of parents rocks (lithogenic carbonates), and the secondary carbonates (pedogenic carbonates) derived from the pedological processes. The formation of secondary carbonates an important process of sequestration of atmospheric CO_2. Similarly, formation of new humus or soil organic matter content from decomposition of the fresh biomass produced by plants within a land unit leads to sequestration of atmospheric CO_2.

SOC stock has been exploited for its nutrient reserves ever since the dawn of settled agriculture about 10 millennia ago. Conversion of natural to agricultural ecosystems, by deforestation and burning of biomass along with drainage and plowing of land, accelerates the process of decomposition of SOC. Mineralization of SOC and its lateral transport over the landscape by accelerated soil erosion by water (hydric erosion) and wind (aeolian erosion) also depletes the soil C stock. Thus, most agricultural soils are depleted of their original C stocks. The magnitude of loss of SOC stocks is estimated at about 130 Pg C. Total loss of C from land use conversion since the beginning of agriculture (from vegetation and soil) may be about 600 Pg, compared with the emissions from fossil fuel combustion at about 460 Pg since circa 1750.

Thus, re-carbonization of world soils and vegetation, by choice of a restorative land use and adoption of management practices which create a positive soil C budget, is an important option for adaptation to and mitigation of the anthropogenic climate change. Finding a non-carbon fuel source as a substitute of fossil fuel and re-carbonization of the soil and vegetation are important strategies to keep global warming to below 2 C. Soil carbon sequestration has many co-benefits. Important among these benefits are food and nutritional security, water quality and renewability, strengthening of the biogeochemical cycling of element in conjunction with that of water, and providing energy source for soil biota. Thus, SOC stock, an important determinant of soil health, is critical for numerous ecosystem services. Sustainable management and restoration of SOC stock is also essential to advancing Sustainable Development Goals of the Agenda 2030 of the U.N. Indeed, it is a win-win option, and a bridge to the future until no-carbon fuel sources take effect.

Key words: SOC, SIC, global warming, no-carbon fuels, climate changes

CLIMATE CHANGE IS A REALITY AFFECTING FOREST VITALITY AND PRODUCTIVITY

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ABSTRACT

Forest stands are fulfilling an important role in the mitigation of Global Climate Change (GCC) impact. Their ability to store carbon thanks to the photosynthetic carbon dioxide binding is exceptional. Carbon is storage either in biomass or in the soil. What is important from the GCC mitigation point of view is the duration of carbon binding. For the conditions of temperate zone forests this time amount to decades. The duration of carbon storage in the soil is strongly dependent on the mechanism of carbon storage, i.e. physical or microbial pathway. The physical binding and storage are shorter compared to the microbiological one.

The process of carbon storage is closely related to the stand vitality, which is under the impact of the environment. GCC is manifested by the distinctive enhanced air temperature. However, this phenomenon is not conceited to the annual amount of precipitation. The sum of precipitation has not changed. As a result of this, evapotranspiration has increased. The effect of seasonal abundance of soil drought is detrimental. The decrease of stem radial increment and photosynthetic assimilation – thus the ability of forests to mitigate GCC is endangered. Moreover, drought events are responsible for secondary damages – attack of bark beetle.

Because of the significant effect of mentioned factors, the role of "smart" forestry started to be extremely important. The Climate Smart Forestry could be a new alternative to forest social role, especially under the current situation when the carbon sink in the Czech forest is decreasing. Thus, intensive forest smart phytotechnic- especially intensive and creative thinning, re-introduction of copy systems and selective sylviculture are a new challenge for forestry under the impact of GCC.

Key words: GCC, carbon storage, stand vitality, soil drought, smart forestry

CURRENT DEVELOPMENTS IN SUSTAINABLE FOREST MANAGEMENT POLICY

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ABSTRACT

Sustainable forest management was introduced as the lead forestry paradigm in the 1990s in the wake of the Rio conference and was the catalyst to finding common definitions and language, more streamlined monitoring, and comprehensive reporting through criteria and indicators. The FOREST EUROPE process facilitated that forest could be tackled on a Pan-European scope.

Today, we observe that the winds are changing. Biodiversity and climate change are becoming the main driver of forest policy, and recent forest calamities like increasing forest fires, drought, and bark beetle infestations rise big concerns in the public perception whether our forests and forestry are fit for the future.

The new EU Forest Strategy 2030 points out this new dimension, while still emphasizing the role of multi-functionality and bio economy concerning forests. The concept of circular bio-economy is also very important for the Western Balkan countries, given that the focus is on the economic function of forests, including logs as (still) the main product. Other roles of forests (ecological and social) are not properly valued, and diversification of products (biomass, plantations of fast-growing species, carbon credits, non-wood products, agroforestry, ecotourism) is implemented on a very limited scale.

Such development is not only important for the EU countries but also for neighboring countries and importers of forest products. Given that Western Balkan countries export the largest part of wood and wood products to the EU market, it is necessary to harmonize forest policies and strategies, following the new European and global trends. In addition, communication and exchange of good practices should always be included in a dialogue, considering the great biodiversity and significant areas of natural forests in the countries of the Western Balkans.

We will discuss the recent progress in forest-related policy instruments and provide an outlook on the future of SFM.

Key words: Sustainable Forest Management (SFM), EU Forest Strategy, Climate change adaptation/mitigation, Forest-related policy instruments

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THEMATIC AREA 1
Forest and sustainable development in light of climate change

TEMATSKA OBLAST 1
Šuma i održivi razvoj u svjetlu klimatskih promjena

FORS²D
ŠUMARSKA NAUKA ZA ODRŽIVI RAZVOJ

SUCCESS OF TRANSPLANTING SEEDLINGS (WILDLINGS) WITHIN GAPS IN HIGH MOUNTAIN SPRUCE DOMINATED STANDS ON ACIDIC SOILS

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ABSTRACT

High-mountain mixed forests on siliceous parent material cover large areas in Europe and Slovenia. For historical reasons, the area of Norway spruce forest is much higher compared to its natural distribution and the soil organic cycle is decelerated. The lack of a natural forest structure leads to the growth of exuberant ground vegetation, which slows down natural regeneration. To improve regeneration, planting is a valid option. For planting, we used transplanted seedlings (wildlings). They are an alternative to seedlings from the nursery. They are adapted to the local environment and their use is inexpensive because there is no need for seedlings production. In the forests of Pahernik (Pohorje region - northern part of Slovenia) we created six canopy gaps with a diameter of about 50 meters. Each gap had 5 plots located in all cardinal directions and in the centre of the gap. Plot number 6 was a control plot within the closed stand. In 2017, test wildlings (silver fir, Norway spruce, and common beech) were planted. In 2018, we continued planting within the gaps. After planting, the wildlings were remeasured every year (growth vigor, height, increment ...). On the plots, ecological factors such as light, air temperature, soil and air humidity were continuously monitored. The first results show that both conifers (fir and spruce) had the lowest vigor (10 – 40 %) in the warmest parts of the gap, while beech seems to be more adaptable (60 % growth vigor). So far, Pahernik forests have been quite stable due to the long tradition of close-to-nature management, high altitude and good soil conditions, but there are already signs of upcoming extreme events (bark beetles, storms ...). Norway spruce, as the predominant tree species, is at risk. In the discussion, we provide guidelines on how to improve regeneration and forest structure.

Key words: planting, mountain forest, gaps, wildlings

APPLICATION OF STRUCTURAL INDICES FOR THE ANALYSIS OF THE SPATIAL STRUCTURE OF THE OLD-GROWTH BEECH FOREST

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ABSTRACT

The aim of the research is to estimate the structure of the stand by applying structural indices with simulation of different types of cuttings. The object of research is the pure high beech stand located in 105th compartment, FMU "Dubička Gora", on the mountain massif "Manjača". There was no cutting in the stand since 1968 and stand has the character of an old-growth forest. Field research was carried out on the part of the permanent experimental area where a smaller rectangular experimental area was set up, with a total area of 0.6 hectares. Measurements were performed with Field-Map technology. Data were processed by common dendrometric-statistical methods and presented in the form of bivariate distribution. Spatial data were analyzed using the structural indices of the nearest neighbours using the CRANCOD software. The plot was divided into three subplots and their indices were compared. Simulation of selective cutting increased the relative variability of tree diameters on all subplots, while simulation of shelterwood cutting reduced variability. Selective cutting affected the increase of mingling index. The Clark and Evans aggregation index after shelterwood cutting fell toward a random distribution while selective cutting made a slight grouping of trees. The dominance index decreased its value after both types of cutting, which means that the remaining trees were freed from dominant trees in all subplots, which improves the conditions for growth.

Key words: CRANCOD, UAI, mingling index, aggregation index, bivariate distribution

ASSESSMENT OF SPECIES STRUCTURE OF MIXED FORESTS OF CENTRAL RUSSIA BASED ON JOINT PROCESSING OF MEDIUM- AND HIGH-RESOLUTION SATELLITE IMAGES

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ABSTRACT

Satellite multispectral images of medium spatial resolution (10-30 m) are the main remote sensing tool for assessing changes in forest parameters occurring in the context of global warming. Despite the achievements in this field, there are significant problems associated with the influence of atmosphere, soil and different regional factors. The most significant errors occur when processing images of mixed forests. These difficulties can be substantially reduced by employing joint spectral-texture analysis of images having high (~2 m) and very high (<1 m) spatial resolution. Here we propose an improved method for the assessment of forest species and canopy structure based on joint processing of satellite images of various spatial and temporal resolutions such as Sentinel 2 and Worldview-2. The method consists of several stages. At the beginning, the main classes of natural and anthropogenic objects are segmented using texture features extracted from panchromatic images of very high spatial resolution. Further the pixels within the stand outlines are used to classify the species and structural features of the forest canopy. To classify the mixed forest species, evergreen stands and some groups of deciduous stands are preliminarily segmented according to medium resolution multi-temporal images. The species recognition is carried out separately for each of these groups based on the joint processing of high- and medium-resolution multispectral images, taking into account differences in the lighting conditions of individual elements of the forest canopy. The method is validated using ground-bases data for test areas containing main forest-forming species of Central Russia.

Key words: thematic processing, pattern recognition, texture analysis, forest inventory

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IMPACT OF TOPOGRAPHIC, LAND COVER AND ANTHROPOGENIC FEATURES ON THE FOREST FIRE OCCURRENCE AND BURNT AREA IN CENTRAL SERBIA

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ABSTRACT

Forest fire is the most important damaging agent in the forest ecosystems. Number of forest fires and burnt area vary from year to year in Serbia. Despite tremendous loss of forest in the previous decades, factors that contribute to forest fire occurrence and burnt area size remain unknown or poorly understood. This research describes factors that contribute to the forest fire occurrence and burnt area in 2012 on the territory of the central part of Serbia. During the season 2012 there were 196 of forest fires resulting with 7198 ha of burnt area. Our results, in absolute numbers, showed that the most of fires occurred in deciduous forests, but, if the obtained results are presented as the number of fires per 100 km^2 of vegetation type, then the most susceptible type of vegetation were the coniferous forests with the 2.7 forest fire per 100 km^2. The lowest number of fires (only 13) occurred in the transitional woodland-shrub type of vegetation, but they destroyed the area of 1491 ha. The most of these fires occurred between 5 and 10 degrees of inclination with the biggest burnt areas. The most of these fires occurred at the northern slopes while the biggest burnt areas occurred at the southern slopes. The highest frequency of fire was at elevation between 300 and 600 m, while the biggest burnt area occurred at elevation between 600 and 900 m. Among anthropogenic features, distance to local roads had the highest impact on the forest fire occurrence.

Key words: forest fire frequency; forest fire size, terrain; vegetation, infrastructure

ASSESSING THE SUCCESS OF NATURAL REGENERATION AND ARTIFICIAL REFORESTATION USING VERIFIABLE CRITERIA

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ABSTRACT

The intensity and frequency of disturbances and extreme weather events have increased worldwide in recent decades. More than one third of annual logging in Europe and Slovenia is due to sanitary reasons. In order to reduce the impact on the ecological and economical functions of forests, we have to improve forest restoration after disturbances. Most of the affected forest areas are going to be restored naturally due to great restorative potential of ecologically and economically interesting light-demanding tree species. The current level of artificial regeneration is near the lowest point in the history of sustainable forest management in Slovenia. The main reason for this is the success of natural regeneration, which has almost completely replaced artificial regeneration, and accounts for up to 90% of all forest areas. The increase in artificial regeneration in Slovenia is necessary for two reasons: i) to adapt to climate change we need to plant genetically diverse seedlings of species adapted to the future climate and ii) by increasing the intensity, severity and frequency of natural disasters, the need for artificial regeneration will also increase. We currently do not have a system and legislation in place to evaluate the success of natural reforestation and artificial regeneration, and suggest which option should be used. We have developed three methods to assess the performance of young trees on naturally and artificially regenerated areas: i) a method based on comparison with planting densities for uniform stands, ii) a method based on a combined estimate of density and coverage, and iii) a method based on mortality.

Key words: planting, densities, mortality, methods

MACHINE LEARNING METHODS FOR FOREST TAXATION SUPPORTED WITH FEATURE IMPORTANCE ANALYSIS

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ABSTRACT

Forest taxation is one of the most important problems for forest ecosystem monitoring. However, traditional approaches to taxation are expensive and time-consuming tasks. Forest classification using machine learning methods and satellite images is one of the most promising methods for reducing the cost of forest mapping. However, although various machine learning methods have become a solution for this task, the classification of mixed forests in complex areas remains difficult.

Our main goal was to develop a system that would accurately identify species using satellite images, calculate features, and contain different classification models. This study used multispectral and multitemporal Sentinel-2 satellite images to classify seven tree species and seven non-tree objects in 230 marked areas. The study area was a mixed forest near the Bratsk city, Irkutsk region in Russia. The pixel-wise classification was performed using classical machine learning models and convolutional neural networks. In addition, the use of spectral indices and texture features was evaluated.

Based on the study results, it can be said that the classification of tree species based on satellite images shows a high average overall accuracy of 80%. As expected, a 5-7% improvement in classification accuracy can be achieved by combining spectral indices and texture features. The results also show that the accuracy of convolutional neural networks is better than that of classical models. The development of this project will help to model a map of forest species and provide different forest characteristics for any area.

Key words: Multispectral imagery, Classification, Forest taxation, Texture features

THE MOST IMPORTANT PESTS AND PATHOGENS OF WOODY PLANTS IN THE ARBORETUM OF THE FACULTY OF FORESTRY, UNIVERSITY OF BELGRADE

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ABSTRACT

The natural area "Arboretum of the Faculty of Forestry" of the University of Belgrade is a green area with a specific purpose and exceptional botanical and landscape-architectural value. This natural monument of floristic character was founded in 1955 and 1956 in the former site of mixed autochthonous forests of Hungarian oak and Turkey oak *Querceto-frainettocerris* subass. *aculeatetosum* Jov. = syn. *Rusco-Quercetum frainetto-cerris*. Its purpose is primarily educational and scientific, but also bioecological, sanitary-hygienic, ornamental and cultural. The Arboretum has an exceptional educational role as it serves as the training spot for students of the Faculty of Forestry and other faculties belonging to the University of Belgrade.

It occupies an area of about 3.5 ha on which about 200 exotic, autochthonous and allochthonous woody species, subspecies, hybrids and cultivars are planted, represented by about 1,500 specimens. Due to its exceptional values, it was declared a protected natural area of category III by the Decision of the Assembly of the City of Belgrade.

Due to numerous factors (harmful insects, pathogenic fungi, extremes in temperature and humidity) that can have a negative impact on woody species, health monitoring is carried out on this isolated area. Trees are inspected twice a year, symptoms are recorded, and parts of plants are sampled and analyzed in laboratories.

Monitoring of woody plant health status is carried out in this specific area and significant pathogenic fungi are identified: *Cladosporium humile, Verticillium albo-atrum, Cytospora pinastri, Schizophyllum commune, Neonectria coccina, Cyclaneusma niveum, C. minus, Sphaeropsis sapinea, Botryosphaeria dothidea, Microsphaera syringae*, and *Ophiostoma ulmi*. The most significant mites and insect pests identified are: *Oligonychus ununguis, Cacopsylla pulchella, Corythucha arcuata, Cydalima perspectalis, Dasineura gleditchiae, Metcalfa pruinosa, Rhyacionia buoliana, Unaspis euonymi, Zeuzera pyrina* and others. Parasitic and saprophytic species of fungi, mites and insect pests have been found that effect assimilation organs, conduction vessels, bark and root system, which, together with unfavorable climatic factors, can lead to dieback.

Key words: pathogenic fungi, insect pests, protected natural area, arboretum

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STRUCTURAL CHARACTERISTICS AND FUNCTIONAL USE OF SPRUCE SEED STAND „VRŠAK-UVALA"

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ABSTRACT

The stand in which the research is located in PJ "Potoci - Resanovača" in the compartments 57 (escarpment "b", P = 4,7 ha) i 58 (escarpment "b", P = 19,4 ha). The stand belongs to the area of the Dinarides in the western - Bosnian limestone - dolomite area and the Ključ - Petrovac region. The stand is at an altitude of 850 to 900 m, on the southwestern exposition of Veliki Vršak (1042 m) and on a slope of 6 to 15 degrees. The research area is dominated by perhumid climate. The geological base is limestone and smaller parts of the surface are occupied by dolomites. The stand belongs to the community Pleurozio (Schreberi) Picetum subinversum and are characterisided progressive succession which indicates the formation of a mixed stand of fir and spruce with beech in which the ratio of the mixture would be dominated by fir. So far, the stand has developed mostly spontaneously and silvicultural and melioration felling have not been carried out, so it can be characterized as an uncultivated stand at maturity. Trees have a high coefficient of slenderness (Kv = 98.1) and reduced tree crowns. The stand has two floors and belongs to the first site class quality. The age of spruce trees on the upper floor is 130-140 years, and fir trees on the lower floor 50 to 60 years. Diseases and damage were found in 32% of trees. The total volume of the stand is 739.0 m3/ha, and the volume increment is 13.2 m^3/ha. Dendrometric analysis of trees showed that spruce trees have a very intense diameter increment at the age of more than 100 years, in contrast to fir, which at about 50 years of age has extremely low values of height and diameter increment. In a small space, surfaces of different composition, degree of regeneration, degree of maturity and different health condition alternate in a small space. Silvicultural units were singled out: mature stand with sapling stand and spruce trees (8.42 ha), with thinner pole stage trees of fir and spruce (1.28 ha) and with thicker pole stage fir and spruce without seedings (2.98 ha). The functional use of the seed stand is significantly reduced, but hers potentials for sustainable development and others forest functions (ecological, tourist-recreational, etc.) are expressed. In the stand, it is necessary to apply measures tending of stands accordance with the close-to-nature silviculture, remove mature trees in the upper floor of the stand and creating a new, young mixed stand of fir and spruce with beech.

Key words: smrča, struktura sastojine, funkcije šuma, sjemenska sastojina

Acknowledgements: We thank the Ministry of Agriculture, Forestry and Water Management of the Republic of Srpska for their support in the implementation of the project.

ASSESSMENT OF PROVISIONING ECOSYSTEM SERVICE BY IDES APPROACH: CASE STUDY OF FORESTS FOR TIMBER/ FIREWOOD PRODUCTION POTENTIAL IN KOVILJKSKO-PETROVARADINSKI RIT, SERBIA

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ABSTRACT

There are many benefits of forests which may be seen through ecosystem services (ES). The concept is relatively new and it offers a prospective of viewing all benefits of nature to humans in both descriptive and monetary aspect. In this light, ES of forests can be assessed within four main categories of benefits: provisioning (forests for timber/firewood production, habitat for other wildlife species), regulating (microclimate, flood protection), cultural (recreational, aesthetic value as inspiration for arts, architecture) and supporting (photosynthesis - CO2 capturing, O2 release; nutrient and hydrological cycling, and creation of soil). The EU Interreg project IDES (Improving water quality in the Danube river and its tributaries by integrative floodplain management based on Ecosystem Services; https://www.interreg-danube.eu/ides) has developed a tool for assessing most of the ES provided by floodplains. As a case study, we have selected the Koviljsko-Petrovaradinski Rit (KPR), Serbia. It lies in a floodplain of the Danube River in the middle of its flow through Serbia, and, due to its rich biodiversity it has been protected by law as a special nature reserve. In this paper we present application of the IDES tool in assessing the forests for timber/firewood production in KPR and the mapping of this ecosystem service. Results contribute to the more comprehensive assessment of a whole array of ecosystem services within the IDES project, which then enables to conclude about multiple benefits (or tradeoffs) arising from certain management or restauration measures in that Danube floodplain.

Key words: special nature reserve, sustainability, IDES tool

Acknowledgements: This article was supported by the Danube Transnational Programme, project IDES - Improving water quality in the Danube river and its tributaries by integrative floodplain management based on Ecosystem Services.

SMALL-SCALE SPATIAL VARIABILITY OF STAND STRUCTURAL FEATURES UNDER ACTIVE AND PASSIVE FOREST MANAGEMENT APPROACHES

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ABSTRACT

In the last two decades, studies on sub-stand structural variability based on large plots have become more numerous in old-growth forests, while comparative studies from managed forests are less common. In this study we compared vertical layering and small-scale horizontal variability of structural features in four even-aged stands managed by the shelterwood system, and in an uneven-aged plenter (selection) stand, with that in an old-growth stand. All stands were composed of late-successional and shade-tolerant tree species. Each of the six studied stands was represented by one plot of 1.5 ha in size, which was further divided into smaller square-shaped plots for fine spatial scale (moving window) analysis. We built and compared variation models of the structural features at fine scales ranging from 0.01 ha to 0.36 ha, with the old-growth stand serving as a reference. For assessing the spatial correlation of tree density and basal area at different fine scales, we applied detailed experimental semivariograms. The analysis of semivariance did not detect a positive spatial autocorrelation of basal area regardless of the management approach, whereas adjacent and nearby plots appeared to be more similar (autocorrelated) in terms of tree density in all examined stands. The variation models for tree density were similar only between the plenter stand and the old-growth stand, whereas the models for this feature in the shelterwood stands deviated significantly from the old-growth stand. The variation models for the basal area and Gini coefficient of all managed stands were significantly different from old-growth reference values.

Key words: fine-scale structural variability, spatial analysis, shelterwood system, selection system, old-growth

SUSTAINABLE FOREST MANAGEMENT ON THE EXAMPLE OF SE "SRBIJAŠUME"

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ABSTRACT

The aim of this paper is to perform an analysis of sustainable forest management on the example of the State Enterprise for Forest Management "Srbijašume". In 1991, by the Law on Forests, SE "Srbijašume" was formed from 53 business entities, with the aim of sustainable and integrated management of forest resources in the Republic of Serbia. In the past three decades, the Enterprise has undergone major organizational changes, whereby it had 27 forest areas (i.e,, forest estates) from 1991 to 1999, 21 forest areas from 1999 to 2002, and 17 forest areas since 2002. Continuity of management has been presented in the past 30 years for the region of Central Serbia, i.e,, 17 forest areas/estates. The area managed by SE "Srbijašume" in the period 1991-2021 kept changing slightly in the range of 909,515 ha to 895,338 ha, primarily due to resolving property and legal matters (restitution, inclusion of new plots, return of property, etc.). The area of overgrown land ranged from 755,938 ha (1991) to 774,418 ha (2021). In 1991, the total amount of wood volume was 94.4 million m^3, and in 2021 - 134.4 million m^3, which was an increase of ca. 42%. The most illustrative example of sustainable management was the increase in average wood volume from 127.5 m^3/ha (1991) to 173.5 m^3/ha (2021), i.e., 46.0 m^3/ha or ca. 36%. Volume increment went up from 2.7 million m^3 to 3.5 million m^3, which was an increase of about 30%. Having in mind the parameters mentioned, there has been a significant increase in the growing stock, which is, among other things, the result of sustainable and integrated management of forest resources. The importance lies not only in increasing the wood volume and current volume increment, but even more so in strengthening the public benefit functions of forests (protective, social, productive), which ultimately makes an immeasurable contribution to mitigating the negative effects of climate change. A forest that is in optimal condition fully performs its public benefit functions.

Key words: sustainable management, integrated management, forest condition, wood volume, volume increment

DETECTION AND MONITORING OF DAMAGE ON THE OAK AND ASH STANDS BY REMOTE SENSING METHODS

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ABSTRACT

Climate change, which has a significant impact on forest ecosystems, is leading to increased damage, degradation and decline of forests. Damage results in reduced increment, difficult management and reduced forest quality. Therefore, it is necessary to approach the rapid assessment and remediation of affected forests with the primary detection of infested stands in order to maintain their productivity and vitality at a satisfactory level with timely measures. The application of remote sensing methods contributes to a faster insight into the condition of forests, the degree of damage, the size of the affected areas and the proportion of damaged trees. Due to the recent appearance of the pathogenic fungus *Chalara fraxinea* and the invasive pest *Corythucha arcuata* in Croatia, decline in ash and oak stands was recorded in the lowland vegetation zone. The aim of the research was to determine the condition of oak and ash stands using the remote sensing methods and images from unmanned aerial vehicle, compare it with the current situation in the field, and to show the advantages of remote sensing over terrestrial methods. Based upon interpretation of the images from two periods of recording (before and after the damage), the intensity of the attack, the size of the affected area and the condition on default locations were determined. The application of remote sensing methods allows us to immediately observe and assess the damage presence in forest ecosystems, as well as facilitating the monitoring of forest health.

Key words: unmanned aerial vehicle, interpretation of the images, damage on the oak and ash stands, lowland vegetation zone

FOREST ECOSYSTEM SERVICES AND CLIMATE PROJECTS – PLANNING OPPORTUNITIES USING REMOTE SENSING

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ABSTRACT

Renewable biotic and abiotic resources are an important component of regional development. They determine the level of production of useful biological products and the conditions of human habitation and production activities. Within the framework of ecological economics, the term "resources" mostly replaced by the term "ecosystem services", including climate projects as means to conserve and amplify natural capital. One of the key problems in building an ecosystem economy is the lack of knowledge about the "depth of market" and the dynamics of natural capital in the context of climate change. The theoretical basis of the assessment technology is a functional multidimensional relationship of various properties and components of the environment. Moreover, multidimensional complex systems with a large number of individual elements, described by dozens of variables, can be reduced to a few order parameters that describe most of the dynamics and properties of such systems. This opens wide possibilities for assessing the difficult-to-measure properties of ecosystem through spatially continuous, reliably measurable variables: multispectral measurements from satellites, relief and its derivatives, and measurements of climatic variables. Using methods of dimensionality reduction over series of remote sensing data such order parameters are extracted for forest ecosystems on both regional and local scales (Central forest reserve and European part of Russia). Results allows to determine the conditions for maximizing the useful work of the forest ecosystem, as well as to evaluate the contribution of individual components of the system. This opens up the possibility of adaptive territorial planning that optimizes the use of natural capital.

Key words: Landscape ecology, order parameters, natural capital

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FOREST FIRE PROBABILITY MODELING AND MAPPING BY MACHINE LEARNING METHOD IN LOWER AND UPPER AUSTRIA

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ABSTRACT

Forest fires are global phenomena that threats many countries around the world. More than 6,600 forest fires occurred in Europe in 2021, burning an area of about a million hectares. The Mediterranean region is the most affected in Europe, but in recent years, forest fires have become an important issue in Central Europe as well. To model forest fire occurrence probability in two regions of Austria, besides historical fire data, several types of predictors were collected and generated including topographic, vegetational, weather and anthropogenic features. All data were attributed to the polygons in a 1 × 1 km grid using GIS software. After variable selection, Random Forest (RF) method was applied to assess forest fire occurrence probability for each 1 x1 km grid cell. Random forest belongs to the decision trees branch of the same group of machine learning (ML) methods. This method uses a large number of decision trees, which produce their predictions and combine them into a single, more accurate, prediction. Model evaluation was conducted by a ROC analysis. AUC values from ROC analysis between 0.5-0.7 indicate poor precision, values between 0.7-0.8 indicate acceptable precision, values between 0.8-0.9 indicate excellent precision, and values higher than 0.9 indicate outstanding model precision Additional evaluation of the models was conducted by 2 × 2 classification tables based on the overall accuracy. Final model, selected for mapping, had 81% of overall accuracy and AUC values of 0.871 and 0.867 in training and validation sets of data, respectively.

Key words: Occurrence of forest fire, Random Forest, variable importance, prediction accuracy

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AGROFORESTRY AND ITS ADOPTION IN KILOMBERO CLUSTER OF SAGCOT, TANZANIA

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ABSTRACT

Agroforestry systems and practices are perceived to improve livelihood and sustainable management of natural resources. However, their adoption in various regions differs, with the biophysical conditions and societal characteristics. Study was conducted in Kilombero District to investigate the factors influencing the adoption of different agroforestry systems and practices in agro-ecosystems and farming systems. A Household survey, Key informant interviews and focus group discussion was used for data collection in three villages. Descriptive statistics and multinomial logistic regression in SPSS were applied for analysis.

Results shows that Igima and Ngajengwa villages had home garden practices dominated, as revealed by 63.3% and 66.7%, respectively, while Mbingu village had mixed intercropping practice with 56.67%. Agrosilvopasture systems were dominant in Igima and Ngajengwa villages with 56.7% and 66.7%, respectively, while in Mbingu village, the dominant system was agrosilviculture with 66.7%. The results from multinomial logistic regression show that show that different explanatory variable was statistical significance as predictors of the adoption of agroforestry systems and practices. Residence type and sex were the most dominant factor influencing the adoption of agroforestry systems. Duration of stay in the village, availability of extension education, residence, and sex were the dominant factor influencing the adoption of agroforestry practices. The study concludes that agroforestry will be more successful if the local priorities which include social-economic need characteristics of the society will be considered in designing systems and practices. The socio-economic need of the community should be addressed in the process of expanding the adoption of agroforestry systems and practices.

Key words: Agroforestry adoption, agroforestry systems, agroforestry practices, agroforestry, Kilombero

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DEFOLIATION CHANGE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) DEPENDS ON PREVIOUS YEAR DROUGHT

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ABSTRACT

European beech (*Fagus sylvatica* L.) forests provide multiple essential ecosystem goods and services. The projected climatic conditions for the current century will significantly affect the vitality of European beech. The expected impact of climate change on forest ecosystems will be potentially stronger in southeast Europe than on the rest of the continent. Therefore, our aim was to use the long term monitoring data of crown vitality indicators in Croatia to identify long-term trends, and to investigate the influence of current and previous year climate conditions and available site factors using defoliation (DEF) and defoliation change (ΔDEF) as response variables.

The results reveal an increasing trend of DEF during the study period from 1996 to 2017. In contrast, no significant trend in annual ΔDEF was observed. The applied linear mixed effects models indicate a very strong influence of previous year drought on ΔDEF, while climate conditions have a weak or insignificant effect on DEF. The results suggest that site factors explain 25 to 30 % DEF variance, while similar values of conditional and marginal R2 show a uniform influence of drought on ΔDEF. These results suggest that DEF represents the accumulated impact of location specific stressful environmental conditions on tree vitality, while ΔDEF reflects intense stress and represents the current or recent status of tree vitality that could be more appropriate for analysing the effect of climate conditions on forest trees.

Key words: defoliation, monitoring; tree vitality, drought, climate change

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FORESTS WITH A LEADING SOCIAL FUNCTION IN POLAND: AN EFFECTIVE SOLUTION OR AN INCREASED RISK IN TERMS OF CLIMATE CHANGE?

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ABSTRACT

Poland's State Forests account for about 80% of all forests. The organization managing them is trying to respond to social expectations. In the course of revising the principles of forest management, silviculture and protection, it is introducing a separate category of forests with a leading social function. This category is to include forests within the administrative boundaries of cities (approximately 300,000 ha owned by the state) and others, in which the role of recreational functions is to be significant. Their area may reach up to approx. 10% of all forests in the country, but so far the rules for their delimitation are not known. However, the principles of management are being established which exclude the clearcutting system and transformation to continuous forests with permanent presence of old trees. Such transformation will take place within the existing conditions of habitats and forest condition and predicted climate changes. Existing models of forest response to climate change allow evaluating the proposed solutions and predicting the effects of implementing social expectations in such forests. The paper presents the most important assumptions of changes in the management of forests with the leading social function in Poland and tries to classify them in terms of the risk of threats to the sustainability of forest ecosystems. The paper uses climate change scenario analyses and projected changes in risk to forest sustainability in areas covered by the new management rules.

Key words: urban and suburban forests, social expectation, climate changes in forest management

PRICE SIGNALS COULD DELIVER MUCH MORE CARBON SINKING BY THE HUNGARIAN FOREST SECTOR

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ABSTRACT

Our work assesses the unused carbon sequestration potential of forests in Hungary by introducing the currently missing carbon price signal. We developed our Forest Carbon Sink Optimization Model (FOX) to enable a complex climate economic approach to forest carbon removals. Our FOX Model is a bio-economic optimization model where production of forest wood is fuelled by biologically determined growth functions but decision making about harvesting or further growth is resolved by an economic profit maximization objective function. This introduces the potential for wood as a carbon instrument in addition to wood as a commodity. Besides the benefits of wood products, we built in an additional item into the FOX model: the potential benefit of a carbon, by providing a certain payment after the incremental carbon sequestration when harvesting is delayed by another period. Similarly, the model internalizes an equivalent level of carbon release cost in the time period when the final cut is realized.

The FOX Model determines the optimal harvest of forests on a national level based on the exogenous forest growth functions, timber and carbon prices. It is a dynamic, linear mathematical optimization model. The harvesting process includes both cutting and thinning of forests. The model allows the co-existence of multiple forest age classes. Timber and carbon prices are exogenously set for the model. The timber prices are defined for three main demand segments: 'sawlogs' for the timber industry, 'pulpwood' for the fibreboard and paper industries and 'firewood' for all energy purposes. The model can process up to 10 species/species groups in 10-year age classes and can be run for up to 220 years (with 10-year time periods). All characteristics can be further expanded upon based on the input data. The model is written in GAMS with Excel interface. Currently, the model is calibrated with country specific datasets collected from the forest authorities of Hungary. Efforts are ongoing to calibrate the model for Romania and Bulgaria as well.

We appraise the cost and volume of potentially available additional carbon removal by forests in the context of the climate policy instruments. We find that existing forests in Hungary could deliver substantial amounts of additional carbon removal. We also show that enhanced forest carbon sequestration can be more cost efficient than some other climate policy instruments.

Key words: bio-economic model, sequestration, biomass energy, marginal carbon abatement cost, non-timber benefits

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ECOSYSTEM MANAGEMENT DECISION SUPPORT SYSTEM IN FORESTRY

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ABSTRACT

The Ecosystem Management Decision Support System (EMDS), version 8.6, is a state-of-the-art decision support framework for geospatial analysis in environmental studies, and is available as an add-in to the ArcMap, ArcGIS Pro and QGIS desktop systems, as well as via web services that are coming shortly. EMDS applications can address multiple interdependent spatial scales, which is a main strength of the program. EMDS implements four interoperable analytical engines to support multi-criteria decision analysis (MCDA), logic-based processing (NetWeaver), decision trees (VisiRule), and Bayesian networks (GeNIe). For MCDA methods, EMDS uses the Analytic Hierarchy Process (AHP) and Simple Multi-Attribute Rating Technique (SMART), and both methods are implemented in the Criterion DecisionPlus software. Interoperability of the four analytical engines is augmented by a built-in workflow editor based on WexFlow, and by scripting languages, including R, Python, JavaScipt and C++. Numerous applications have been developed since 1997, and these can be divided into two main groups: (i) geospatial modeling and analysis and (ii) tactical and strategic planning. The latest release adds advanced reporting features based on a built-in report editor that supports maps, tables, and graphs. This paper presents an overview of the features of the latest version 8.6, and briefly summarizes a recent application for assessing terrestrial ecological integrity on National Forest System lands in the continental US.

Key words: EMDS, modeling, geospatial analysis, scripting languages, forest ecosystems

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PRIVATE FORESTRY ON AGRICULTURAL LAND AS A TOOL FOR REFORMING THE RUSSIAN FOREST SECTOR?

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ABSTRACT

Resolution of the Government of the Russian Federation No. 1509 dated September 21, 2020, aimed at legalizing private forestry on agricultural land, has come into force. By January 2022, 2,487 notifications in relation to 10,116 plots with a total area of 552.73 thousand hectares were received by the territorial administrations of the Rosselkhoznadzor (Federal Service for Veterinary and Phytosanitary Surveillance) from owners of agricultural land plots to use this lands for forestry purposes.

Forest on agricultural land can be used for forest growing purpose and the implementation of Forest Carbon Projects (FCP) in compliance with fire and sanitary safety requirements common to all lands, as well as turnover of wood.

In Russia, vertically integrated timber companies are focusing on supplying existing industries with timber and likely will be late in coming to more bio-productive and logistically accessible regions. The investments growth in timber processing (board products, plywood, wooden housing construction, etc.) is noticeable in the middle and southern parts of the forest belt of European Russia (ETS) outside the dominance area of timber companies integrated around the pulp and paper mill in the north of the ETS. Return on investment in old-developed areas is provided by transport logistics. In the North-West regions of the ETS, the delivery distance to the railway dead end is 250-300 km, while the forest on agricultural land is often located 10-80 km from the "machine tool".

The strategy of transition to leasehold and private forestry on agricultural lands could be more profitable than "greenfield projects" in the forests of Siberia and the Far East in regions with poor road infrastructure and high environmental risks.

Key words: Forestry policy, agroforestry, intensive forestry vs. extensive exploitation, Russian Federation

TREE PLANTATION TO MITIGATE CLIMATE CHANGE, USING NEW TECHNOLOGIES AND INNOVATIVE APPROACHES

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ABSTRACT

Iran is experiencing unprecedented climate-related problems such as drying of lakes and rivers, dust storms, record-breaking temperatures, droughts, and floods. Planting of trees across the country is one of the biggest and cheapest ways to absorb CO_2 out of the atmosphere and then sequestrate in the soil to reduce the CO_2 emission which might be the only way to control the impacts of climate change. This paper highlights the method which is the planting trees don't need any land use change and mostly using the gray water for irrigation. The target lands are usually the degraded areas that are separated on various geographic sections under the different land uses, e.g., arable lands, range lands and forest areas in Iran.

This paper is focused on two platforms (Treejer and Baazdam) which are designed based on updated internet technologies under the blockchain and local knowledge management frameworks. They both also have been used for the first time in Iran. Each single tree which is collected or funded through Treejer and Baazdam has unique social and environmental impacts. Rural planters in high-impact locations plant and maintain the trees. Most of them are located in less developed areas in Iran. The both platforms are the links between those who fund trees and those who plant them even in the most remote places on our planet. It records credit ownership and enables secure payment between different parties using smart-contracts. Treejer and Baazdam are using blockchain and bottom approaches to authorize/mange tree plantations respectively.

Key words: Tree plantation, climate change, Treejer, Baazdam

PRELIMINARY RESULTS ON STEM CARBON ALLOCATION IN MIXED FLOODPLAIN FOREST

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ABSTRACT

Recent changes in floodplain forests in Central Europe, mainly caused by hydrological management and more frequently occurring droughts, have resulted in severe deterioration of floodplain ecosystems. To test species sensitivity, drought effects on sap flow and tree water deficit derived from automatized dendrometers were investigated during 2016-2018 period with contrasting weather conditions. Additionally, the impact of drought on ecosystem gross-primary production (GPP) derived from eddy-covariance method was studied. The study was performed in a floodplain forest located at the confluence of Morava and Dyje rivers in the Czech Republic, on deciduous broadleaved *Quercus robur, Fraxinus angustifolia*, and *Carpinus betulus*. Dendrometer and eddy covariance measurements revealed some shortcomings regarding the actual magnitude of drought stress on carbon allocation. Evidently, the year 2018—with one of the driest and hottest summers—did not affect radial growth, which was the highest due to favorable spring conditions compared to the year 2016. However, although GPP was enhanced in spring, it firmly declined in the second part of the year 2018 compared to the corresponding periods in 2016. Evidently, dendrometers capture volumetric growth (i.e. cell division and cell enlargement), whereas cell wall thickening is not detected. Considering that secondary wall thickening is a considerably more carbon demanding process, we speculate that drought in the second part of the growing season is detrimental to the overall carbon uptake. Therefore, we show preliminary results on xylogenesis and photosynthesis derived from phloem isotopes and sap flow which are crucial in explaining carbon allocation in forest ecosystems.

Key words: Sap flow, dendrometers, xylogenesis, eddy covariance, phloem isotopes

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RADIAL GROWTH RESPONSE OF ICE STORM DAMAGED SILVER FIR AND EUROPEAN BEECH TREES IN THE CROATIAN REGION GORSKI KOTAR

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ABSTRACT

Forests in the Gorski Kotar region of Croatia were severely affected by the ice storm in February 2014. To assess this natural disturbance impact, a sample of 20 circle plots (20 m radii) was established within the disturbed forest area. All sample trees (>10 cm dbh) were measured (dbh, height, crown damage category: A >75%; B 50-75%; C 25-49%; D <25%) in 2015 (1.389 trees) after the event and in 2020 (1.204 trees). In addition, up to 6 fir and beech trees closest to the plot center were sampled in 2020 for tree coring (85 firs, 160 beeches) to "cover" crown damage categories within tree's layers. Resistance and recovery indexes of sampled tree radial growth were calculated. Variance analysis was used to compare indexes among tree species, crown damage categories, and tree exposure. The results showed, for both tree species, that as crown damage increased, the resistance index decreased (beech: I_{res}>1 for C and D categories; fir: I_{res}>1 for A and D categories). This indicates that crown damage of up to 50% doesn't cause a significant decrease in radial growth 3 years after the event. Due to small sample and absence of severely damaged crowns, fir showed some growth inconsistency, however, this may indicate its high capacity of growth recovery. For both species, more exposed trees (upper-story) showed a lower recovery index (1.14) compared to under-story trees (1.26). The obtained results indicate that the two main tree species in the area have high resistance to ice storm of moderate intensity.

Key words: ice storm, crown damage, radial growth, tree resistance and recovery, climate change

Acknowledgements: This research was funded by the Croatian Science Foundation (project no. 603 IP-2018-01-8820)

GROWTH RESPONSE AND SAP FLOW OF *PICEA ABIES* (L.) KARST. SEEDLINGS TO ELEVATED CO_2 CONCENTRATION

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ABSTRACT

Since the beginning of the industrial revolution, carbon dioxide (CO_2) in the atmosphere has increased significantly, on average 2 parts per million (ppm) annually. Whereby the global atmospheric CO_2 level is likely to increase to 550–1000 ppm by the end of the century, depending on the success of our efforts to reduce CO_2 emissions. Most physiological studies have shown that elevated CO_2 induces changes in tree growth patterns, tissue structure and developmental processes. Therefore, the response of the terrestrial C sink to increasing atmospheric CO_2 remains the largest uncertainty in global C cycle, and is a huge contributor to uncertainty in projections of climate change. Hence, in this study, we grew 168 four-year-old seedlings of Norway spruce in lamellar glass domes at the Experimental Site Bílý Kříž in the Beskydy Mountains. The objectives of this experiment were to determine the effect of elevated CO_2 (eCO_2) concentration on aboveground biomass growth, transpiration, and wood anatomy. In order to estimate seedling's water consumption, sap flow was measured using commercially available EMS 62-type measuring sensors so-called "baby sensors". Total aboveground biomass was higher by (1.81%) in eCO_2 condition, also eCO_2 showed a statistically significant impact on height, diameter, and consequently cross-sectional area. Overall, seedlings growing under eCO2 had significantly higher densities (4%). We tested the hypothesis that the Norway spruce seedling's biomass growth will be stimulated by the CO_2 "fertilization" effect. In accordance with the hypothesis, our results confirmed existence of effects of eCO2 concentration on wood density and particularly on biomass production.

Key words: Norway spruce, "baby sensors", transpiration, oven-dry wood density

Acknowledgements: The work was supported by the Ministry of Education, Youth and Sports of CR within the CzeCOS program, grant number LM2018123 and IGRAČEK MENDELU project CZ.02.2.69/0.0/0.0/19_073/0016670, reg.numb.SGC-2021-013.

POSSIBILITY OF APPLICATION OF AERIAL PHOTOGRAMMETRY IN THE INVENTORY OF POPLAR PLANTATIONS

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ABSTRACT

In Serbian forestry, data on the forest resources are obtained mainly by applying terrestrial inventory methods. The experience of some European countries shows that part of the information on forests can be obtained on the basis of aerial images - using aerial photogrammetric methods. In that sense, the aim of this paper was to consider the possibility of applying aerophotogrammetry in the process of collecting information in poplar plantations. The reliability of the data from the aerial images was determined by comparative analysis in relation to the data obtained by terrestrial measurement. The research was conducted on 12 experimental plots set up in poplar plantations, planting spacing 5x5 m, in the area of Vojvodina. Poplar plantations are classified into 4 age categories 10, 15, 20, and 25 years. In addition to the assessment of numerical data, aerial photogrammetry also performed the assessment of certain qualitative information from the domain of the site and stand description. The results of the research partially confirmed the European experience on the possibility of applying aerial photogrammetry in forest inventory. Comparative analysis of numerical elements of the stand directly read from the images, such as a number of trees, tree height, and crown area, and derived elements - breast diameter, basal area, stand volume, and their distribution, in relation to values obtained by terrestrial measurement methods, indicated the possibility of limited use of aerial photogrammetry in the inventory of these forests. The differences were reflected in the reading of lower values of the crown area and tree heights, which is why lower values of breast diameters were estimated using mathematical models. This implied movement in the distribution of trees by diameter degrees, consequently leading to differences in the basal area and volume of the research plantations in relation to the values obtained by the terrestrial measurement. When it comes to information related to the site and stand description, the results also indicate the limited use of aerial images in determining information from these categories. Therefore, a combined inventory is imposed as the optimal solution, which sublimates the positive effects of the tested methods.

Key words: aerial photography - photo interpretation, stand forest inventory, comparative analysis, combined inventory

Acknowledgements: We are grateful to the Ministry of Education and Science of the Republic of Serbia for the financial support to this research within the Projects Sustainable management of total forest potentials in the Republic of Serbia"- EVBR 37008

CLIMATE CHANGE AND ADAPTATION OF FOREST ECOSYSTEMS IN SERBIA

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ABSTRACT

The greatest challenge to the management of the forests and other natural resources is posed by the development of the adaptive measures in forest management, as well as by their increasing vulnerability under various climate change scenarios. Most projections of future climate changes (SRES - Special Report on Emissions Scenarios, IPCC, 2000, 2001, 2007, 2014) indicates to temperature and precipitation significant changes, as well as increasing concentrations of greenhouse gases in the atmosphere, that will caused many ecological problems and affected on sustainable development across the world. The paper is not based on the experimental methods, but on the methods of analysis and synthesis, with the elements of generalization and specialization, comparative analysis and inductive-deductive methods, modelled on the current theoretical-methodological knowledge. The proposed potential strategic and operational measures of forest ecosystems adaptation in Serbia are based on the previous works, international declarations and experiences verified by practice.

Climate changes causes numerous problems in forest ecosystems: degradation, deforestation, increased mortality rates, biodiversity loss, reduced forest ecosystem vitality due to cumulative impact of different stresses etc. The concept of the spatial development of the Republic of Serbia, aimed at the alleviation of the effects of global warming and climate change on the forest ecosystems in Serbia, should include the determination of the effects of climate change on the availability of the natural resources, above all forest ecosystems and biodiversity aimed at planning sustainable development and ecologically acceptable activities in the domains susceptible to the climate change.

Key words: forest, ecological problems, adaptation, sustainable development

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ANALYSIS STATE AND FOREST MANAGEMENT OF UNEVEN-AGED STANDS IN BOSNIA AND HERZEGOVINA: A CASE STUDY FROM THE AREA OF MOUNT BORJA

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ABSTRACT

Fifteen experimental plots (50 m x 50 m) were set up in pure fir stands and mixed fir and beech stands on the Borja Mt., located in the northern part of central Bosnia. The diameter structure of the investigated stands significantly deviates from the diameter structure characteristic for uneven-aged stands, and also from the diameter structure characteristic for even-aged stands. For the investigated stands, the normal state was determined based on Susmel's (for Fir) and Collete's (for Beech) correlations. Normal state was determined by Matić's method which is used in the practice of forest management in Bosnia and Herzegovina to define the technical goal of management. The deviation of the current state from the normal state determined by the Matic's method is greater. In pure stands there is a higher deviation compared to mixed stands. In pure stands, there is a lack of thinner trees, a significant excess of medium-thick trees and a lack of thick trees. In mixed stands, established range in relation to the normal range of trees has a lack of thin and thick trees. The determined deviation from the normal state is a consequence of the fact that for the management class of the investigated stands, a group-selection system is prescribed, but the mentioned system is applied so that it represents "some" combination of group-selection system and selection system, resulting in structure that deviates significantly from the structure characteristic of selection forest stands.

Key words: normal uneven-aged stand, fir, beech, Bosna and Herzegovina

APPLICATION OF LYSIMETERS IN SOIL SOLUTION MONITORING IN FOREST ECOSYSTEMS IN SERBIA

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ABSTRACT

As part of the multifunctional research of the ICP program for forests (international cooperation program for monitoring the state of forests in Europe) since 2003, continuously is conducting lysimetric method of monitoring the state of soil solution in forest ecosystems in Serbia. This method covers several forest communities in different ecological conditions. Certain amounts of atmospheric sediment that seep through the soil are collected in gravity lysimeters, which are placed in the vertical front wall of the existing pedological profiles, at a constant depth below the humus horizon. As a filter in a plastic container, there is annealed quartz sand for the purpose of purifying soil solution from soil particles. Sampling is done once a month. Based on these samples, the analysis of soil solution determines the presence of certain nutrients (K, Ca, Mg, Na, N-NO3, S-SO4, N-NH4, Cl) and changes in their concentrations in solution, in order to define the existing vitality of forest complex, as well as in noticing differences in the resistance of certain tree species to the lack of these nutrients. One of the goals is to determine the trend of soil acidification, and the quality of water circulating through a forest ecosystem. In that way, it is possible to determine the buffer capacity of the soil and the extent to which acidification occurred. Monitoring with this method should be extended to other important forest communities in Serbia, primarily oak communities, in order to gain better insight into the impact of forest cover composition on the characteristics of the soil solution, as well as the state of soil damage.

Key words: lysimeters, soil, soil solution, forest ecosystems

SOIL CARBON CONTENT IN FOREST MANAGEMENT UNIT MUŽLJANSKI RIT

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ABSTRACT

In the previous period are determined the soil cover in the forest management unit Muzljanski rit. According this research, soil cover in the forest management unit Muzljanski rit is heterogeneous in relation to position and altitude in floodplain. In addition to the above, the soil spatial distribution analysis was conducted and the most common soil type was determined as meadow black soil, eugley (was delineated according to physiologically active soil depth) and humogley. The analysis of soil properties is pointed out the differences in physical and chemical properties. The paper presents analysis of soil carbon content in forest management unit Muzljanski rit. The paper analyzed carbon content according to the soil type and different vegetation in the same soil type. Analysis of different tree species on the same soil types was necessary, because three different species (poplar, black locust and pedunculate oak) take up the most space in the forest management unit Muzljanski rit. Our research shows that differences in carbon content was established between most common soil type, as well as the same soil type but with a different tree species. Also our research shows that in the area of in the forest management unit Muzljanski rit the most common species for carbon sequestration in future it should be pedunculate oak.

Key words: Muzljanski rit, carbon content, soil types

Acknowledgements: This research was part of project of Ministry of Education, Science and Technological development No. 451-03-68/2022-14/ 200197.

DEVELOPMENT OF NEW TECHNOLOGIES TO SELECT WOODY PLANT SPECIES FOR CULTIVATION IN THE CLIMATE CHANGE CONDITIONS

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ABSTRACT

It is challenging to develop a new woody plant cultivar with traditional breeding programs in the era of global climate change. Scientists urge to develop new technologies and techniques to preserve existing genomes and widen its genetic variability in the battle against various stresses, herbicide tolerance, growth rate and wood quality, or reduction undesirable traits that start weakening forest resources worldwide. Interspecific hybridization and vegetative propagation of clonal cultivars become a constant feature of all breeding programs since the early 1920s. The latest 'Register of Populus L. cultivars' (FAO 2000) includes 330 cultivars that are cultivated throughout the world, are mostly clones. Their growing as monoculture enables easy spreading of various disease and pests across the continents. The development of "in vitro" culture allowed the exploration of new pathways to overleap the limitations of conventional breeding and add ease to breeder's effort without influence of environmental effect to achieve new entity. Development of genome analysis revealed novel molecular markers (RFLPs, RAPDs, AFLPs, STS, SSRs). Large collection of ESTs was established. QTLs are mapped to identify correlation of the molecular marker with a trait. Genome sequencing and freely sharing digital sequence information gives significant impulse to scientific community to accelerate improvement of desirable traits in woody plant species. Newly discovered genome editing techniques opened a new era to speed up tree breeding cycle. Especially CRISPR/Cas system enabled new opportunities to generate new genetic diversity in woody plants thus will help forest trees to be more resilient to various ecological challenges.

Key words: conventional breeding, "in vitro" techniques, molecular markers, genome editing

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MAPPING OF SELECTED CLIMATE REGULATION ECOSYSTEM SERVICES IN PROTECTED AREAS IN PIRIN MT.

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ABSTRACT

Mountain ecosystems play an essential role in sustainable mountain development, providing benefits and values to humanity not only for the rich biodiversity they contain, but also because their important role in climate regulation, water cycle, provisioning of recreation and tourism opportunities, and cultural or spiritual values. The high biodiversity of the mountain areas allow the provision of a wide range of ecosystem services but different impacts to the environment threaten the delivery of these services and, consequently, the human well-being. Assessment and mapping of selected climate regulation ecosystem services (ES) provided by forest ecosystems in protected areas in Rila Mt. were realized, following the MAES concept and methodology. A set of informative indicators for assessment of the condition of forest ecosystems is selected, related to climate regulation and socio-ecological challenges. The analysis of the potential of forest ecosystems to provide regulating ES in the case-study area was done by processing the available data from Management Plan of NP Pirin and the data for Natura 2000 sites, by applying modern GIS-based methods and models. The prioritization of ecosystem services provided by forests in Rila Mt. has been done based on expert assessment and questionnaires. The assessment and mapping of ecosystem services allows proper understandings of the importance of natural resources on human well-being and support decision-makers in facing potential threats for sustainable regional development.

Key words: ecosystem services, assessment, mapping, protected areas, Pirin Mt.

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ECTOMYCORRHIZAL FUNGI MODULATE OAK'S BIOCHEMICAL RESPONSE AGAINST POWDERY MILDEW

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ABSTRACT

In light of climate change, pedunculate oak (*Q. robur* L.) was marked as one of the most threatened European tree species. Pedunculate oak is particularly jeopardized by powdery mildew disease caused by *Erysiphe alphitoides* fungus. Authors hypothesized that priming with ectomycorrhizal fungi could mitigate biotic stress and could have bioprotective properties against the disease. In this study, we tracked the effects of commercial inoculum ECTOVIT (Symbiom, Czech Republic) comprised of several ectomycorrhizal (ECM) fungi upon oaks' biochemical properties in non-infected leaves vs. leaves infected with *E. alphitoides* spores. The experiment comprised of four treatments, pedunculate oak seedling infected by powdery mildew spores previously inoculated with ectomycorrhiza (ECM-PM) and non-mycorrhized seedlings exposed to powdery mildew spores (NM-PM), as well as corresponding controls, oak seedlings that were not infected with powdery mildew, both non-mycorrhized controls (NM-C) and controls previously inoculated with ECM fungi (ECM-C). In all treatments, we measured foliar accumulation of polyamines, soluble osmolytes (proline and glycine betaine) and various phenolics (total phenolic content, flavonoids, and condensed tannins). Quantification of polyamine-dansyl derivates was done by using high performance liquid chromatography (HLPC) coupled with fluorescent detection. Plants infected with powdery mildew that were previously inoculated with ECM fungi (ECM-PM) exhibited significantly higher levels of putrescine, spermine and proline comparing to non-inoculated oak seedlings infected by powdery mildew (NM-PM), indicating priming properties of applied inoculum. Common biochemical parameters are useful for deeper understanding of underpinning mechanisms in three-way interaction among plant, pathogenic and ectomycorrhizal fungi.

Key words: Polyamines; proline; phenolics, pedunculate oak, ectomycorrhizal fungi, powdery mildew

SILVICULTURAL CHARACTERISTICS OF HIGH SESSILE OAK FORESTS AFTER WIND STORM IN THE AREA OF FMU "CRNI VRH"

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ABSTRACT

In the area of the "Prigradske šume" district, FMU "Crni Vrh", FMA "Donjevrbasko", close to Banja Luka, there were windthrows and wind breakages due to strong winds and storms. The stand affected by the stormy weather is mostly built of young, middle-aged and mature trees of sessile oak and other deciduous trees (beech, maple, linden, hornbeam, etc.). The damage was of a mechanical nature and the living trees were completely knocked out of the ground, broken in stem base as well as at higher heights, fractures of branches as well as entire canopies were also observed. The transect sample was circular with a radius of 25 m. Circular areas within each transect were arranged at a distance of 100 m from each other. The measurements determined that every 11th tree in sub-compartment "b" was broken or knocked out. Taking the coordinates of each felled and broken tree, we obtained the data that most of the trees had the direction of fall north - east (NE) and the least south - west (SW). The most damaged tree species is sessile oak (85% of all species). Trees are most damaged by breakages (45%) and windthrows (32%); other trees are damaged by other factors (mixed biotic and abiotic factors). From the ratio of living and dead tree volume, we conclude that most trees were damaged in the diameter classes of 32.5 cm and 37.5 cm, which is understandable considering that the maximum number of sessile oak trees are in the given diameter classes.

Key words: sessile oak, windthrow, windsnap, forest damage

PHYSIOLOGICAL PERFORMANCES OF TREE SPECIES IN THE URBAN AREA OF BELGRADE, SERBIA UNDER EXTREME DROUGHT

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ABSTRACT

Drought stress is frequently identified as the main factor affecting urban trees health status and vitality. Therefore, identification of drought-tolerant tree species for growing in urban settlements imposes itself as a priority in order to maximize ecosystem services provided by urban trees, as well as to mitigate negative effects of climate change. The aim of the study was to evaluate drought-response of different tree species, cultivated in the urban area of the City of Belgrade (Serbia), using gas exchange parameters. The study involved 10 native and non-native tree species planted alongside the main city boulevards. The results showed significant differences in studied tree species physiological response, indicating the potential capacity of certain species to acclimate to urban habitat conditions. *Crataegus monogyna* and *Tilia tomentosa* have potential for adaptation to severe environmental conditions based on high photosynthetic rate (A) and stomatal conductance (gs). Besides these two parameters, *Crataegus monogyna* showed high values of transpiration (E) and intercellular CO_2 concentration (C_i). Moreover, *Tilia tomentosa* and *Ulmus pumila* showed high values of water-use efficiency (WUE). WUE is response mechanism to water deficit and has been the focus of many programs that seek to increase tolerance of drought. Drought stress in urban environment negatively affects the physiological performance of Ginkgo biloba. The results of the study were discussed from the perspective of selecting appropriate tree species for cultivation in urban areas.

Key words: urban forestry, physiological performances, leaf gas exchange, urban environment

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DENDROCHEMISTRY AND DENDROBIOCHEMISTRY: A STABLE ISOTOPES, XENOBIOTICS, AND METABOLIC-RELATED PRODUCTS AS A VALUABLE TOOL FOR TEMPORAL ENVIRONMENTAL RECONSTRUCTION

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ABSTRACT

Tree-rings provide a valuable pool about trees' surrounding environmental changes. In addition to radial increment and anatomy commonly used in dendrochronology studies, a lot of tree-ring chemical traits (such as stable C ($\delta^{13}C$), O ($\delta^{18}O$), H ($\delta^{2}H$), N ($\delta^{15}N$), and S ($\delta^{34}S$) isotope ratios) can be examined to determine the environmental dynamics throughout the tree lifespan. However, research involving reconstruction of environmental pollution based on the content of organic and non-organic pollutants (such as heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), etc.) and different metabolites (e.g., carbohydrates and secondary metabolites – Dendrobiochemistry) based on tree-ring chronologies is limited. Dendrochemistry and especially dendrobiochemistry, while relatively new disciplines, provide a wide range of possibilities for utilizing tree-ring data for a better understanding of historical trends in climate, environment, nutrient availability, presence of pollutants, and other xenobiotics, as well as ecosystem dynamics. In natural as well as contaminated and anthropogenic environments, tree cambial activity and the aforementioned chemical traits are interrelated and influenced by climate events (water balance, warming, and drought). Thus, certain chemical traits (e.g., isotopic answer and pollutants) are a result of complex interactions and the synergy with other tree characteristics (fitness, stem characteristics, and crown and root architecture) and the environmental factors characterizing the habitat.

Key words: Radial growth, Tree ring, Pollutants, Polycyclic Aromatic Hydrocarbons, Heavy metals, Climate extremes

Acknowledgements: This research was supported by the Science Fund of the Republic of Serbia, PROMIS, #6066697, TreeVita.

ANALYSIS OF THE STATE OF BEECH FORESTS FROM THE PLANNING ASPECT IN THE AREA OF THE MANAGEMENT UNIT "VELIKI JASTREBAC PROKUPAČKI" IN SOUTHERN SERBIA

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ABSTRACT

The subject of this research are pure even-aged beech forests in the area of the management unit "Veliki Jastrebac Prokupački". In order to study the state of these forests, 2 experimental fields of square shape and size of 0.25 ha were set up. The age of both stands is 80 years, while the production potential of the habitat differs. The stand on EF-1 is located in a valley where the soil is medium deep and fresh while the stand on EF-2 is located on a steep slope where the soil is shallow and drier. Different habitat conditions have affected the production potential of these stands. The number of trees in the stand on EF-1 is 400 trees per ha, and in the stand on EF-2 356 trees per ha. The volume of the stand on EF-1 is 593 m^3/ha, which is 46% higher than the stand on EF-2 where the volume is 323 m^3/ha. Confirmation of the inequality of habitat conditions can be found in the results of the height of the dominant tree per basal area (hg max), which in the stand on EF-1 is 37.9 m, and in the stand on EF-2 25.6 m. Habitat potential, stand characteristics and mutual relations of tree species within them, have resulted in high productivity and ecological stability of these forests. The variety of conditions in which the analyzed stands occur imposes the need for a different approach when defining management plans.

Key words: beech forests, stand state, production potential, forest management plans

STRUCTURAL CHARACTERISTICS OF MIXED SESSILE OAK AND TURKEY OAK FORESTS ON BUKULJA MOUNTAIN IN CENTRAL SERBIA

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ABSTRACT

The paper presents the results of research on the structural characteristics of mixed sessile oak (*Quercus petraea* /Matt./Liebl.) and Turkey oak (*Quercus cerris* L.) forests on Bukulja mountain in central Serbia. In order to define the structural characteristics and production potential of these forests, 3 experimental fields of square shape and size of 0.25 ha were set up. In terms of phytosociology, these forests belong to the group of ecological units - sessile oak and Turkey oak forests (*Quercetum petraeae - cerris*) on various soils on loess, silicate rocks and limestones. The experimental fields are located at an altitude of 470-520 m, on very steep terrain with a slope of 16-20° and the eastern exposure. The studied forests are even-aged, 70 years old, of coppice origin and complete canopy (0.7). Depending on the stand conditions, the number of trees ranges from 276-484 trees per ha, with sessile oak the most common species whose share ranges from 35.4-85.1%, the share of Turkey oak ranges from 4.1-49.3%, while Hungarian oak is also significantly represented. The basal area ranges from 18.3-20.2 m^2/ha, with the largest share of sessile oak 41.5-86.6%, while the volume ranges from 152.5-161.9 m^3/ha, where the largest share has also sessile oak 41.0-86.6%. The condition of these forests can be generally defined as unsatisfactory, considering their origin, productivity and quality. The management of these forests in the future should be focused on planning and implementing adequate silvicultural and ameliorative measures to improve their condition and conversion into a high forest in parts where possible.

Key words: structural characteristics, sessile oak and turkey oak forests, mountain Bukulja, Serbia

MEASURES OF ADAPTIVE FOREST MANAGEMENT IN A CHANGING ENVIRONMENT - KOPAONIK NATIONAL PARK CASE STUDY

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ABSTRACT

Climate change has been a major global environmental problem over the past decades. In Serbia such changes have caused the average annual temperature to rise by 2-4 °C, reducing the average annual precipitation amount by 20% with precipitation redistribution over a year and increased average number of hot days and more frequent and longer periods of drought. Frequent heat waves, droughts and storms followed by pathogen outbreaks, are considered to be important abiotic and biotic forest stress factors.

In the narrow sense, consequences of climate change reflect in increasingly severe chaining of harmful impacts, as it has been the case at Kopaonik National Park over the last 10 (20) years. Forest drying at increased rate, especially in spruce forest belt, resulted in about 53,470 m^3 of net salvage cutting in the period from 2014 to 2019 only. Due to this phenomenon some strict nature reserves have lost the features / values on which basis, in terms of protection degree, they were qualified and formally established. The current effects of this drying phenomenon are: decreased bio-ecological stability, reduced productivity, unfavourable conditions for mixed forests strongly affecting conifers, moving away from the estimated optimum according to basic inventory indicators, unfavourable stand structure. Increasing negative effects of present and expected risk factors due to climate change have imposed adaptive planning and management within sustainable forest management practice.

The article aims to provide a scientific basis for guidelines related to adaptive forest management at the Kopaonik National Park. It will specifically (1) state the suggested forest management principles in the context of climate change (P. Brang1 et al., 2014), (2) point out possibility of implementing these principles in the forest management practice at the Kopaonik National Park, (3) examine to which extent these principles and practices have already been applied in specific silviculture types, i.e. close-to-nature silviculture (CNS).

Key words: Forests at Kopaonik NP, climate change, risk factors, adaptive management

Acknowledgements: The research for this article was carried out with the "Adaptive forest management" project was funded by JP "NP Kopaonik".

CHANGED FLORISTIC COMPOSITION AND PLANT DIVERSITY DUE TO THE SUBSTITUTION OF CONIFEROUS CULTURES FOR HUNGARIAN OAK-TURKEY OAK FORESTS (*QUERCETUM FRAINETTO-CERRIDIS* RUDSKI 1949.)

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ABSTRACT

The selection of tree species in forest management can have long-term economic and environmental consequences. If we replace an autochthonous forest with a new tree species, we change site conditions, which entails changes affecting edaphic and hydrological conditions as well as the light regime. They are directly or indirectly reflected in plant species. In most cases, the changes affect the floristic composition and diversity of plants. This research aimed to determine how the introduction of some coniferous species affected the floristic composition and diversity parameters (species richness and *Shannon-Wiener* diversity index) of artificially-established stands in the protected area of Kosmaj (Serbia).

The research included four artificially-established stands of different coniferous species: a) Norway spruce (*Picea abies*), Atlas cedar (*Cedrus atlantica*) and Douglas fir (*Pseudotsuga menziesii*); b) Douglas fir (*Pseudotsuga menziesii*); c) Austrian pine (*Pinus nigra*); d) Austrian and Scots pine (*Pinus nigra, Pinus sylvestris*). The stands are located at altitudes of 360 to 462 m, with different aspects and slopes ranging from 11 to 19º. They all grow on eutric cambisol overlying a flysch bedrock.

The largest total number of species was registered in the artificially-established stand of Norway spruce, cedar and Douglas fir (41). The highest Shannon-Wiener diversity index was found in the artificially-established Douglas fir stand (3.22) and the lowest in the pine stands (2.95-2.97). Cluster analysis showed that the highest degree of floristic similarity (above 40%) was in the artificially-established stands of Austrian pine (*Pinus nigra*) and of Austrian and Scots pines (*Pinus nigra, Pinus sylvestris*).

Key words: Substitution, floristic diversity, conifers, Kosmaj

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RESEARCH OF THE OCCURRENCE AND INTENSITY OF ATTACKS OF THE OAK LACE BUG (*CORYTHUCHA ARCUATA* SAY.) AT THE TERRITORY OF THE REPUBLIC OF SRPSKA

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ABSTRACT

Oak lace bug (*Corythucha arcuata*) is an insufficiently studied invasive species in the territory of Republic of Srpska. The aims of this research were to determine the areas of oak forests that are under attack by the oak lace bug, the intensity of the attack, as well as the potential hosts on which this harmful species can develop. Out of 63 municipalities in the territory of Republic of Srpska, *Corythucha arcuata* (Say.) is registered in 49 municipalities. To study the intensity of the attack of the oak lace bug on the oak forests in the territory of the Republic of Srpska, 155 localities within 58 municipalities were selected, with total of 465 oak trees, of different species and different ages. From each tree, 30 leaves were collected and analyzed. The analysis referred to the presence or absence of traces of oak reticulate bedbugs (presence of egg litters, larvae and traces of nutrition). At several localities the intensity of the attack was 0% (Nevesinje, Gacko, Ljubinje, Trebinje), while at some localities the intensity of attack was about 100% (Donji Žabar, Bijeljina, Šamac). The species of oaks on which the oak lace bug was found are: *Q. petraea* ((Matt.) Liebl.), *Q. robur* (L.), *Q. cerris* (L.).

Key words: Invasive species, oak forests, oak lace bug

PRODUCTIVITY-ENVIRONMENT MODELS FOR SCOTS PINE PLANTATIONS AT THE MARGINS OF THE SPECIES RANGE IN EUROPE

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ABSTRACT

While the impact of climate change on the distribution range of the terrestrial plant communities has been extensively investigated, the global warming effect on the rate and duration of their growth remain uncertain. Our study tests the hypotheses that climate change has a specific impact on the growth and yield of the Scots pine plantations in Bulgaria due to their anthropogenic origin and marginal distribution regarding species natural range and that the specifics of this influence can be adequately modeled through productivity-site relationships.

Certain empirical methodological approaches, such as the productivity-environment relationships, that are designed to encompass environmental gradients covering a considerable fraction of the species range, allow sound anticipation of species productivity levels in a future climate. Forest site quality, as a complex of physical and biological factors characterizing the ability of a site to support tree growth, can be evaluated through phytocentric and geocentric measures. Site index, defined as the average height of the dominant portion of the stand at an arbitrarily chosen age, is the most commonly used phytocentric site quality measure and dynamic site index models for Scots pine plantations in Bulgaria, employing longitudinal data and difference equation modelling approach, are intended. Two types of geocentric productivity-environment relationships, directly or indirectly incorporating the environmental variables into the model, are under examination. An original classification of the forest sites to evaluate the ecosystem fit of the pine plantations, combining latitude, altitude and assessments of soil moisture and fertility, is being tested to differentiate the productivity-environment relationships.

Key words: site quality, geocentric site index model, phytocentric site index model, *Pinus sylvestris* L.

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IMPACT OF CLIMATE CHANGE ON FOREST MANAGEMENT: BIAŁOWIEŻA PRIMEVAL FOREST CASE STUDY

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ABSTRACT

The assessment of changes and knowledge about the current forest state allows to decide what actions should be taken to improve the condition of forest ecosystems. One can also evaluate the processes taking place and their direction, and therefore also assess the need for any actions. Nowadays, historical knowledge combined with the latest technologies allows us to create tools supporting decisions in forest management. One of them is the prognostic model developed at the Faculty of Forestry WULS-SGGW, whose results will be presented on the example of analysis of changes in the occurrence of spruce in Białowieża Primeval Forest.

Ecosystems of Białowieża Primeval Forest, including managed ones, are characterized by a high degree of naturalness and biodiversity. Changes in species and age structure in the long-term period resulted from natural processes and human impact (indirectly and directly).

In the conducted research, the changes occurring in managed forest ecosystems with particular emphasis on spruce were assessed. An almost 100-year process of evolution of the species share in stands was analyzed and an attempt was made to explain it. In addition, forecasting of the share of this species was performed depending on the adopted scenarios of the climate change and recognized historical conditions.

Key words: spruce dieback, bark beetle, forest history

TREE SLENDERNESS COEFFICIENTS AND WIND RESISTANCE FOR THE MAIN SPECIES OF SESSILE OAK FORESTS IN THE CROATIAN PANNONIAN MOUNTAINS

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ABSTRACT

Tree slenderness coefficients (SC), defined as the height/DBH ratio, are often used as an index of tree resistance to windthrow. SC have been intensively studied for many European tree species, especially in pure forest plantations, but very little information is available for tree species in natural temperate mixed broad-leaved forests. A sample of 50 National Forest Inventory plots within the sessile oak forests in the Croatian Pannonian Mountains was selected. SC, age class and structural elements were calculated for the main tree species. Variance analysis was used to compare coefficients among tree species (464 oaks, 160 beeches, and 82 hornbeams), three forest age categories and four stocking classes. For all three species, the results showed that SC was significantly affected by tree species, age class, and stocking. The coefficient is highest for common hornbeam (105.3), especially in conditions of highest stocked stands (> 1.1) with an obtained SC of 135.1. The obtained mean SC for sessile oak (73.8) and beech (88.2) indicate a lower risk of wind breakage. Although these are "close to nature" managed forests, a large proportion of trees are endangered by windbreaks (19.1% of trees with SC above 100, and 44.1% with SC above 80). However, compared to pure forest plantations, these forests are more resistant to windbreaks. Given the increasing frequency of storms in Europe, it is necessary to revise the intensity of thinning with the aim of forming more wind-resistant forests.

Key words: windbreak, windthrow, tree shape, wind-resistant forests, climate change, sessile oak

Acknowledgements: This research was funded by the Scientific support program of Faculty of Forestry and Wood Technology, University of Zagreb (Adaptive models of forest management planning in the conditions of natural disasters).

CLIMATE SIGNAL IN TREE RINGS OF SCOTS PINE (*PINUS SYLVESTRIS* L.) AND BLACK PINE (*PINUS NIGRA* ARN.) GROWING ON THE COASTAL DUNES ON BALTIC COAST

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ABSTRACT

Coastal dunes have very difficult conditions for plant growth, especially woody vegetation. Trees grow on poor, permeable soil, in an environment with high salinity, subject to the constant action of drying wind, often damaging the crowns of trees. The 'Mierzeja Sarbska' forest reserve, located on coastal dunes between the Baltic Sea and Sarbsko Lake, is a unique place in Poland where such phenomena can be observed.

The aim of this study was to characterize the climatic signal contained in the radial increments of two pine species used to stabilize coastal dunes: the native Scots pine and a species alien to Poland – black pine. The study was carried out in single-aged, nearly 100-year-old stands of both species, growing under very difficult conditions on the Sarbska Spit. Material was taken from trees with the highest biosocial positions in the stand, taking into account, in addition to the species, distance from the sea as a factor potentially differentiating the radial growth of trees. Residual chronologies of both tree species were used in comparative analyses. The relationship between the magnitude of standardized radial increments and selected meteorological elements was examined, both for the entire period of tree growth and in moving time windows of 30 years.

Despite the similar adaptability of the two species to coastal dune conditions, the sensitivity of Scots pine and black pine to environmental conditions was found to differ depending on the distance from the Baltic coastline.

Key words: growth-climate response, tree-ring width, alien species, Sarbska Spit

FCS PESTICIDES POLICY IN CERTIFIED FORESTS

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ABSTRACT

The pesticide uses and pest management in FSC (Forest Stewardship Council) certified forests, today is a subject of widespread debate. FSC-certified organizations are required to apply pesticides in accordance with the principles and criteria of the FSC pesticides policy. The FSC pesticides policy restricts the use of pesticides that are dangerous to human health and the environment, classified as prohibited (list comprises 48 pesticides), highly restricted (list comprises 120 pesticides) and restricted (list comprises 221 pesticides).

Before applying any pesticide, certificate holders must include the results of their ESRA (Environmental and Social Risk Assessment) in operational plans, to identify site-specific risks. Based on ESRA, they must select the control option that has the least potential for social and environmental damage, the greatest effectiveness, and equal or greater social and environmental benefits.

The main changes in pest management for FSC certified forests are with non-chemical measures that reduce the pesticides use. When is necessary controlled pests, you must give preference, as a matter of principle, to:

- non-chemical methods over chemical,
- pesticides not listed in the any lists over those listed in the lists
- restricted pesticides over highly restricted pesticides

The policy is reviewed regularly and considers both global differences and social, environmental, and economic needs via a procedure that is transparent and monitored. If it were raising certification rigor that would lead to can increase costs, making certification impracticable, forcing forest companies to adopt less restrictive schemes or reduce its adoption or simply to give up certify.

Key words: FSC certification, forests, pesticides

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THE MOST IMPORTANT CAUSES OF SPRUCE (*PICEA ABIES* KARST.) DIEBACK IN KOTOR VAROS

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ABSTRACT

Spruce is of great economic and environmental importance in the area of Kotor Varos forest management area. High-quality forests in which it is represented are often influenced by various factors that, through their negative effects, impair their stability and lead to accelerated dieback and decay. The paper presents the research of the most important causes that lead to the dieback of spruce at the studied sites in Kotor Varos. Four experimental plots at different exposures and altitudes were selected for the study, and the degree of dieback of all trees was assessed on them. The largest number of completely healthy trees was recorded at the experimental area No. 3, while the largest number of completely dying off trees was recorded at the experimental area No. 2. Experimental area No. 3 is located at an altitude of 960 m and is exposed to the southern exposure, and experimental area No. 2 is located at an altitude of 870 m and is exposed to the eastern exposure. Dieback of spruce in this area occurs as an interaction of many harmful abiotic, biotic and anthropogenic factors. The most significant harmful fungi recorded on spruce during this research were *Heterobasidion parviporum* (Niemelä & Korhonen) and *Armillaria ostoyae* (Romang.) Herink. Harmful insects that play a major role in the dieback process of spruce and which have been recorded on experimental plots were: *Ips typographus* (L.), *Pityogenes chalcographus* (L.).

Key words: forest decline, biotic factors, insect, fungi, pathogens

EVALUATION OF NON-CHEMICAL PROTECTION STRATEGIES AGAINST *DIDYMASCELLA THUJINA* ON NORTHERN WHITE CEDAR (*THUJA OCCIDENTALIS*) SEEDLINGS

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ABSTRACT

Fungus *Didymascella thujina* is widespread pathogen on northern white cedar (*Thuja occidentalis*) causing leaf blight. Using of pesticides is still the most accepted method of control, especially in nurseries. The aim of this research was to examine protection strategy based on using primarily mechanical methods and potential of mechanical methods to contribute to chemical protection. A sample of 200 seedlings was used for research. Results showed that mechanical removal of symptomatic parts of northern white cedar (*Thuja occidentalis*) reduced development of infection on seedlings. Also, after this method has been applied seedlings showed signs of recovery. This measure reduced defoliation at 40% of seedlings and was the most effective when performed in period March-May decreasing defoliation at 60% of seedlings. After the same mechanically protected seedlings had one treatment with 0,0002% benomyl defoliation decreased at 75% of seedlings. Method was effective if done properly and should be done more frequently in order to decrease usage of pesticides.

Key words: *Keithia thujina*, reducing infections, mechanical protection

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NICKEL INDUCED MODULATION OF POPLAR'S BIOCHEMICAL RESPONSE

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ABSTRACT

Environmental pollution is one of the biggest problems in the world today. The contaminated soil can be a secondary source of pollution to other parts of the ecosystem - water, air, and plants grown on contaminated soil. Phytoremediation, the use of plants to extract, sequester and detoxify pollutants is a new and powerful technique for environmental clean-up. Due to their advantages (fast-growth, large biomass production, feasible reproduction, high transpiration rate, and recently sequenced genome of *P. trichocarpa* etc.), poplars (*Populus* spp.) present a great candidate for investigation in an aspect of so-called phytoextraction, but continued research is necessary to fully exploit their potential. The aim of this study was to examine the effect of different concentrations of nickel (Control - 0, MAA (maximum allowed amount) and tripled MAA according to National legislation)) in *Populus deltoides cl. PE19 / 66* in the greenhouse under controlled conditions. Furthermore, assessment of disturbances in root and leaf antioxidant potential by measuring ferric reducing antioxidant power (FRAP), total phenolic contents, and enzymes activities (SOD and POD). Obtained results indicate statistically significantly higher values for all examined parameters obtained in the leaves in relation to the root. According to statistical analysis show that there are significantly lower values of FRAP, SOD, and POD in the tripled MAA treatment compared to the control. Obtained results could be used for selection of clones suitable for phytoremediation purposes as well as for deepening the understanding of heavy metal induced stress in plants.

Key words: Heavy metals, Populus deltoids, phytoremediation, antioxidant

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УНИВЕРЗИТЕТ У БАЊОЈ ЛУЦИ
ШУМАРСКИ ФАКУЛТЕТ
FACULTY OF FORESTRY
UNIVERSITY OF BANJA LUKA

THEMATIC AREA 2
Nature-based solutions

TEMATSKA OBLAST 2
Prirodom inspirisana rješenja

FORS²D
ŠUMARSKA NAUKA ZA ODRŽIVI RAZVOJ

VEGETATION AND MICROCLIMATE CHARACTERISTICS IN THE AREA OF CRNI VRH ON GRMEČ MT.

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ABSTRACT

In the subalpine karst oldgrowth spruce forest complex, affiliated microclimatic and vegetation research was implemented on various configurations (peaks, slopes, bottoms and wings of dolinas). Observations were realized from 12.6.-31.8.2021, at 4 localities with several measuring points. Temperatures were measured at heights of 0.5 m, 2.0 m and 3.0 m above the ground. A phytocenological releve is attached to each measuring point. The paper provides a more detailed insight into the 24-hour temperature regime of different forest and non-forest communities that are present in them during the summer aspect.

Key words: Crni Vrh, Grmeč Mt, microclimates, mountain vegetation

TURNOVER OF PLANT SPECIES ALONG SLOPES REFLECTED IN PLANT TRAITS AND LANDFORM-VEGETATION UNITS IN DOLINES ON KRAS PLATEAU (SW SLOVENIA)

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ABSTRACT

The objects of research were karst depressions, called dolines. Dolines were found to have a pronounced ecological gradient from the bottom to the top, from humid, cool and shaded bottoms to progressively sunnier, drier and warmer slopes and tops. We used the transect method and sampled the floristic composition of the doline from the bottom to the top. Geomorphic parameters of individual dolines were calculated using a high-resolution digital elevation model (Lidar). We collected information about plant traits from various literature sources.

The results show life forms and plant architecture explain the ecological gradient in doline well and, to a lesser extent, chorotypes, however functional strategies possess a low explanatory power. Life forms and plant architecture are the result of adaptation of species to the environment and chorotypes are defined by species with an overlapping geographical distribution pattern due to their biogeographic and environmental histories. Functional strategies, which have evolved to enable plants to succeed in various environments, unexpectedly possess a low explanatory power.

We also aimed to divide dolines into landform-vegetation units (LVU) according to basic geomorphic characteristics and indicator plant species. Based on cluster analysis providing discrete plant communities, transects were disintegrated into four LVUs: bottom, lower slope, upper slope and top. Communities within LVUs were compared by Ellenberg indicator values and according to habitat preference of species. We found that all four LVUs appear only in dolines that are at least 13.5 meters deep and those can serve as a good safe haven for cool-adapted species in foreseen climatic change.

Key words: doline, geomorphology, gradient, plant trait, vegetation

TRADITIONAL ECOLOGICAL KNOWLEDGE IN THE FORESTRY SECTOR: A CRITICAL ANALYSIS OF CURRENT TRENDS AND FUTURE PROSPECTS

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ABSTRACT

Ensuring the protection of the natural environment is vital for the prosperity of future generations. In all forested regions of the globe, local traditions have been essential in creating healthy human-forest relationships. These practices constitute Traditional Ecological Knowledge (TEK) – an increasingly importance factor to consider when developing practical and effective forestry policy. Despite the international community's gradual acceptance of TEK as a valid policy guide, the field of forestry in many regions of the world continually ignores this crucial concept. As such, many forest ecosystems are harvested in ways that do not reflect the values of local - and often Indigenous - communities, resulting in socio-economic divisions and unsustainable environmental degradation. To better understand the current state of TEK in the forestry sector, this paper will examine how policy-makers and leaders have approached this variable in current decision-making. Through conducting a comprehensive synthesis report of international research pertaining to TEK in the forestry sector, this paper will identify critical trends regarding the present and future status of this governance tool. It will also provide recommendations and strategies for the successful adoption of TEK within the forestry sector.

Key words: Traditional Ecological Knowledge (TEK), Forestry Governance, Indigenous Rights, Socio-economics, Policy tools

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SOIL EROSION AND TORRENTIAL FLOOD PROTECTION: EDUCATION AND PRACTICE IN FORESTRY

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ABSTRACT

Erosion, as the most prominent type of physical degradation, occurs rapidly on soil surfaces with no or scarce vegetation cover and is one of the causes of torrential floods occurrence. In the second half of the 19th century, organized works on torrent control in Europe (France, Austria) began with check dams construction and afforestation. The engineers of that time established a system of integrated protection of catchment areas, which included the application of technical, biological, and biotechnical works. This concept of torrential flood protection has been developed within forestry and has been applied in many countries in Southeast Europe. The forms and intensity of erosion processes, as well as the frequency and intensity of torrential floods, along with the specifics of socio-economic development, have caused differences in the educational status of soil and water resources protection in a certain country. The floods that occurred in 2014 had catastrophic consequences, especially in Bosnia and Herzegovina and the Republic of Serbia. Forestry engineers from these countries have expressed the need for greater knowledge in the field of soil protection from erosion and torrential flood prevention. This resulted in a joint project within the Erasmus + projects of the European Union (EACEA) in which, among other universities and institutes, three Faculties of Forestry took part (the University of Belgrade-UB, University of Banja Luka-UBL, University of Sarajevo-UNSA). This research includes the analysis of study programs at the mentioned faculties with the analysis of the syllabus of subjects that have contents related to soil protection and torrential flood prevention. The Faculty of Forestry UB has developed study programs (bachelor's and master's) in the field of erosion protection and torrent management 60 years ago, while the Faculties from B&H had one or no courses at all with a subject matter regarding this field. For these reasons, existing study programs have been improved by introducing new courses and modernizing the syllabus of existing ones. In addition, a joint study program of master's academic studies has been formed and accredited, in which teachers from all three forestry faculties participate in teaching. Students of completed bachelor studies (forestry and others) from both countries may enroll. The goal of modernization of existing study programs and a new master program implementation is to improve the knowledge of future forestry engineers to solve the problem of land degradation protection, especially erosion, and torrential flood prevention.

Key words: forestry, soil erosion, torrential floods, joint master program

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THE ROLE OF FORESTS ON RUNOFF REGULATION IN MEDITERRANEAN URBAN AREAS

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ABSTRACT

As part of the urban ecosystems, forests generate multiple services such as water regulation. Although several studies have investigated the role of forests on runoff, less is known about the impact of different forest types in urban catchments. This study investigates the impact of three different types of forest (semi-natural oak stand, sparse eucalyptus stand and dense eucalypt plantation) in overland flow processes. The study focuses in a peri-urban catchment in central Portugal, under Mediterranean climate, and is based on runoff plot measurements performed over two hydrological years. Besides overland flow, throughfall, soil moisture content and hydrophobicity were measured at c. 1- to 2-week intervals. Although the three types of forest produced limited overland flow (<3% of the overall rainfall), the dense eucalypt stand generated twice high overland flow. This was due to infiltration-excess processes recorded after dry antecedent weather conditions, due to widespread soil hydrophobicity. In the sparse eucalypt stand, moderate hydrophobicity under dry settings was easy to break down with the first rainfall events, and thus infiltration was higher than in the eucalypt plantation. In the oak stand, hydrophobicity was low or even absent and the overland flow was driven by the rather limited saturation-excess processes triggered in the shallow soil during the wettest periods. The results show that semi-natural and managed forests are critical to retain rainfall and promote infiltration. Urban planning should incorporate forest patches in any development proposal to reduce total runoff-generating areas and to provide sinks for overland flow from upslope urban surfaces.

Key words: Eucalypt plantation, semi-natural oak stand, runoff processes, Mediterranean region

LEGAL AND INSTITUTIONAL TOOLS IN THE FIELD OF LAND DEGRADATION IN THE FEDERATION OF BOSNIA AND HERZEGOVINA

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ABSTRACT

With the rise of environmental concerns in the world, increasing attention is being paid to the introduction of an appropriate legislative framework and the establishment of institutions to prevent or control land degradation. The research established that according to the legislation in FBiH, the issue of land protection from various types of degradation is not regulated by a single regulation. It intertwines through several sectoral regulations governing spatial planning, environmental and water protection, agricultural land, forests, and construction land. Through face to face interviews with representatives of key institutions in FBiH, quantitative and qualitative data on the role and importance of existing legal and institutional tools in the context of sustainable land management have been collected. Existing tools have been found insufficiently efficient. As a reason for such a situation, the lack of FBiH forest Law is cited, bearing in mind that forest land accounts for about 60% area of all land in FBiH, and the failure to adopt a spatial plan as a key document for sustainable land resource management. Respondents consider that there is not sufficient quality coordinated work between institutions in the field of monitoring the situation, analysis and protection of land. Respondents consider that the complex administrative political situation in the state and the lack of common framework legislation, effective vertical and horizontal communications contribute to a reduced impact of individual sectors in terms of the existence and efficiency of tools/instruments that should contribute to the implementation of policies for the conservation and sustainable use of natural resources.

Key words: FBiH, land degradation, forest land

IMPORTANCE OF DRYING AND RE-WETTING EVENTS ON SOIL ION LEACHING IN ACIDIC AND CALCAREOUS SOILS

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ABSTRACT

This research explores soil-specific processes of ion leaching in relation to drying and re-wetting events. We observed acidic and calcareous forest soils wishing to compare ion concentrations in the leachate. We hypostatize that loosely bounded ions react differently to drying and re-wetting events which is important for better understanding of climate change effects on ion depletion. The effect of freezing-rewetting on solution fluxes is challenging to predict, and there is a lack of knowledge on this subject. Two sets of composite soil samples were taken one on the Mt Bjelašnica Calcaric Cambisol and other on the Mt Trebević Dystric Cambisol in Bosnia and Herzegovina. Soil was sampled by horizons (O, Ah, A/Brz, Brz1, Brz2). Porous plastic glasses were filled with 120g of air-dried soil (O+Ah, Ah, A/Brz, Brz1, Brz2), and thus prepared for two different treatments (rewetting-freezing vs. rewetting-heating) and one soil sample representing the control. Treatments: A) four cycles of wetting (30', 120cm^3 of rainfall) followed by freezing (-10 °C) and B) four cycles of wetting (30', 120cm^3 of rainfall) followed by heating for 3 hours at 40 °C. Control sample involved wetting and drying at the room temperature. After each wetting cycle, leachate was captured and left in freezer until determining concentrations of ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Al^{3+}, Fe^{3+}, Mn^{2+}) and anions (NO_2^-, SO_4^{2-}, NO_3^-, PO_4^{3-}). Microclimate parameters were measured. We analyzed 16 samples per profile and per treatment, and 14 control samples, in total 78 samples. The results obtained through this study point that different thermodynamic conditions influence different leaching intensity of soil ions. Ion concentrations were specific for soil geochemical characteristics.

Key words: forest soil, anions cations, thermodynamic conditions

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CHANGES IN THE FLOODPLAIN CAPACITY TO PROVIDE ECOSYSTEM SERVICES: AN ASSESSMENT BASED ON EXPERT EVALUATION AND LAND-COVER

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ABSTRACT

Ecosystem services (ES) are commonly considered as the benefits that people obtain from nature (ecosystems). People depend directly or indirectly on these services. This includes a range of services: from 'exploiting' the basic resources necessary for life, to the socio-psychological benefits that ecosystems provide.

One of the most important and potentially most beneficial to society are ecosystems and their services in floodplains. These ecosystems are, however, endangered by many factors (land-use change, climate change, human activities, drought, etc.). To adequately manage and plan the protection measures aimed to improve the status of ecosystems and provide services from nature, required actions include analysis of the changes in land cover over time and identification of trends.

To facilitate the analysis, presentation, and further manipulation of extensive sets of data, one appropriate approach is to map the services provided by a given ecosystem in a given floodplain. If the data availability is limited, mapping the ES can be based on a concept for land-cover-based assessment proposed by Burkhard et al. (2009). Over the years, this approach proved to be a useful tool for the quantification and spatial modeling of multiple ecosystem services of various landscapes. This approach we applied to determine the changes in land cover and trends in the capacity of the Special nature reserve "Koviljsko-petrovaradinski rit", a floodplain in Serbia, to provide selected five ES: nutrient regulation, flood protection (regulating services), crop production (provisioning service), biodiversity (ecological integrity), and recreation and aesthetic values (cultural service). These assessments are based on CORINE LAND COVER maps: from 1990 and 2018. The results obtained can be used to identify the possible priority of measures to protect and improve ecosystems.

Key words: ecosystem services, floodplain, land cover, Special Nature Reserve 'Koviljsko-petrovaradinski rit'

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LEGISLATIVE FRAMEWORK AND ACHIEVEMENT OF LAND DEGRADATION NEUTRALITY TARGETS IN WESTERN BALKANS DEVELOPING COUNTRIES

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ABSTRACT

The increasing awareness of the importance of soil to food security, sustainable forestry and agriculture, and finally human health has stimulated the development of the concept of land degradation neutrality (LDN). LDN encourages countries to set up national targets, adopt a broad range of measures to avoid, reduce, and reverse land degradation thus to be neutral by 2030. Comparative analysis of the LDN implementation in two western Balkan developing countries, Serbia (SRB) and Bosnia and Herzegovina (B&H) that are still burdened with the consequences of the Civil War (1991–1995), will bring new perspective about challenges and opportunities to achieve LDN, under specific administrative and policy frameworks. For example, one of the most significant impacts of the Civil War in B&H was the destruction of historical land and soil data, including land records. Also, land data shortage and availability in both countries is still scarce and represents one of the major challenges to assess land degradation status and implement environmental policy frameworks. In 2014, B&H voluntarily committed to the Land Degradation Neutrality (LDN) target setting process, SRB in 2019. Both countries do not have specific legislation to address the broad range of processes involved in land degradation where until now, soil law and policy are of secondary importance concerning higher-profile environmental and natural resources issues. Administrative structure and policy framework will be compared and assessed upon EU framework relevant for the achievement of LDN. Aim is to present existing policy and administrative structure of two developing and post-communist countries, analyzing influences and factors important to achieve LDN. It will conclude with a set of recommendations that might be followed toward the control and prevention of land degradation in developing countries.

Key words: LDN, developing countries, legislation, policy framework

ECOLOGICAL-VEGETATION ANALYSIS OF FOREST TYPES WITH SERBIAN SPRUCE (*PICEA OMORIKA* (PANČIĆ) PURKYNE) IN BOSNIA AND HERZEGOVINA

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ABSTRACT

Since the discovery of Serbian spruce by Josif Pančić in 1876, this endemic-relict tree species has been the subject of numerous studies, as evidenced by more than 500 papers devoted to this species. However, systematic research of plant communities of Serbian spruce has never been carried out on the territory of Bosnia and Herzegovina, and many of the described associations seem to be insufficiently substantiated, so a systematic revision is needed.

In the period of 2018-2020 new phytocoenological relevés (61 in total) were collected and served for ecological and vegetation analysis, with systematic study of the bryological component of the ecosystems. Hierarchical cluster analysis was used for classification, from which a set of diagnostic types for each type was obtained.
The analysis revealed four clearly ecologically and floristically characterized types of forests with Serbian spruce in Bosnia and Herzegovina:

1. sciophilous and frigophilous mixed (deciduous-) coniferous (beech-) fir and Norway spruce forests with Serbian spruce on mild slopes
2. semi-sciophilous and semi-frigophilous pure or mixed forests of Serbian spruce on steep slopes of the montane hillsides
3. Semi-heliophilous and xero-mesothermal relict polydominant stabilized successions with Serbian spruce on steep slopes of canyon refugia
4. Semi-scophilous chasmophytic forests with Serbian spruce on very steep slopes of limestone cliffs.

Key words: Bosnia and Herzegovina, ecological-vegetation forest types, *Picea omorika*, plant communities

PUBLIC INTEREST, SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL PROTECTION

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ABSTRACT

Quality of environmental protection is one of the clearest indicators of understanding the concept of social justice and respect for the public interest, which sublimates the needs of the majority in the community. The attitude towards the environment in Balkans, during the period from 1990 to 2022, showed the weaknesses of certain legal solutions, administrative procedures, the work of government bodies and inspection services, excessive pressure on ecosystems, often against the interests of the local population. Balkans needs harmonious development that uncompromisingly protects the nature, improves the life quality of the population, and mitigates the effects of climate anomalies and achieves effective prevention of natural disasters.

Energetics and mining are very attractive economic branches for domestic and foreign investors, mainly private companies. These activities produce worrying levels of air, water and soil pollution, with huge deterioration of ecosystem services and degradation of biodiversity. Simultaneously, they endanger traditional way of living local population in rural areas and worsen health conditions. Development aimed at satisfying the lucrative interests of individuals and organized groups is a direct negation of the concept of social justice. Carelessness and tolerance of harmful activities lead to serious ecosystem disorders and environmental degradation, which is a manifestation of the inability of the system and wider community to perceive the self-destructiveness of this form of behavior. It is necessary to achieve an effective social agreement, based on a clearly defined public interest, through coordinated, complementary activities of state institutions, academia and citizens organizations.

Key words: public interest, environment protection, energetics, mining, ecological activism, social justice

INFLUENCE OF THE SOIL PROPERTIES ON THE SESSILE OAK STANDS (*QUERCUS PETRAEA*)

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ABSTRACT

Oak forests are widespread forest communities in the deciduous vegetation. From the 10 species of oaks in Serbia, next to pedunculate oak (Quercus robur), the most valuable and common type of tree is sessile oak (Quercus petraea). Sessile oak is characterized by a relatively wide ecological amplitude, so it is almost present in all forest areas, as well as in low mountains. In addition to the economic importance of sessile oak forests, their protective role against soil erosion is also important. However, degradation and drying of sessile oak forests is very pronounced. Proper land management not only increases its productivity, but also provides a valuable mechanism for mitigating the effects of climate change and a way to preserve ecosystem services. The aim of this study is to determine the dependence of soil properties on sessile oak forest condition. For this purpose, properties of sites with endangered oak stands were compared with a sites with stand in a good health condition. Results indicate significant dependence of oak condition on soil properties. Sites with endangered oak have higher silt component and bulk density, lower EC-electrical conductivity, pH, Corg, porosity and Atterberg limits, while contents of micro and macroelements is similar between sites. This study contributes to understanding of the impact of soil properties on the natural regeneration of sessile oak forests, which is an important prerequisite for improving forest cultivation, especially related to the climate change.

Key words: soil quality, oak forest, soil erosion, climate change

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VEGETATION OF BOSNIA AND HERZEGOVINA: PHYTOSOCIOLOGICAL CLASSIFICATION AT THE ALLIANCE LEVEL

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ABSTRACT

Although Bosnia and Herzegovina (BiH) is in Europe's top concerning plant and ecosystem diversity, and the beginnings of vegetation research, according to Braun-Blanquet's approach, date back to early 1930s, the richness of BiH vegetation remained underrepresented in syntaxonomical reviews. Furthermore, these overviews were not given in accordance with the International Code of Phytosociological Nomenclature, nor they were in line with the framework of the European syntaxonomic system (EuroVegChecklist). Therefore, our aims were to compile a nomenclature harmonized syntaxonomic list of classes, orders and alliances dominated by vascular plants in BiH, which complies to European syntaxonomic system (EuroVegChecklist). In addition, we gave a crosswalks of alliances to EUNIS habitats according to EUNIS Habitat Classification at Level 3, We also included EU Habitat Directive Annex I code and European Red List status (where applicable). A consistent description of every alliance and higher syntaxa in local language was introduced. A total number of alliances recognized in BiH is 207 (165 verified and another 42 with uncertain occurrence). Comments on uncertain and other ambiguous occurrences were given.

Key words: Braun-Blanquet method, EUNIS, habitat classification, syntaxonomy

THE URBAN GREEN SPACE PROVISION USING THE STANDARDS APPROACH: STATE AND POTENTIAL FOR URBAN PLANS OF SARAJEVO

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ABSTRACT

Standards approach is conventionally used to attain consistency and certainty in urban green space planning. The concept has been widely used by urban planners in Bosnia and Herzegovina. However, values which were once adapted on the city level evaluated based on the environmental conditions, like in case of Sarajevo city need to be reassessed. Regarding growing pressure of traffic, climate change effects, increased urban densification, financial circumstances of city inhabitants in critical situations like COVID 19 epidemic crises, there is a possible need for increasing the area of green spaces. In this study we assessed values of total green area relative to different green urban space categories in Sarajevo. Further relative share of green space and public green space area per capita was estimated. In this study we are discussing minimum area of green space per capita in regard to different categories and overall minimum sum of functional green public space per capita.

Key words: public green space, green space categories, minimum green space area per capita

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MANAGEMENT OF PROTECTED AREAS IN SERBIA WITH SPECIAL REFERENCE TO SE "SRBIJAŠUME"

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ABSTRACT

The aim of this paper is to perform an analysis of the management of protected areas in the Republic of Serbia, with special reference to the management of protected areas entrusted to the State Enterprise for Forest Management "Srbijašume".

Serbia is characterized by a rich and diverse natural heritage that is reflected in a wide range of geological, geomorphological, pedological, climatic, hydrological and biological diversity. A large number and diversity of plant and animal species, their communities and ecosystems make Serbia a Europe in miniature, and one of the centers of its biological diversity.

In order to preserve special natural values and improve their condition, certain parts or natural ecosystems, as well as species, are declared protected natural assets.

According to the Law on Nature Protection, protected natural assets in Serbia are protected areas, protected species and movable protected natural documents.

The State Enterprise for Forest Management "Srbijašume" manages 54 protected areas on a land surface of 348,725 ha, which is 51.4% of the total land surface of protected areas in Serbia (691,434 ha or 7.81% of the Republic of Serbia).

Preservation, protection and improvement of natural values represent part of the strategy and one of the key goals in the business policy of SE "Srbijašume", the leading enterprise in the management of protected areas. Of the total land surface of protected areas, there are 9,445.63 ha (2.71%) in the protection regime of 1st degree, 64,679.07 ha (18.52%) in 2nd degree of protection, and 274,699.96 ha (78,77%) in 3rd degree of protection.

Key words: biodiversity, nature protection, manager, protection regime

BIOLOGICAL RECLAMATION OF DEPOSOLS AS THE MOST ECOLOGICALLY ACCEPTABLE WAY OF REVITALIZATION OF DISTURBED AREAS CAUSED BY EXPLOITATION IN COAL OPEN MINES

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ABSTRACT

Of all energy sources, coal is still the most important energy resource in the world, as it makes up about half of the total reserves of all resources used for energy production. Large lignite basins in Serbia, as well as in many other countries, are an energy potential of strategic importance, which is mainly used for electricity production. The growing need for electricity means that the natural orography of the area above the coal deposits will continue to be disrupted and the destruction of existing ecosystems will continue. In order to mitigate the harmful consequences of the development of surface mines, it is necessary for mining works to be accompanied by biological reclamation by afforestation of landfills. Recultivation of degraded areas enables the re-establishment of various vegetation and other ecosystems on deposited tailings, deposols. Based on the agreement with the Kolubara Mining Basin and the Institute of forestry afforestation of the post-exploitation area covering over 1,000 hectares were performed. A large number of species have been used for afforestation of landfills not only due to the great variability of microecological conditions in small areas, due to non-selective tailings disposal, but also due to the difficulty of enriching the landscape aesthetics of newly created forest ecosystems. Today, these areas are remarkable anthropogenic forest ecosystems mostly with mixed forests. Research and work done through biological reclamation in the Kolubara Basin have proven that it is possible to create new agricultural, forest, aquatic, meadow and other ecosystems of higher functional values than natural ecosystems in the pre-exploitation period.

Key words: reforestation, surface mines, degraded areas

APPLICATION OF NDVI DERIVED FROM LANDSAT 8 IN MONITORING CHANGES IN VEGETATION COVER AFTER FIRE ACTIVITIES ON GARAČ MOUNTAIN (MONTENEGRO)

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ABSTRACT

The use of remote sensing techniques in the research of fire activities is a topic that began in the last century and whose possibilities are increasing as new sensors are built into international Earth observation programs. Garač is a mountain that belongs to the region of central Montenegro on the territory of the municipalities of Danilovgrad and Cetinje. For the purposes of this paper, data from the Visible Infrared Imaging Radiometer Suite (VIIRS) satellite sensor are used. For the investigated time period from July 1, 2014 to August 12, 2019, on the mountain Garač, the VIIRS satellite recorded 294 anomalies and identified areas where fire activities existed. For the purpose of monitoring the state of vegetation Normalized difference vegetation index (NDVI) was used. NDVI values in our study area range from 0.11 to 0.63. For ease of insight, NDVI values are divided into 5 categories: unhealthy vegetation (0.11-0.23), moderate unhealthy vegetation (0.23-0.34), medium healthy vegetation (0.34-0.43), healthy vegetation (43-0.51), extremely healthy vegetation (0.51-0.64). Fire activities and drought had a great impact on the reduction of areas under healthy vegetation and extremely healthy vegetation. The share of healthy vegetation in the total area of the study area decreased by 16.61%, while the share of extremely healthy vegetation in the total area decreased by 8.18%. The results of this research can provide a clear insight into the harmful effects of fire activities on vegetation cover, as well as a large amount of information on the course of vegetation recovery after numerous repeated fires.

Key words: remote sensing, vegetation index, fire activity

INCREASE OF URBAN FORESTS SUSTAINABILITY BY ASSESSING LANDSCAPE SENSITIVITY

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ABSTRACT

Urban forest includes individual trees, but also associated vegetation and the soil beneath the trees. In many regions, urban forests are the most extensive, functional and visible form of green infrastructure in cities and occupy an important place in mitigating and adapting to climate change and preservation of forest ecosystems. These forests are safe islands for biodiversity and play a key role in preserving human health and raising the quality of life in the city. However, urban forests face many challenges including difficult growing condition, insufficient resources for proper care and problems for development, which are enhanced by incomplete public understanding of benefits that urban forests provide. Urban soils are often subject to several degradation processes, such as erosion, compaction and pollution.

The Košutnjak urban forest (Belgrade, Serbia), occupies a total area of 305.32 ha, of which 83% is forested. In 2014, 93% of the area was declared a Monument of Nature "Košutnjak Forest" while the remaining 7% of the forest is intended for recreation and general cultural and educational functions. The stand is mostly natural deciduous hardwood tree and covers almost 70% of the forest. Košutnjak is home to many plant and animal species, some of which are under strict protection. There are 521 plant species, including for example oak (*Quercus* sp.), chestnut (*Aesculus hippocastanum*), cedar (*Cedrus* sp.), pine (*Pinus* sp.), hazel (*Corylus* sp.). In 2015, the average age of the trees has been estimated to be 60–70 years. During the same year, about 50 ha of Košutnjak has been re-forested with 4,400 seedlings of ash (*Fraxinus* sp.) and sycamore (*Platanus* sp.). However, trees in Košutnjak present a poorly developed canopy, often rotten. The forest was seriously affected by the snowfall in December 2021, when a large number of trees fell, broke and bent. The general condition of the forest is unfavorable, the assembly is interrupted and damaged. Due to steep slopes and generally poor condition of vegetation, erosion processes are observed in the form of scouring, rills, gullies and local movements of soil masses. Other forms of physical degradation include compaction namely in observed wheel tracks.

The aim of this study is to investigate the connection between the productivity of forest ecosystems and soil quality. Soil physical- chemical characteristics contribute to determining the sensitivity of the soil of the urban forest Košutnjak to degradation processes and the connection between the state of vegetation and soil quality. The study is based on the detail analyses of the data of the current state of land and vegetation, as well as expected deviations due to the impact of selected climate change scenarios.

Three potential climate scenarios were tested and contribute to understanding the possibility of adapting the Košutnjak urban forest to degradation processes and soil nutrient losses favored by climate change. This knowledge will aid in determining proposed measures and strategies to mitigate the effects of land degradation processes based on the principle of environmental engineering. The study introduces a new framework for valorization of the current and future state of land and vegetation in the urban forest Košutnjak. The results provide a basis for mitigating or restoring land degradation, which inevitably arises from the management practices. With application of anti-erosion, remediation and prevention measures and application of nature-inspired solutions and ecosystem services, the condition of the land will be improved.

Key words: soil quality, land degradation, soil erosion, nature-inspaired solutions, climate change

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BELGRADE'S URBAN GREEN AREAS CURRENT SOIL STATE AND ITS WAY TO SUSTAINABILITY

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ABSTRACT

Urban forests are important part of cities' green infrastructure, especially in cities with great anthropogenic pressure as Belgrade is. Urban green areas enable people to connect with nature and contribute to livability in cities, but some studies reported soil pollution particularly with heavy metals.

Due to that, soil samples from Avala Mt,. and Byford's and Zvezdara Forests were collected from 15 sites and three depths (0-10 cm, 10-20 cm and 20-40 cm), making a total of 45 analyzed samples. Among all analysis, content of microelements was measured for the purposes of this research. No significant changes were observed comparing sites or depths and among all measured elements Zn was the most and Hg the least abundant. Analysis of microelements in soil showed that sustainable soil quality Ni levels are exceeded in all samples, while Cr, Cd and Co levels only in some. All of these results can be explained by forests' age, geological origin and anthropogenic origin and influence.

Even though due to Serbian Soil Quality Regulation no remediation is required for now, in the light of predicted climate change, regular monitoring and assessment should be done to display soil quality and to maintain or improve urban forests sustainability.

Key words: urban protected areas, soil pollution, microelements, forests sustainability

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ASSESSMENT OF CARBON STORAGE IN FLED SHELTERBELTS IN THE AREA OF PANČEVO (SERBIA) USING REMOTELY SENSED VEGETATION INDICES

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ABSTRACT

The agricultural sector has a widely known role in greenhouse gas emissions (GHG) to the atmosphere which leads to ongoing risks regarding global warming and climate change. Shelterbelts within agricultural systems represent multifunctional green objects that provide numerous ecosystem services, including the climate regulation and the potential for climate change mitigation through carbon sequestration. Traditional forest biomass measurement is limited in space and time in terms of demanding costs and time which led to the development of alternative solutions for biomass assessment in the application of remote sensing methods. The objective of this research is to estimate the carbon stock of five shelterbelts located in the Pančevo municipality (Republic of Serbia) using allometric equations (IPCC) together with remotely sensed vegetation indices (NDVI, EVI, MCARI). Firstly, carbon stock was calculated according to IPCC methodology, afterwards, the correlation analysis was employed to explore the relationship between several vegetation indices and calculated carbon stock in biomass (IPCC). Finally, the regression analysis was employed in order to establish the equation which describes the relationship between the selected vegetation index and calculated carbon stock biomass. The highest Pearson correlation coefficient was found for the MCARI vegetation index with the r-value of -0.73. By the regression analysis, the equation (Cstock = -94,12 MCARI + 111,0, R2=0.53) was obtained. This research could provide some basic consideration about the assessment of carbon stock in shelterbelts used by UAVs and show the possibility of applying the MCARI vegetation index for that purpose.

Key words: shelterbelts, carbon sequestration, UAV, remote sensing

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FIELD LESSONS OF PHYTOCENOLOGY AT THE FACULTY OF FORESTRY IN BANJA LUKA

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ABSTRACT

Field lessons are important component of the course of Phytocoenology from the very beginning of the Faculty of Forestry in Banja Luka. The content, method, possibilities, problems, opportunities and styles of work changed, depending on the teacher, but the basic goal and task remained the same, i.e., practical introduction to vegetation and methods of its research in situ. During the last 30 years, a total of 434 relevés were made, which were analyzed statistically, by chronological, geographical, forestry, authorial and phytocoenological characteristics, referencing their significance in the teaching process.

Key words: field teaching, phytocoenology, phytocenological releves

INFLUENCE OF FOREST MECHANIZATION ON LAND DEGRADATION IN "MRKONJIĆKO" FOREST MANAGEMENT AREA

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ABSTRACT

Land degradation, as a result of various factor, further accelerated by climate change, is a problem that has become increasingly important in the last decade in the Republic of Srpska and the region. Forest lands are often exposed to degradation, where erosion and torrents take a significant place and are the result of the influence of forest mechanization when using forest biomass. When designing the primary and secondary network of forest roads, the character of the relief, the bedrock and the land cover should be taken into account in order to minimize the removal of land, but this is often not the case. The paper analyzes the impact of forest mechanization on the limestone-dolomite soils of the "Mrkonjićko" forest managment area in relatively similar ecological and geografical conditions. The aim of the research is to gain insight into the situation on the ground as the result of the impact of forest mechanization on the land and to identify potential measures for repairing the damage. The most pronounced influence of forest mechanization was reflected in the compaction of the soil and the creation of preconditions for its removal down the slope. Based on the insight into the situation on the ground, a proposal of measures for the rehabilitation of forest roads was defined in order to reduce soil erosion. These measures should be taken into account in the planning documents of the forest management area in the coming period.

Key words: degradation, forest mechanization, erosion, remediation

IMPROVING THE RECREATIONAL FUNCTION OF URBAN FORESTS THROUGH URBAN REGULATION AND LANDSCAPE DESIGN: A CASE STUDY OF THE AREA OF THE PARK FOREST TRAPISTI IN BANJALUKA

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ABSTRACT

The research presented in this paper points to the fact that the recreational function, as an urban planning category, receives inadequate treatment in the spatial and urban plans in Republic of Srpska, at least not to the extent corresponding the new approach to evaluation and defining forest areas. Uncertainty at the level of urban plans prevents concrete actions in terms of better arrangement of these areas, and makes it difficult to understand their sustainable development. Obscurity on level of urban plans doesn't allow concrete actions in terms of better planning of such spaces, and it hinders supervision of their sustainable development. The aim of this paper is to investigate the possibility of improving the recreational function of forests through urban regulation and to seek a new design solutions in the green matrix. In order to recognize the character and quality of urban forests, a method of separation of gravitational area and recreational zones in the city has been proposed. With this method, the recreational value in the circle of the gravitational area is determined by two factors: the position of the urban forest and the value of the natural characteristics of the forest area for recreation. The second part of the paper discusses a case study in the area of the park forest Trapisti in Banjaluka. The phases of urban regulation, the conceptualization of a design inspired by nature and the details of its development were analyzed, thus completing the process of improving the recreational function of the parkforest Trapisti.

Key words: urban forests, recreational function, gravitational area, park forest Trapisti, Banja Luka

VARIABILITY OF *PLATANUS* × *ACERIFOLIA* (AITON) WILLD. LEAVES UNDER THE HETEROGENEOUS URBAN ENVIRONMENTS OF BANJA LUKA AND TREBINJE

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ABSTRACT

Urban environments and their soils, known as urbosoils, are often heavy polluted with potentially toxic elements and other contaminants originating from extensive traffic, industry, and heating plants. Dendroflora plays a significant role as a bioindicator of the degree of urban pollution and presents the basis of nature-inspired solutions for urban soils sustainability. At present, the information on the morphological variation of common urban trees, grown in the parks and alleys, are scarce. Therefore, the aim of this study is to determine the morphometric variation of leaves of plane tree, *Platanus* × *acerifolia* (Aiton) Willd., regarding the urban environments of Banja Luka and Trebinje as a source of differentiation. Following morphometric leaf traits were analyzed: leaf blade length (L), maximum width of the axis of the midrib (W), distance from the midrib to the right margin (X), distance from the midrib to the left margin (Y), distance from the right lateral vein to the main vein (WR), distance from the left lateral vein to the main vein (WL), length of the right lateral vein (RL) and length of the left lateral vein (LL). Measurements were performed on the scanned leaves by Digimizer Image Analysis Software Version 5.7.2. The results showed that foliar comparisons have been useful in determination of morphological differences of urban trees influenced by contrasting urban environments. The results also indicate the importance of applied analyzes in the biological monitoring of the pollution level of urban environments and urbosoils.

Key words: urban environment, urbosoils, plane tree, leaf, morphometric traits

PHYTOREMEDIATION BY TREES AS A NATURE-BASED SOLUTION FOR MITIGATING METAL CONTAMINATION IN URBAN SOILS

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ABSTRACT

Trace metals in the environment are important pollutants affecting human health, particularly in urban areas worldwide. Phytoremediation as a nature-based solution (NBS) and environmentally friendly technology may decrease high concentrations of trace metals in urban soils, protecting public health (especially children) and contributing to urban sustainability. This study examined trace metal contamination of urban soils and trees in six cities in the Republic of Srpska (Bosnia and Herzegovina), and investigated the potential of selected tree species for phytoremediation as a NBS for metal-polluted urban soils. Contamination of urban soils was assessed by quantifying the concentrations of 11 trace metals (B, Ba, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, and Zn). To estimate phytoremediation potential of urban tree species, concentration and bioconcentration factor of the 11 metals were quantified in leaves of three common and abundant tree species, *Aesculus hippocastanum* L. (horse chestnut), (*Platanus acerifolia* (Aiton) Willd.) (plane), and (*Tilia* sp.) (lime). The results showed that trace metal concentrations in leaf samples did not exceed toxicity threshold guideline values. Further assessments are needed to establish the true potential of the three species in NBS for urban soils.

Key words: urban areas, trace metals, soil contamination, phytoremediation, NBS

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ORIGIN AND SPATIAL DISTRIBUTION OF HEAVY METALS IN MOUNTAIN BEECH FORESTS SOILS ACROSS EUROPE

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ABSTRACT

The objectives of this research were to investigate the concentration; characterize the distribution; and determine the sources of heavy metals in European mountain beech forest soils. Total of 37 soil samples were collected from 11 countries (Bosnia and Herzegovina, Bulgaria, Czech Republic, Germany, Italy, Poland, Romania, Serbia, Slovakia, Slovenia and Spain). Concentrations of As, Cd, Co, Cr, Cu, Ni, Pb, Zn, and Hg were in ranges of 0.98-22.98 mg kg^{-1}, 0.99-6.03 mg kg^{-1}, 2.51-26.01 mg kg^{-1}, 4.22-83.42 mg kg^{-1}, 11.25-39.77 mg kg^{-1}, 4.79-56.34 mg kg^{-1}, 1.38-91.76 mg kg^{-1}, 32.50-252.20 mg kg^{-1}, 0.20-5.07 mg kg^{-1}, respectively. Hotspots of heavy metals were observed in luvisol and rendzina soils developed on carbonate bedrock. Multivariate analyses discriminated between component 1 with a large positive associations of As, Cd, Cr, Zn, Hg, Pb, $CaCO_3$, Corganic, pH, EC, Mg, and Ca and component 2 with a large positive associations of Co, Cr, Cu, Ni, clay, Al, and Fe. Positive matrix factorization Factor 1 was defined by As, Pb, and Zn, Cu and Hg provided similar contributions for Factors 1 and 2. Cd, Co, Cr, and Ni provided the highest percentage contributions for Factor 2. Pollution index, Enrichment factor of Cr, Hg, As, Pb, Ni, Cd, Cu, Zn, and Co ranges: 0.05–1.17, 4.48–246.63, 0.01–3.21, 0.06–2.97, 0.18–3.40, 4.30–81.62, 0.56–3.20, 0.52–3.83 and 0.21–3.81, respectively.

Key words: geostatistical analysis; principal component analysis; source apportionment; enrichment factor

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PHYTOCENOLOGICAL ANALYSIS OF FIR DOMINATED FOREST (*ABIES ALBA* MILL.) ON SILICATE SUBSTRATE IN SITNICA (NORTHWESTERN BOSNIA AND HERZEGOVINA)

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ABSTRACT

The aim of this research was to study phytosociological characteristics of *Abies alba* dominated community on silicate substrate in locality Sitnica at Manjača mountain (northwestern part of Bosnia and Herzegovina). This community originated from artificially forested mixed stands of fir and spruce planted in habitat of mountain Dinaric fir-beech forest. With regular selective cuttings and natural regeneration the structure shifted from even-aged to uneven-aged. At the same time beech is still absent from tree and tall shrub layer while the spruce is present in all layers.

In total 20 phytosociological relevés were collected using Braun-Blanquet method during vegetation seasons of 2021 and 2022. Relevés were stored in Turboveg database from which dataset was transferred to Juice software where analyses was done. Diagnostic, constant and dominant species were calculated. Box and whisker diagrams were used to display ecological factors which were calculated based on bioindicator values. Dataset was further analysed using hierarchical classification and ordination in R.

Phytosociological analyses indicate that those relevés can be classified as the association *Galio rotundifolii-Abietetum albae* belonging to alliance *Fagion sylvaticae*. Characteristic species for this association are present and frequent. Species characteristic for alliance *Vaccinio-Piceion* are present but with much lower occurrence than those of alliance *Fagion sylvaticae*. It should be noted that species characteristic for alliance *Aremonio-Fagion* are rare and mostly with low level of occurrence. Further research should be done to determine the reason for missing of those species. Hierarchical classification and ordination in R did not justified further division.

Key words: Vegetation, Braun-Blanquet approach, Plant communities, *Galio rotundifolii-Abietetum albae*

SOIL CHARACTERISTICS AND TYPES OF FOREST SITES IN THE "ZAŠTIĆENE ŠUME" MANAGEMENT UNIT

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ABSTRACT

The forest cover percentage of the North Bačka forest area of 5.4% is far below the optimal (10.1%) (Vlatković, 1997). Having in mind this fact, as well as the presence of climate change, it is very important to know the site characteristics of a given area, in order to get a good basis for preserving existing and also successfully establishing new forests. Research in this study was conducted in the „Zaštićene šume" management unit. 7 soil profiles were opened at the research area, and disturbed samples for laboratory analyzes were taken from genetic horizons with the aim of studying and defining soil classification units. Phytocenological studies were also performed (taking phytocoenological relevés and grouping them into phytocenological tables) in order to define associations. The parent material is an alluvial deposit of sand of different structure. Defined soil types belong to the order of hydromorphic soils, and the most dominant type is Haplic Gleysol. Based on phytocenological and pedological studies, new vegetation-ecological types of forests have been determined: *Populeto albae-Quercetum roboris* on Haplic Gleysol; *Ulmeto-Quercetum roboris* on Haplic Gleysol and *Ulmeto-Quercetum roboris* on Haplic Planosol. Knowing the characteristics of the soil and the current vegetation provides a good basis for further planning of silviculture measures and management of these forests.

Key words: hydromorphic soils; Haplic Gleysol; common oak; North Bačka forest area

GREEN ARCHITECTURE AS ONE OF THE PRINCIPLES OF GREENING URBAN AREAS IN NOVI SAD, SERBIA

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ABSTRACT

In the first fifth of the 21st century, Novi Sad marked an intensive urban development that continues. This means that zones of single-family housing eventually become multi-family housing zones so that single-family houses, with backyards, have been replaced with multi-story buildings with yards that most often serve as parking spaces. With such development of the city and lack of averseness of investors about the importance of greenery, street, ie publicly available greenery, has gained importance as the only one available in the immediate vicinity. During the transformation of urban zones from single-family housing to multi-family housing, the amount of publicly available greenery did not decrease much in percentage, but the subjective feeling of the citizen's lack of green space in such parts of the city became dominant. Such a feeling is increased due to the change in the street profile, i.e. the change in the height of the objects that make up the street profile.

In order to reduce the feeling of lack of green areas and increase the green areas in general, one of the nature based solutions can be green roof gardens on buildings, as well as vertical landscaping.

The research conducted an analysis of the existing roof gardens and vertical green walls in the territory of the City of Novi Sad, which included an analysis of the choice of plant species and their adaptation to environmental conditions. The aim of this paper is to obtain a list of plant species that have adapted well to the conditions of the roof gardens and vertical walls, all with the aim of more successfully establishing of new green areas. The results showed that the best-adapted plant species are those from the group of plants that grow in direct sunlight as well as those that have enough space to develop the root system in depth. When it comes to vertical walls, the best results were shown by plants planted on the ground, whose root system develops without limitations.

Key words: Green roofs, Vertical landscaping, Nature based solutions

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VEGETATION OF PROTECTED AREA "PROTECTED HABITAT GOSTILJ" IN THE REPUBLIC OF SRPSKA (BOSNIA AND HERZEGOVINA)

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ABSTRACT

The protected area "Gostilj" is located at the Ozren Mt. in the northern Republic of Srpska (Bosnia and Herzegovina). It was designated as "Category IV – Protected habitat" on 29 January 2022 with a total area of 131.97 ha with the main motive to acknowledge and protect the traditional practice of harvesting the medicinal plant Teucrium montanum, which, as an event, was included in the UNESCO Representative List of the Intangible Cultural Heritage of Humanity in 2018. Regardless of its small size, this area possesses respectable floristic and habitat diversity due to serpentine bedrock and pronounced relief. 29 relevés were collected in the field using the standard Central European phytosociological method. The classification was done expert based, according to floristic and ecological similarities between relevés. After analysis of data gathered in the field five, floristically and ecologically well-defined vegetation types were distinguished: (1) Ultramafic xeric rocky grasslands of Bosnia (*Polygonion albanicae* Ritter-Studnička 1970), (2) Meso-xerophytic basiphilous grasslands of the subcontinental regions of Central and southeastern Europe (*Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944), (3) Low heath on ultramafic substrates (*Erica carnea* community), (4) Relict *Pinus nigra* forests on dolomite and ultramafic substrates of the Dinarides (*Erico-Fraxinion orni* Horvat 1959), and (5) Thermophilous Central European acidophilous oak forests (*Quercion petraeae* Issler 1931).

Key words: habitats, nature protection, phytosociology, serpentine, syntaxonomy

POLYCYCLIC AROMATIC HYDROCARBONS IN EUROPEAN MOUNTAIN BEECH FOREST SOILS

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ABSTRACT

Soil is recognized as an excellent sink for polycyclic aromatic hydrocarbons (PAHs). At forest stands, this effect is enhanced by the canopy scavenging of trees, which increases pollutant fluxes from air to soil, e.g. by litter fall. Soil samples of 37 mountain beech forests from 11 European countries (Bosnia and Herzegovina, Bulgaria, Czech Republic, Germany, Italy, Poland, Romania, Serbia, Slovakia, Slovenia and Spain) were analysed for concentrations of polycyclic aromatic hydrocarbons (PAHs) in two sampling depths (0 - 40, 40 – 80 cm). A Quick, Easy, Cheap, Effective, Rugged and Safe (QuEChERS) method was applied forthe simultaneous analysis of 16 PAHs (Kim et al., 2019). High-performance liquid chromatography with diode array detector (HPLC–DAD) analyses of PAH-containing extracts were carried out on an Agilent 1100 Series chromatograph.

This study's main objectives were (i) to study the PAHs occurrence in mountain forest soils across Europe, and (ii) to decipher the processes behind potential variability in depth distribution, considering both PAH fingerprints and concentrations.

The total concentrations of ∑16 PAHs in the surface layer (0–40 cm) and sublayer soils (40–80 cm) ranged from 271.52 - 1154.52 and 318.95 - 1052.54 μg/kg, with a median of 580.79 and 604.53μg/kg, respectively. Thereisno statistically significant differencebetween groups. The 4-ring and 5-ring PAHs were the most prominent components in all samples.

The concentration of Σ16 EPA PAHs did not exceed the precautionary values set by the soil quality guidelines.

Key words: PAHs distribution, QuEChERS method, beech forests

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DETERMINATION OF THE IMPACT OF PARENT MATERIAL ON ELEMENTAL COMPOSITION, ACTIVITIES OF RADIONUCLIDES, AND SITE PRODUCTIVITY IN EUROPEAN MOUNTAIN BEECH FORESTS

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ABSTRACT

Fagus silvatica L., or European beech, is one of the most important and widespread deciduous tree species in Europe. The research included the analysis of As, Cd, Co, Cr, Ni, Pb, Zn, Hg, Rb, Sr, Y, Zr, Sn, Ba, W, ^{22}Na, ^{40}K, ^{137}Cs, ^{232}Th, ^{226}Ra, ^{238}U, and ^{235}U, and calculation of site productivity index. Soil samples in beech forests were taken from 20 sites in 11 European countries and performed at two depths of 10 - 40 cm and 40 - 80 cm. The results of this research showed that the soils formed on the limestone contain the highest average concentrations of the examined microelements at a depth of 40 - 80 cm. Exceptions are samples from Slovenia that have the highest content in surface samples, although they were developed on a limestone (dolomites). The activity concentration of all measured radionuclides is slightly higher for sandstones, limestones, and granites. The only concentration of activity is ^{137}Cs is slightly higher in soil samples on a carbonate parent material. Higher values of the productivity index of the locality were found on acid silicate rocks, which correlate with the concentrations of Th^{232}, Ra^{226}, K^{40}, U^{238}, U^{235}, Rb, and Zr. The aim of this paper is to analyze the impact of the parent material on the elemental composition and activities of radionuclides in the soil of European beech forests and to analyze the impact of the parent material on the productivity of analyzed sites.

Key words: European beech, elemental composition, radionuclides, site productivity index

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SOIL CHARACTERISTICS AS CRITERIA FOR "SMARTNESS" FOR THE EUROPEAN MOUNTAIN FORESTS

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ABSTRACT

Climate-Smart Forestry in mountain regions is an approach that can help to realize potential of the forest sector to contribute to climate change mitigation and to identify new principles and measures to reap this potential. These new measures and criteria include identification of key soil characteristics of beech forests in Europe. Total of 80 soil samples from 15 soil profiles were collected from beech forests of Spain, Czech Republic, Slovakia, Germany, Poland, Romania, Serbia, Italy, Bosnia and Herzegovina and Slovenia. Methodology used for soil analyses: electrical conductivity (EC) and pH (measured by portable meters), content of organic carbon (Corg – elemental analyser), grain size distribution (pipet analysis), content of major and minor minerals determined by XRF and ICP-OEC. Also concentrations of anions were determined by ion-chromatogarphy. The average content of organic carbon in tested soils is 2.4%. The highest concentrations are found in soils on limestones than on granite rocks and lowest concentrations on soils developed on sandstones. Concentrations of carbonate and sulphate anions are also highest in limestone soils, while phosphate and nitrate ions do not show variation with bedrock type. From the obtained results it can be concluded that the bedrock has strong influence on soil properties. The obtained differences are reflected in the depth of soil profiles, structure of aggregates and physico-chemical composition. The results of this study will help in the definition of climate-smart forestry and identification of "smartness" criteria for the European beech forests.

Key words: climate-smart forestry; soil quality; concentration of anions

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IMPROVEMENT OF THE MANAGEMENT OF PROTECTED AREAS IN SERBIA TO ACHIEVE THE GOALS OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

Protected areas (PA) represent healthy natural ecosystems which support and sustain biodiversity and human well-being by providing essential ecosystem services and health benefits. However, maintaining such ecosystems to provide these environmental benefits becomes a more and more challenging issue with climate changes, biodiversity loss, land degradation and the continued erosion of the natural capital, particularly in the developing world. The main objective of this research is to establish a methodology for achieving the United Nations Sustainable Development Goal 15 "Life on Land" and to assess the effect of nature-based solutions (NBS) for enhancing the sustainability of management of the Pas. The methodology included the determination of heavy metals in soil and needle samples, pollution status assessment and questioners for different stakeholders.

In this study 58 forest soil samples and 50 conifer needle samples from four protected areas in Serbia (Tara, Zlatibor, Golija, Đerdap) were analyzed. Concentrations of minor elements (Cd, Co, Cr, Cu, Ni, Pb, V and Zn) were determined using Inductively coupled plasma – optical emission spectrometry (ICP-OES). Quantitative pollution indices (Contamination factor (Cf), Geoaccumulation index (Igeo) and Degree of contamination (Cd)) were calculated since they are effective tools for converting the raw environmental data into information relevant to support decision-making. Results of this study provide a scientifically-based overview of the conditions of soil health and health of the forest ecosystem and help to propose nature-based solutions for enhancing the sustainability of management, especially in the context of improving ecosystem services and climate change adaptation and mitigation.

Key words: nature based solution; ecosystem services; soil quality status; conifer needles

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УНИВЕРЗИТЕТ У БАЊОЈ ЛУЦИ
ШУМАРСКИ ФАКУЛТЕТ
FACULTY OF FORESTRY
UNIVERSITY OF BANJA LUKA

THEMATIC AREA 3
Let’s green, be seen

TEMATSKA OBLAST 3
Ozelenimo, budimo vidljivi

25 YEARS OF RESEARCH ON THE VARIABILITY OF SILVER FIR (*ABIES ALBA* MILL.) IN BOSNIA AND HERZEGOVINA

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ABSTRACT

Silver fir (*Abies alba* Mill.) is one of the economically and ecologically most important species of forest trees in Bosnia and Herzegovina. To understand the importance of silver fir forests, one should know that silver fir is present in mixed beech and silver fir forests, beech, fir, and spruce forests, and very rarely in pure fir forests in an area of about 50% of all high (economic) forests. The total area of silver fir forests, pure and mixed, is 562,237 ha. Research on the variability of silver fir in Bosnia and Herzegovina can be divided into two significant phases. The first phase included the analysis of properties at the species level to obtain some basic morphological and physiological indicators. The second phase was focused on the study of interpopulation variability at the morphological, physiological, and molecular level. The variability obtained in both phases indicates that priority should be given to sustainable management and natural regeneration of silver fir, with constant monitoring of genetic structure, and take necessary measures to maintain the genetic diversity that characterizes each population. That will guarantee that silver fir will last for a long time in our forests.

Key words: Silver fir, *Abies alba*, morphological variability, genetic diversity

A NEW MODEL FOR CALCULATING PLANTING DENSITY IN ESTABLISHING PLANTED FORESTS

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ABSTRACT

The parameter that significantly affects the survival and activities during establishment, maintainance, protection and utilization of planted forests is planting density. Planting density is in most cases defined at the species level, and does not adequately incorporate: species-habitat interaction, planting material quality, production target and post-establishment works.

The paper proposes a new model for defining planting density. The model takes into account 20 parameters divided into 6 data categories: (i) the expected number of trees at the end of the rotation, (ii) production aim, (iii) bioecological characteristics of the species, (iv) habitat characteristics, (v) planting material quality and vi) maintenance after planting. Each parameter has a different value of the coefficient ranging from 1 to 1.8. The values of the coefficients are defined on the basis of the assessment of the impact on the success of new forests, and it is verified by applying the Elenberg's coefficients for species and habitats. The value of afforestation density is defined as the product of the coefficients, the expected number of trees at the end of the rotation and the production aim.

The average values of planting density, calculated in this way, are within the recommended planting densities for forest species in Europe in general. However, this model provides flexibility based on a number of parameters, in order to adjust the planting density to the specific habitat conditions, the selected species and the expected production aims.

Key words: forest establishment, species-habitat interaction, coefficients, adjusted planting density

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GENETIC DIVERSITY OF SERBIAN SPRUCE POPULATIONS FROM BOSNIA AND HERZEGOVINA

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ABSTRACT

Flora and fauna in Bosnia and Herzegovina (B&H) are characterized by a high degree of endemic and relict taxa. One of them is the Serbian spruce (*Picea omorika* (Panč.) Purk). This species is IUCN red-listed European conifer, endemic to the Balkan region. A total of 284 Serbian spruce trees were sampled in 12 different populations which cover the current distribution of the *Picea omorika* in B&H. Eleven nuclear simple sequence repeats (SSR) markers were used to assess genetic diversity and genetic structure in this species. A total of 143 different alleles were identified in 284 individuals, and the number of detected alleles per locus varied from 2 (Pa_51) to 30 (WS0019), with an average of 13 alleles per locus. The effective number of alleles varied from 1.56 (Pa_51) to 7.70 (WS0019), with an average of 3.73 alleles per locus. The observed heterozygosity ranged from 0.395 (Tesla) to 0.701 (Grad), and averaged 0.601. Values of expected heterozygosity varied from 0.483 (Tesla) to 0.669 (Arsenov rid), with an average of 0.604. Null alleles were not detected at any locus in any of the investigated populations. The differentiation coefficient (Fst) was 0.122 and the gene flow among populations was 2.089 migrants per generation. Structure analysis revealed nine genetic clusters, and the UPGMA analysis confirmed those results. The results show significant differences among analyzed populations, which is important in the choice of methods in future activities related to in situ and ex situ conservation of this endangered species.

Key words: *Picea omorika*, nuclear microsatellites, genetic structure, conservation

ANALYSIS OF FOREST PLANTING MATERIAL PRODUCTION IN CROATIAN NURSERIES DURING 2021

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ABSTRACT

Forest seedlings/cuttings have recognized role in Croatian forestry. The need for forest seedlings grows continuously with needs for forest restoration and artificial regeneration. Thus, importance of harmonized and quality seedling production is referred to as backbone of silvicultural activities and interventions. According to the Law on forest reproductive material, Croatian Forest Research Institute is the official body for conducting control of nurseries and forest seedlings'/cuttings' quality in the Republic of Croatia. Paper aims to describe and analyze forest planting material production during 2021 based on data collected during supervision (descriptive statistics). In 2021 a total of 14.603.756 forest seedlings/cuttings of different tree species, ages, and silvicultural methods of production have been produced in Croatian nurseries. Number and area of nurseries with active production as well as the amount of produced planting material varies significantly with a clear negative trend, if long-term production is taken into account (1992–2021). The assortment is not in line with current international legislation to which Croatia is subjected as well as with scientific and professional trends. Produced planting material does not cover the needs of private forest owners, biological revitalization (quarries, landfills, etc.), and no significant fulfilment of export was observed, for which there are capacities in Croatian nurseries. The conducted analysis of production in nurseries and oscillation of their numbers and capabilities over the course of time suggests that there are possibilities for further expansion and optimization of planting material production in the Republic of Croatia, which will be needed considering the current demands as well as the increased demands expected in the near future.

Key words: total production; broadleaves, conifers, adapted production assortment, nursery production planning

QUALITY OF CONTAINER SEEDLINGS OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.) OF DIFFERENT AGES

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ABSTRACT

The analysis included 15 randomly selected Pedunculate oak seedlings from multicontainers Lieco V-395 at the age of 1+0 and 2+0. The treatments and preparation of the filling substrate of the containers, as well as the type, amount and timing of fertilizer addition were uniformly performed on the automatic filling and seedling line (Urbinati). The following parameters were analyzed on the seedlings and substrate: height, root collar diameter, slenderness coefficient, seedling biomass, root morphological characteristics, substrate pH, and nutrient content (P, K, Ca, Mg, Fe, Mn, Cu, and Zn). The average height of seedlings 1+0 was 24.2 cm, root collar was 7.40 mm, and the slenderness coefficient was 3.37. The average height of seedlings 2+0 was 20.0 cm, root collar was 7.23 mm, and the slenderness coefficient was 2.82. A statistically significant difference was found between the seedling heights of 1+0 and 2+0. The average biomass of seedlings 1+0 was 2.28 g, roots 5.90 g, and stem/root ratio 0.40. The average stem biomass of seedlings 2+0 was 1.93 g, roots 6.00 g, and stem/root biomass ratio 0.32. A statistically significant difference was found between seedlings 1+0 and 2+0 in the following root variables: average diameter, volume, and number of tips. There is a significant difference in the content of P, K, Mg, Mn and Cu in the substrate, which may also indicate inhomogeneous filling that should be further controlled to improve seedling quality. Due to the limited volume, Lieco V-395 containers are not recommended for growing seedlings 2+0.

Key words: seedling morphology, root morphology, substrate pH, nutrient content in the substrate

SELECTION OF GENOTYPES OF SERVICE TREE (*SORBUS DOMESTICA* L.) WITH REGARD TO SEED QUALITY

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ABSTRACT

Service tree seeds were collected in autumn 2021 from five trees (genotypes) originating from five localities in the Republic of Croatia: Kravarsko, Cekovići, Šiljakovina, Daruvar and Velika. Seeds were taken from fruits immediately after harvest and stored at room temperature until the time of scanning, weighing and stratification. Stratification was done according to ISTA recommendations for overcoming seed dormancy in species of the genus *Sorbus* L. After stratification, all germinated seeds were counted. A total of 1287 seeds from five trees were sown in Dunemann nursery beds on March 29, 2022. Seed weight was statistically different between trees, ranging from 0.02552 g (Cekovići) to 0.04385 g (Velika). The tree from Velika is characterised by the highest values of the following seed characteristics: projected area (mm^2), straight length (mm) and curved length (mm). The percentage of germinated seeds after stratification averaged 30.82%, ranging from 10.75% (Velika) to 56.04% (Kravarsko). Seed germination was complete 49 days after sowing (May 10, 2022). Germination ranged from 37.00% (Cekovići) to 66.00% (Velika) or an average of 52.77% for all 5 trees. From these studies, it can be concluded that the selection of the Service tree from Velika is justified, given the quality of the seed. Such genotypes are interesting for forestry (forest seedlings, clonal seed orchards) and fruit growing (raising grafted fruit trees).

Key words: seed mass, seed morphology, stratification, nursery germination

ECO - INDICES AS A TOOL IN THE SELECTION OF SPECIES FOR AFFORESTATION – CASE STUDY REPUBLIC OF SRPSKA (BIH)

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ABSTRACT

According to the data obtained from the planning documents, in the territory of the Republic of Srpska (entity of Bosnia and Herzegovina), there are 86.458,48 hectares of land suitable for afforestation. This area can and should be better used and there is a consensus it should be afforested as soon as possible. At the same time the concept of „Target seedling production" is being promoted.

Promoting the above concept in the selection of tree species for afforestation, the Elenberg's coefficients as eco-indices are applied. For each habitat (235 in total) and 50 main tree species, coefficients from 1 to 5 were assigned for the following parameters: (1) air temperature, (2) soil moisture, (3) soil pH and (4) amount of nitrogen in the soil. Instead of parameters such as light, continentality, etc., an additional parameter (5) soil depth was estimated. With compatible matrices, species corresponding to each analyzed habitat with their bioecological characteristics were selected.

The results indicate the justified use of the Ellenberg coefficients as eco - indices in order to objectify and better select species. Unlike to the current practice of seedling production, in further activities the production of the following species is recommended: *Fagus sylvatica* - 13%; *Pinus nigra* - 12%; *Abies alba* - 12%; *Quercus petraea* - 12%; *Picea abies* - 9%, etc.

Key words: afforestation, Elenberg's coefficients, species selection, target seedling production

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SURVIVAL AND JUVENILE-AGE PERFORMANCE OF *SALICACEAE* CLONES FOR BIOMASS

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ABSTRACT

The adaptability of three *Salicaceae* clones selected for biomass (*Salix* x 'Terra Nova', *Populus* x 'AF-18' and *Populus* 'AF-8') was tested in the first year of growth at nursery in comparison with a poplar cultivar for wood production (*Populus* x 'I-214').

An experimental plantation was established in April 2020 with standard hardwood cuttings on 0.2 ha nursery land along the Danube River in Central Northern Bulgaria. Principal leaf gas exchange parameters were measured, diameter increment, height growth and increment, and normalized difference vegetation index were monitored on representative samples of plants. The influence of the genotype was analyzed, and correlations with main climate parameters were sought.

The willow clone showed early increment culmination and a sharp decline in growth and viability with suspension of watering. It had the lowest net photosynthetic rate (8.312 ± 0.107 μmol $(CO_2)\cdot m^{-2}\cdot s^{-1}$), low biomass growth (0.098 ± 0.01 kg DM) and a high survival rate.

Unlike the other poplar genotypes, 'I-214'showed rapid growth at the beginning of the summer, a high transpiration rate (1.222 ± 0.034 mmol $(H_2O)\cdot m^{-2}\cdot s^{-1}$) and a stronger dependence on moisture. Clones 'AF-8' and 'AF-18' had high photosynthetic (10.238 ± 0.231 and 11.480 ± 0.193 μmol $(CO_2)\cdot m^{-2}\cdot s^{-1}$, respectively) and low transpiration (0.672 ± 0.024 and 0.682 ± 0.015 mmol $(H_2O)\cdot m^{-2}\cdot s^{-1}$, respectively) rates, and their growth was positively affected by the temperatures. The water use efficiency of the poplar biomass clones was the highest. 'AF-8' genotype showed the best diameter and biomass (0.194 ± 0.036 kg DM) growth, while 'AF-18' genotype grew best in height.

Key words: : growth, adaptability, Salix x 'Terra Nova', Populus x 'AF-18' and Populus 'AF-8'

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POTENTIAL OF AREAS DEGRADED BY SURFACE COAL MINING FOR BIOMASS PRODUCTION

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ABSTRACT

Adopting the principles of the Kyoto Protocol, many countries have developed a strategy to replace fossil fuels with renewable energy sources, so biomass is becoming a realistic alternative. In Serbia reserves of lignite occupy the area of more than 1000 km^2. Past experiences show that in the procedure of biological restoration of mine spoil banks, the ratio of forest and agricultural revegetation is mostly 60:40, which means that finally it can be expected that forest ecosystems should establish on about 600 km^2, and agricultural areas, urban ecosystems and infrastructure - on about 400 km^2. Also, the deposited tailings in the internal landfills of the mines, which are deposited in layers, are a suitable space for the formation of energy crops. These surfaces last for several years before they have been covered with a new layer of deposols. In the aim of determination of possibilities of biomass production at the disposal sites of barren soil (deposols) the comparative experiment was set with fast-growing plant species, two conifers (*Larix europaea* L. and *Pseudotsuga menziesii* Mirbel. Franco.) and two deciduous species (*Populus x euramericana* I-214 and *Salix* sp.). On the experimental plot the following parameters were monitored: the degree of the survival of the planted plants, dynamics of the height and diameter growth increase, effects of the applied care measures and fertilization. Using different tree species in our research, even under unfavourable soil conditions, the increment was estimated from 5.3 to 19.6 t of dry matter per ha at the age of 4 years. The paper data point to significant, so far unutilised potentials of woody biomass produced on deposols, which could be used for energy production.

Key words: deposols, biological reclamation, open pit mines

SPRING AND AUTUMN LEAF PHENOLOGY OF COMMON BEECH AND SESSILE OAK PROVENANCES IN RELATION TO DIFFERENT SOIL PHOSPHORUS CONCENTRATION

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ABSTRACT

This research was conducted on a four-year-old common beech and sessile oak saplings originating from two mature mixed common beech and sessile oak stands (provenance) from the Republic of Croatia (HR). Provenances differ in annual amount of precipitation, which in provenance Slavonski Brod (SB) from the eastern part of the HR is about 770 mm (dry provenance), and in Karlovac (KA) from the north-western part of the HR is about 1112 mm (wet provenance). During year 2021, after the establishment of the experimental trail, the transplanted saplings grew into two soil types, one was characterized by high (0.30 g P_2O_5/l soil) and the other by low (0.16 g P_2O_5/l soil) phosphorus (P) concentration. The aim of this study was to examine the effect of higher soil P concentration on the average onset of spring bud burst and autumn leaf senescence in beech and oak saplings. The results showed that the onset of bud burst and leaf senescence in beech compared to oak saplings occurred significantly earlier, in six and ten days, respectively. Differences in the onset of bud burst and leaf senescence between oak provenances were not significant, whereas these differences between beech provenances were significant. Therefore, the onset of bud burst and leaf senescence in beech of dry SB provenance compared to wet KA provenance occurred earlier in five and three days, respectively. The higher soil P concentration significantly affected only the onset of leaf senescence in beech saplings. This means that the onset of leaf senescence in beech saplings under the higher compared to lower soil P concentration occurred three days earlier in the dry SB provenance and four days earlier in the wet KA provenance.

Key words: *Fagus sylvatica* L., *Quercus petraea* (Matt.) Liebl., saplings

Acknowledgements: This research was conducted as part of the research project "IP-2020-02-5204 Phenotypic response of common beech and sessile oak provenances to long-lasting drought in interaction with different phosphorus concentrations in the soil" funded by the Croatian Science Foundation.

THE EFFECTS OF DROUGHT AT VARIOUS TIMES OF THE GROWING SEASON ON HEIGHT GROWTH AND LEAF SENESCENCE OF A GOAT WILLOW CLONE

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ABSTRACT

Previous studies have shown that drought stress, among other things, results in reduced height growth and leaf phenology alterations in many forest tree species. However, we were interested whether there are variations in those effects if drought stress was induced at different times of a growing season.

A female goat willow tree was cloned by hardwood cuttings. 151 ramets were divided into eight groups. Seven groups were exposed to drought stress, but at different times during a growing season, from early March to mid-July. The eighth group was the control. Each ramet was exposed to drought until the appearance of stress symptoms, when the treatment was stopped, and the plant was rehydrated. Control ramets were watered regularly. Plant heights were measured at the beginning and end of the growing season, and autumn leaf phenology was scored with an ordinal scale of 1-5. Data on height increment and the day of a year when a ramet was in the phenophase 3 (more than 50% of dead leaves) were used for statistical analysis.

The average height increment of most groups was lower than the control group, though only groups 5 and 6 (exposed to drought in late May/early June) differed significantly. The first four groups (exposed to drought from early March to early May) showed a delayed leaf senescence date. However, only the first group significantly differed from the control. This study indicates variations of drought effects on forest trees, depending on the part of the growing season when the stress occurs.

Key words: *Salix caprea* L., phenology shift, stress

MORPHOMETRIC ANALYSES OF THE ACORN VARIATION WITHIN *QUERCUS PETRAEA* (MATT.) LIEBL. IN THE BOSNIA AND HERZEGOVINA AND SERBIA

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ABSTRACT

The morphological characteristics of an Sessile oak acorns were investigated in order to determine the differences between the populations in Serbia and Bosnia and Herzegovina (B&H). We have studied the natural variability of sessile oak by analysing acorns materials collected from 10 populations representings different regions of Serbia (Košutnjak, Valjevo, D. Milanovac, Zlatibor, Goč and Medveđa) and of B&H (Foča, Teslić_1, Teslić_2 and Konjic). The acorns have been collected from 50 trees per populations and 50 acorns per tree. The following morphometric measurments were conducted: seeds weight, seeds length, seeds width, scar diametar, volumen and index of acorn shape. The statistical methods implemented in this paper are descriptive statistics, ANOVA, cluster analysis and discriminant analysis. Acorns weight varied from 0.75 to 9.33 g, acorn lenght from 12.03 to 36.1 mm, acorn width from 16.8 to 21.27 mm, scar diametar from 4.14 to 11.17 mm. The volume of an acorn ranged from 1.37 to 11.83 cm^3. The shape index of an acorn were found ranging from 1.00 to 2.31. Analysis of variance indicates statistically significant differences between all of the examined characters. The cluster analysis for the measured properties of acorns singles out the populations of Foča and Zlatibor. Discriminant analysis based on the first two canonical variables that make up 83.3% of the total variation among the populations singles out the population of Foča and Zlatibor. The results obtained represent a good starting point for future research on selection and breeding of the species.

Key words: Sessile oak, populations, acorn, variability

POTENTIAL OF NEW BIODEGRADABLE CONTAINER FOR FOREST SEEDLINGS PRODUCTION

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ABSTRACT

Container production of forest seedlings has numerous advantages that make it widely accepted and often used technology, but on the other hand, numerous disadvantages implicate the need for constant innovation in this field. A solid plastic containers are commonly used in Serbian nurseries for seedlings production of coniferous and deciduous (Hiko V-120SS and Bosnaplast 12; respectively Hiko V-265 and Bosnaplast 16). This research was conducted with the aim to provide some information about possibilities for use biodegradable container for this purpose. We compared a cardbord container (patent number 1570 U1) during the first growing season in the nursery with the commonly used containers. Differences between Austrian pine (*Pinus nigra* Arnold), Scots pine (*Pinus sylvestris* L.), Common beech (*Fagus sylvatica* L.) and English oak (*Quercus robur* L.) seedlings grown in commonly used and new biodegradable containers were negligible for shoot height (SH) and height diameter ratio (HD) inside seeedlings of same species. Root collar diameter (RCD) showed significant differences (OneWay ANOVA, $p<0.05$) relative to container type for *P. nigra* and *F. sylvatica* seedlings, where the lowest values were recorded in biodegradable containers. Coniferous seedlings from this research were stronger, while deciduous species had lower values of SH and RCD than average seedlings of these species in Serbian nurseries. Obtained results suggest the possibility of using the new biodegradable container in forest nurseries, but also implicate the need for testing on more species and need for testing od additional attributes of seedlings.

Key words: forest seedlings, biodegradable container, morphological attributes

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THE ASSESSMENT OF ROOT ANATOMICAL CHARACTERISTICS OF *SALIX* SPP. IN THE PREDICTION OF THE MOST SUITABLE CLONES FOR DENDROREMEDIATION

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ABSTRACT

Many morpho-physiological research have found that species from the genus *Salix* L. represent suitable tool for forest management and dendroremediation of forest soils contaminated by cadmium (Cd). However, only a few studies have followed anatomical changes of tree roots exposed to Cd stress. The aim of our study was to analyze the root anatomical characteristics of *Salix alba* L. clone 'B-44', *Salix viminalis* L. 'SV068' and *Salix matsudana* Koidz. clone 'SM4041' in response to 3 and 6 mg Cd kg-1 dry weight in soil and to assess application of the root characteristics in the selection of willow clones for dendroremediation. The stem cuttings of clones were obtained from the Institute for Lowland Forestry and Environment in Novi Sad, Republic of Serbia. The cuttings were grown in the greenhouse of the Department of Biology and Ecology, Faculty of Science, Novi Sad, in the soil culture. The root anatomical traits were measured on microscopic sections, including root cross-section area and diameter; percentage of periderm, secondary phloem and wood; number and diameter of xylem vessels. Our study revealed that Cd treatment caused genotype-specific anatomical responses in the roots of the *Salix* clones. Clone 'B-44' had the greatest values of root cross-sectional area, vessels lumen and diameter, after Cd treatment. On the other hand clone 'SV068' had the smallest values of these root parameters. This indicate the relationship between Cd stress and characteristics of root xylem and importance of root anatomy in assessment of potential use of clone 'B-44' in the dendroremediation, nature-based solution.

Key words: *Salix*, Cd stress, root characteristics, dendroremediation

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GENERATIVE PROPAGATION OF *LIQUIDAMBAR STYRACIFLUA* L. ELITE GENOTYPES ADAPTED TO URBAN CONDITIONS IN BELGRADE

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ABSTRACT

Liquidambar styraciflua L. (American sweetgum, sweetgum) is a large, ornamental, slow-growing deciduous tree, valued for its leaves' autumn color. It tolerates moderate drought and salt stress, and it can withstand urban pollution well. Although American sweetgum originates from North America and it is an alien species in Serbia, it is not recorded as an invasive species in Serbia or Europe. Recent studies showed that sweetgum is well-adapted to urban environments in Serbia and therefore its use in urbanized areas can be recommended. For that reason, the elite tree of *L. styraciflua* growing in Belgrade was selected as a seed source for obtaining plants well adapted to local conditions. The seeds were collected in April, stored at room temperature for one month and placed on germination in May. The germination energy was recorded after 7 days and it was low, only 13.3%, but germination rate recorded 21 days after placing seeds on germination was high – 92%. Therefore, the seeds collected from the selected tree can be used for generative propagation of *L. styraciflua*. However, it is recommended to monitor seedlings' appearance and development in the surrounding area in order to prevent possible naturalization and invasiveness of this species in the changing climatic conditions.

Key words: American sweetgum, germination, trees for urban forests

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GERMINATION OF *MORUS NIGRA* L. SEEDS COLLECTED FROM ELITE TREES ADAPTED TO URBAN CONDITIONS IN BELGRADE

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ABSTRACT

Mulberry (*Morus nigra* L.) is a fast growing deciduous tree adapted to different environmental conditions. It is an ornamental, edible and medicinal plant that can also be used for ecorestoration of degraded lands, bioremediation of polluted sites, afforestation and planting in urban areas. In order to obtain planting material well adapted to local climatic conditions in Belgrade, the mulberry trees growing in Belgrade have been evaluated and appropriate elite tree was selected as a possible seed source and seed germination was tested. The fruits were collected in June and after maceration, part of obtained seeds were sown immediately and part was stratified at the temperature 3ºC - 5ºC for one month. The germination of seeds sown immediately after collection was low (8.7%), but after cold naked-stratification, the germination of seeds was high (89%) and germination energy was satisfactory (69.5%). Obtained results indicated that selected trees can be used as a seed source for production of *M. nigra* plants well adapted to unfavorable urban conditions in Belgrade, suitable for planting in Belgrade urban forests.

Key words: black mulberry, trees for urban forests, germination

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CONSERVATION OF FOREST GENETIC RESOURCES AT THE LOCALITY „JELAK" IN THE NATIONAL PARK „KOPAONIK" - SERBIA

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ABSTRACT

The main long-term goal of conservation and sustainable development of National Park (NP) „Kopaonik" is to conserve and improve the natural values, including forest genetic resources. It is located in central Serbia, covering an area of 11,969.04 ha. One of the 13 localities with the first protection regime is „Jelak" (60.39 ha, 1000-1490 m a.s.l.). This research aimed to identify rare, endangered, relict, endemic, or species „at-risk" at the locality „Jelak", as a basis for proposing a program for its conservation. Its main value is a presence of a mixed forest of yew and fir. By terrain reconnaissance, a total of 13 forest tree species were recorded, among which *Ulmus glabra* (rare), *Betula pendula* (rare/endangered), *Populus tremula* („at-risk"), and *Taxus baccata* (relict), which indicates a significant diversity. In addition, 14 species were recorded in the shrub layer, among which *Acer heldreichii* (endemic) and *Acer platanoides* (rare/endangered). English yew (*Taxus baccata* L.) is a very rare species that occurs only in the locality „Jelak" in the entire area of NP „Kopaonik". This species is under varying degrees of nature conservation in different European countries, and it is categorized on the European Red List Category and Criteria („least concerning"). Since it is considered a tertiary relict in the forest fund of Serbia, it is important to conserve the available gene pool. Based on the results, measures of *in situ* conservation and monitoring of the *Taxus baccata* population and all identified rare and endangered species at the locality „Jelak" have been defined.

Key words: *Taxus baccata*, relict and endangered species, *in situ* conservation, protected areas

Acknowledgements: This research was supported by the Public Enterprise "National Park Kopaonik", project: "*Identification of Endangered and Legally Protected Trees and Shrub Species*", and Ministry of Education, Science and Technological Development of the Republic of Serbia according to the agreement number 451-03-9/2022-14/200169.

GENETIC DIFFERENTIATION OF WILD CHERRY (*PRUNUS AVIUM* L.) POPULATIONS IN SERBIA BASED ON SEEDLING'S MORPHOLOGICAL TRAITS

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ABSTRACT

This study aimed to determine the amount and the pattern of phenotypic variations within- and among Serbian wild cherry populations due to seedling morphological traits.

Seeds were collected from 10 trees in each of nine natural stands (populations), in total 90 half sib lines. Leaf morphological traits (leaf blade area, lamina width, lamina length and petiole length) and growth traits (height of seedlings and root collar diameter) of one (1 + 0) and two-year-old (2 + 0) seedlings were analysed. The phenotypic variations were examined using analysis of variance (ANOVA) and multivariate analyses: principal component analysis (PCA) and cluster analysis. The Pearson's correlation coefficients among the analysed traits as well as among the traits and climate variables of the original populations stands were calculated.

The ANOVA results showed statistically significant differences ($p < 0.01$) among the populations. The variability within the populations had the largest share in the total variability. The PCA results showed discrimination of the populations due to elevation and related climatic parameters indicating ecoclinal pattern of differentiation.

The phenotypic variations indicates high genetic variations among and within populations and therefore high potential of the species to adapt to climate change. Significant genetic variability of Serbian wild cherry populations emphasizes their importance as valuable sources of forest reproductive material.

Key words: *Prunus avium* L., phenotypic traits, variability, populations

THE STATE OF THE AQUATIC GENETIC RESOURCES (AQGR) IN BOSNIA AND HERZEGOVINA

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ABSTRACT

Hydrological diversity in the Bosnia and Herzegovina in terms of number, size, geographical position and rivers runoff has led to high biodiversity related to aquatic habitats. The study includes a large number of data collected on the field, as well the literature data. Bosnia and Herzegovina is characterized by great, not only genetic and species, but also ecosystem diversity. The aquatic genetic resources (AqGR) of Bosnia and Herzegovina are very diverse and rich. The natural disconnection of sea basins (Black Sea and Adriatic) and geotectonic events have conditioned today's isolated and locally specific populations of freshwater crustaceans and fishes. The aquatic ecosystems of Bosnia and Herzegovina are inhabited by five species of decapod freshwater crustaceans, four of which are indigenous. Amphipods are represented by 42 species of which 20% are endemic. Species that are limited to Bosnia and Herzegovina (*Gammarus bosniacus* Schäferna, 1932, *Niphargus dabarensis* Fischer, Trontelj & Sket, 2006, etc.) are particularly prominent. Recent research has also registered two invasive amphipods species (*Dikerogammarus villosus* Sowinsky, 1894, *D. haemobaphes* Eichwald, 1841) that are confined to the Sava River. Fish are represented by 118 species. Indigenous species make up more than 2/3 of the recorded number (88.98% or 105 species), among which 40 are endemic to a very narrow range, while 13 allochthonous species have been registered in our waters, some of which are invasive. Within the recorded number of fish species, 17 of them live in both brackish and salt waters. A significant number of freshwater crustaceans and fishes are included in some of the endangered categories according to the International List of Endangered Species (IUCN). These are mostly indigenous and endemic species.

Key words: aquatic genetic resources, indigenous species, endemic species, freshwater crustaceans, fish

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GENETIC DIVERSITY OF THE *QUERCUS FRAINETTO* TEN. POPULATION FROM THE PROTECTED AREA „KOŠUTNJAK FOREST" (BELGRADE, SERBIA) ASSESSED BY NUCLEAR MICROSATELLITES

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ABSTRACT

The protected area „Košutnjak Forest" (Belgrade, Serbia), occupies 267 ha, with numerous forest tree species, among which are five native oak species, including the Hungarian oak (*Quercus frainetto* Ten.), mostly represented by very old, sometimes diseased trees, with the poor possibility of natural regeneration. Therefore, oaks can be categorized as „at-risk" species in „Kosutnjak Forest". This research aimed to determine the genetic variability of the Hungarian oak population in the „Košutnjak Forest" using nuclear microsatellites. DNA extraction was performed from young leaves, collected from 56 adult trees, using a commercial peqGOLD Plant DNA Mini Kit (PEQLAB). In total 13 nuclear microsatellites were used, and values of standard genetic diversity parameters were calculated using GenAlEx 6.5 software. The number of alleles per locus ranged from 6 (QrZAG108) to 35 (QrZAG90), with an average of 16.077. The number of effective alleles per locus was in the range from 2.575 (QrZAG108) to 26.304 (QrZAG90), with an average of 8.698. The average value of the observed heterozygosity (Ho) was 0.744, and the average unbiased expected heterozygosity (uHe) was 0.829. A statistically significant deviation of the expected heterozygosity from the observed heterozygosity occurs at 5 loci (PIE239, QrZAG108, MAQ4, PIE242, and QrZAG7). The average values of the fixation index were positive and statistically significant, indicating an excess of homozygotes. Determining the level of genetic variability of Hungarian oak served to assess its genetic status and as a basis for defining adequate *in situ* conservation measures for the available gene pool in „Košutnjak Forest".

Key words: Hungarian oak, conservation, forest genetic resources, molecular markers

Acknowledgements: This research was supported by the Secretariat for Environmental Protection of the City of Belgrade, project: Identification and monitoring of the gene pool of rare, vulnerable and endangered plant species in NM „Kosutnjak Forest" and Ministry of Education, Science and Technological Development of the Republic of Serbia according to the agreement number 451-03-9/2022-14/ 200169.

CONSERVATION OF THE TARGET SPECIES GENE POOL IN NATURAL MONUMENT „KOŠUTNJAK FOREST" (SERBIA)

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ABSTRACT

By terrain reconnaissance of the protected area Natural Monument (NM) „Košutnjak Forest", 59 tree species were recorded. The conservation status of each species was determined based on its categorization in the forest fund of Serbia. The degree of endangerment was assessed based on: representation in the population; the age of trees; degree of rejuvenation; health condition; yield and genetic variability. The following criteria were applied for the selection of „target" species, included in conservation strategic planning: endangerment criterion; the criterion of representativeness and the scientific criterion. The following „target" tree species were selected: *Quercus pubescens, Quercus frainetto, Quercus robur, Quercus petraea*, and *Quercus cerris*. Due to the presence of a large number of older trees of coppice origin and reduced vitality, very weak natural rejuvenation and anthropogenic pressure, indigenous oaks in this area can be considered endangered or vulnerable species. In addition to autochthonous oaks, the „target" species also include forest fruit trees (species at risk in Serbia): *Prunus avium, Pyrus pyraster, Sorbus domestica*, and *Sorbus torminalis*. To conserve the available gene pool in situ, it is proposed to treat the entire „Košutnjak Forest" as one conservation area, with five conservation units. *Ex situ* conservation of the „target" species gene pool began with the establishment of progeny tests. A plan of activities by priorities has been defined, including conservation of „target" species gene pool; strengthening the capacity of managers; raising public awareness and disseminating information on the importance of forest genetic resources, their sustainable use and management in „Košutnjak Forest".

Key words: forest genetic resources, autochthonous oaks, forest fruit trees

Acknowledgements: This research was supported by the Secretariat for Environmental Protection of the City of Belgrade, project: *Identification and monitoring of the gene pool of rare, vulnerable and endangered plant species in NM „Kosutnjak Forest*" and Ministry of Education, Science and Technological Development of the Republic of Serbia according to the agreement number 451-03-9/2022-14/ 200169.

УНИВЕРЗИТЕТ У БАЊОЈ ЛУЦИ
ШУМАРСКИ ФАКУЛТЕТ
FACULTY OF FORESTRY
UNIVERSITY OF BANJA LUKA

THEMATIC AREA 4
A modern and competitive forestry sector

TEMATSKA OBLAST 4
Moderan i konkurentan sektor šumarstva

FORS²D
ŠUMARSKA NAUKA ZA ODRŽIVI RAZVOJ

POTENTIALS OF FAST-GROWING FOREST PLANTATIONS IN BOSNIA AND HERZEGOVINA FOR CO_2 SEQUESTRATION AND WOOD ASSORTMENTS PRODUCTION

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ABSTRACT

Fast-growing forest plantations in Bosnia and Herzegovina cover below 0,1% of the total area of the country, while the absence of strategic approach and financial framework for investment in fast-growing forest plantation is evident. Plantation production of tree species may provide multiple economic and social benefits such as using the abandoned agricultural land, along with the provision of ecosystem services ranging from preventing erosion, improving water quality, flood protection, as well as serve as an important source of the forest products (roundwood, fibre, fuelwood and non-wood forest products), representing a great CO_2 sink as well. All these benefits can have a positive impact to rural development as well as for creating new ''green'' jobs, while carbon credits generated from carbon sequestration projects have the potential to make a difference to the profitability and other economic aspects of plantation forestry. The main goal of this research is to identify potential areas for the establishment of forest plantations (with a focus on fast-growing tree species along rivers) in Bosnia and Herzegovina, together with economic analysis of the main products (fuelwood, pulpwood and industrial wood) and estimation of the CO_2 mitigation potential and carbon credits generation. Suitable locations were identified after geospatial analysis of relevant raster and vector datasets, i.e. digital elevation model, soil map, hydrological network, mine fields map, road network, the map of forested areas, the map of urban areas, the map of protected areas, etc. CO_2 mitigation potential was estimated using the FAO ExAct v.9 tool, while dinamic methods for investment analysis were used for the economic analysis. The results indicate that there are significant areas for establishment of forest plantations, especially in the northern part of Bosnia and Herzegovina, suggesting that the initiation of carbon projects for generating of carbon credits can be considered as a financially sustainable investment.

Key words: fast-growing forest plantations, ''green'' jobs, carbon credits, wood assortments, carbon projects, economic analysis

VARIABILITY IN TRACHEID LENGTH OF *PSEUDOSTSUGA MENZIESII* (MIRB.) FRANCO WOOD FROM THREE SITES IN CROATIA

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ABSTRACT

Anatomical properties of Douglas-fir *Pseudostsuga menziesii* (Mirb.) Franco wood have not been previously investigated in Croatia. Bearing in mind it is one of the most important timber species in the world and being highly adaptable, preliminary research on tracheid length of *Pseudostsuga menziesii* (Mirb.) Franco wood from three sites in Croatia was conducted. For the purpose of this research, three trees of *P. menziesii* were selected and harvested from each of three sites in Croatia. Maceration procedure was applied and tracheid length (mm) was measured within earlywood and latewood of selected growth rings. Significant radial variation in tracheid length in wood from three sites was determined. As well, differences in tracheid length between earlywood and latewood, as well as between individual trees from each site and between sites were determined. For better understanding of *P. menziesii* wood quality, additional research on wood anatomical, physical and mechanical properties is needed.

Key words: *Pseudostsuga menziesii* (Mirb.) Franco, tracheid length, wood variability, intra-population variability, within tree variability

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THE ROLE OF THE MACROECONOMIC ENVIRONMENT IN THE BUSINESS ACTIVITY OF WOOD INDUSTRY COMPANIES IN THE SOUTH BAČKA DISTRICT

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ABSTRACT

The business environment of a company includes the relationships on which the company builds its business on the market, which affects the effectiveness of a company through several factors. The task of a company within the forestry business is to ensure the continuity of its business by aligning the expectations of stakeholders with real business results, operating under the influence of a large number of external and internal factors. The subject of the paper was 10 companies within the wood processing industry in the territory of the District of South Bačka. PEST analysis was used as the basic research method. It refers to the assessment of political, economic, social and technological factors that represent the business environment of the company. The survey was used as a research technique and included an evaluation of the impact of these factors on the business of the analyzed companies. This paper aims to assess the factors in which companies operate within the wood industry of the District of South Bačka. The purpose of this paper is to form practically applicable conclusions about the functioning of the wood industry within the analyzed area. The largest problem observed in the research, which is related to political factors, is the insufficient support of the state to the forestry sector.

Key words: PEST, the District of South Bačka, wood-processing industry

PERFORMANCE OF LKT 81T SKIDDER AND ITS SUITABILITY TO THE CURRENT FOREST HARVESTING TRENDS

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ABSTRACT

Forestry in BiH is characterized by a hilly and mountainous terrain, with ground obstacles, various climate conditions and selection managed stands. All those are limiting factors for introducing of state of the art technologies in forestry. Forest harvesting is still based on motor-manual felling and using of skidders for timber extraction. Operational sector in PFC "Šume Republike Srpske" uses only LKT 81T skidders, as well as many private companies. These skidders have relatively older construction, although they have been modernized several times. The goal of this research was to analyze its suitability for current use, where there is a pressure for increased productivity, cost competitiveness and environmental soundness of forest operations. This research analyses the performance of LKT 81T skidders in different stands, terrain conditions, and different harvesting methods. The research was done in Forest Administration (FA) "Banja Luka" (28 working cycles, assortment method), FA "Ribnik" (68 working cycles, assortment method; 45 working cycles half-tree length method) and FA "Vrbanja" (29 working cycles, half-tree length method). Time and work study method was used, followed by appropriate statistical analysis. Productivity and other working characteristics were compared with other, more modern skidders in comparable conditions. Results showed that with obtained productivity from 42,29 m^3/day to 83,64 m^3/day LKT 81T is still competitive in some aspects, but in other, more modern skidders should be used.

Key words: extraction, skidding, productivity, suitability

THE CONCEPT OF INTRAPRENEURSHIP: HISTORICAL PERSPECTIVE AND POSSIBLE APPLICATION IN THE FORESTRY SECTOR

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ABSTRACT

The concept of intrapreneurship arose from the study of forestry based on the attitude that forests need to be managed by planned utilization and reforestation. It originates from the beginning of XIXth centure. Intrapreneurship is based on commitment to public goods, nature and disagreement with the concentration of wealth and power. Intrapreneurship also implies creativity and innovations. Given that the forestry sector is considered traditional and mature which can be an obstacle to creativity and innovation, it is justified to analyze the possibility for application of intrapreneurship in the forestry sector. In this paper, a bibliometric analysis was performed as rigorous method for exploring and analyzing large volumes of scientific data. It has been determined that the original historical perspective on which intrapreneurship is based is applicable in forestry sector. Intrapreneurship can be applied within established organizations of any size. It implies State-Owned Forest Enterprises, Public Enterprises and Small and Medium-sized Enterprises. Adequate intrapreneurial climate is conditioned with mutual correlations and influence of organizational elements like: managerial support, work autonomy, professional training, business environment and rewarding system. The application of the intrapreneurial concept in forestry sector can contribute to the introduction of innovations. Such innovation derived from intrapreneurial orientation in sector of forestry could be different from generally accepted role of innovations. Generally accepted roles of innovation force technological changes as proxy for reduction of workforce, concentration of capital and it is suitable for a highly educated staff. New approach to the innovativeness derived from intrapreneurship in forestry sector encouraging technological development that complements rather than replaces the work skills of the existing workforce.

Key words: entrepreneurship, creativity, inovativnost, organizational climate

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INTEGRATION OF EU TIMBER REGULATION REQUIREMENTS INTO FOREST POLICY IN MONTENEGRO AND THE REPUBLIC OF SRPSKA (BOSNIA AND HERZEGOVINA)

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ABSTRACT

Western Balkan is regarded as a priority area for improving forest legality monitoring systems in line with the European Union Timber Regulation (EUTR). Yet, research on EUTR implementation in Western Balkan countries is still quite limited. Our study aims to contribute to the understanding of the integration of EUTR requirements in Western Balkan, by analyzing the forest policy frameworks of Montenegro and the Republic of Srpska, using qualitative content analysis. To this aim, documents were coded using coding categories derived from EUTR. To verify our findings, we conducted key expert interviews in both countries and analyzed them using NVivo software. Our results point out that both countries have well-developed policy frameworks addressing illegal logging and the prevention of illegal activities in forestry, especially through dedicated action plans. Key actors in both countries are public actors, including Ministries responsible for forestry, public forest enterprises, and forestry inspectorates. The forestry sector in Montenegro is facing significant changes due to the termination of concessions, and new organization of management of state forests, including forest certification. Preliminary research indicates that the Republic of Srpska, has relatively well-established bodies for implementation, but, in certain situations, insufficient exchange of information. With ongoing discourses on Green Deal policies and the increasing focus on "deforestation-free" commodities, stricter implementation of EUTR at the European level might be expected. We conclude that both countries would have to build capacities for EUTR implementation and become more transparent and responsible concerning information availability. In addition, to successfully implement EUTR increased number of checks, as well as stricter fines will be needed in both countries.

Key words: policy analysis, the legality of timber, EUTR

Acknowledgments: Research on Montenegro, as well as policy analysis for the Republic of Srpska, was funded by the CARIPARO Foundation Ph.D. scholarship (University of Padova) for the Ph.D. research tentatively titled "Global Trade Flows and Forest Sector: Focus on Western Balkan countries". Data collection and interpretation of the data on the Republic of Srpska are courtesy of the University of Banja Luka. We are greatly thankful to our key informants, as well as all other participants in this research.

COMPARATIVE ANALYSIS OF VALUES OF THE DYNAMIC DEFORMATION MODULUS OF THE PAVEMENT CONSTRUCTION OF FOREST ROADS MEASURED BY LIGHT DEFLECTOMETERS ZORN ZFG 3.0 GPS AND TERRATEST 5000BT

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ABSTRACT

The control of achieved compaction of bulk materials in the layers of the pavement structure and subgrade of forest roads is performed during the execution of work and acceptance of works, then during exploatation or testing for reinforcement or reconstruction. The practice of testing the degree of compaction has been present in civil engineering construction for a long time, but not common during the construction of forest roads in Serbia so far. In recent years, the dynamic procedure of deflection testing has become increasingly important, primarily due to the speed and simplicity of measurement. In this paper, the analysis of the obtained results of comparative measurements of the dynamic modulus of deformation (Evd) on the forest road pavement, with light deflectometers Zorn ZFG 3.0 GPS and Terratest 5000 BT, was performed. The pavement structure of the forest road was built of natural unseparated river gravel in a layer thickness of 0.35 m, on the IV construction soil category.

Key words: forest road, pavement structure, dynamic module of deformation, Evd, light deflectometer

REMOTE MONITORING OF SKIDDER ECOTRAC 140V AS A TOOL FOR COLLECTING MEASUREMENT DATA FOR SCIENTIFIC PURPOSES

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ABSTRACT

The Fleet Manager System (FMS) is a system of remote monitoring and control of the vehicle operation, which enables gathering of data without disturbing the vehicle operation, i.e. it provides the possibility to research in almost uncontrollable exploitation conditions. FMS enables the recording of certain parameters on the vehicle and the wireless sending of recorded data via GPRS or SMS via the control center to the end user. The end user has an insight into the parameters of the vehicle by connecting to the Internet via a computer or mobile phone.

Previous research on the technical characteristics of forest vehicles has been conducted in controlled conditions, and the collection of data from vehicles has been carried out by wired data transmission or data transmission by radio. As most forest vehicles are recently equipped with FMS, the aim of the research is the usability of the commercial vehicle remote monitoring system for the purpose of scientific research with upgrades with additional measuring transducers.

The paper presents a method for measuring the technical characteristics of the Ecotrac 140V skidder when working in real conditions with remote transmission of measurement data. By connecting the CANBUS to the vehicle computer, data on fuel consumption, position and direction of the skidder, winch activity, engine rotational speed, drive engine torque and throttle pedal position were collected and processed.

The results indicate that the FMS with adjustments is considered a favorable tool for remote monitoring of some operational characteristics of vehicles in uncontrolled conditions for scientific research.

Key words: Fleet management system, skidder, data transmission, remote monitoring

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ANALYSIS OF TECHNOLOGIES AND TECHNOLOGICAL PROCESS OF FOREST HARVESTING IN THE SARAJEVO CANTON

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ABSTRACT

This paper shows an analysis of technology and technological process of forest harvesting in the Sarajevo Canton. The analysis is based on data from the Cantonal Enterprise "Sarajevo-šume" Ltd Sarajevo, which is managing state-owned forests and forest lands in the Sarajevo Canton. In this paper the data from subcontractors who provide services to enterprise in the process of forest harvesting were also analyzed. It was determined how much works in the process of forest harvesting in the Sarajevo Canton enterprise realizes by it's own capacity, and how much by private subcontractors. Analysis showed that enterprise by it's own capacities realized 72% of works in the phase of felling and processing of forest wood assortments, and subcontractors realized 28% of works. After processing of data from questionnaires it was found that the enterprise owns 69 chainsaws, and subcontractors 40. In the phase of wood skidding enterprise by it's own capacities realizes 74% of work, until subcontractors in this phase realize 26% of works. Enterprise in it's ownership has 19 tractor, while private subcontractors dispose with 14. In the phase of wood transport, customers on it's own perform the loading and transport of wood in 100% cases. Enterprise does not perform service of wood transport. In this paper injuries during forest harvesting also were presented. Work organization and number of employees were cited.

Key words: felling and processing, skidding, wood transport, Cantonal Enterprise "Sarajevo-šume" Ltd Sarajevo, private subcontractors

SMALL AND MEDIUM ENTERPRISES IN FORESTRY AND WOOD INDUSTRY: ORGANIZATION OF BUSINESS PROCESSES IN SELECTED FOREST MANAGEMENT REGIONS IN THE REPUBLIC OF SRPSKA

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ABSTRACT

Within the Vlaseničko, Milićko, Han Pijesačko and Romanijsko forest management regions (FMRs), a key factor in timber harvesting are contractors for forest services. Wood-processing enterprises are the largest buyers of wood assortments and, at the same time, the largest sellers of final and other wood products in the observed FMRs. The research aims to inquire into the attitudes of the respondents towards the organisation of business processes within the contractors for forestry services and wood-industry enterprises in the selected FMRs, as well as regarding the opportunities for their improvement. Primary data were collected in 2 phases. In the 1st phase, 30 representatives of contractors for forestry services and wood-industry enterprises were surveyed. Interviews with 6 representatives of *leading enterprises* (2 representatives of the contractors for forestry services and 4 wood-industry enterprises) were conducted in the 2nd phase. The contractors for forestry services are engaged through a tendering procedure (public procurement) published by the Public Forest Enterprise "*Forests of the Republic of Srpska*" JSC, Sokolac. All respondents stated that they possess chainsaws and tractors, and only 17% used forwarders and bulldozers in their work. Business entities from the wood industry are most often engaged in the production of coniferous sawn timber. Raw materials are mostly (71%) procured from the state-owned forests. The majority of respondents (62%) stated that they sell their products on foreign markets. Possibilities for improving the business processes of the contractors for forestry services and the wood industry enterprises within the observed FMRs include: education of the workforce, renewal of obsolete mechanization; creating a database to facilitate the analysis of their business, etc.

Key words: organisation, business processes, small and medium enterprises, forestry, Republic of Srpska

USE OF NON-INVASIVE METHODS IN THE TREE RISK ASSESSMENT AT THE PROTECTED AREA "UNIVERSITY CITY"

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ABSTRACT

The paper presents the results of the tree risk assessment of 12 mature trees at the "University City". The assessment was conducted using methods of visual tree assesment and non-invasive acustic tomography. The research was carried out in the protected area "Park Architecture Monument University City" in Banja Luka. A field investigation included semple of 12 deciduous trees, as follows: silver linden (*Tilia tomentosa* Moench) – seven trees, narrow leaved ash (*Fraxinus angustifolia* Vahl.) – two trees and a single tree of english oak (*Quercus robur* L), norway maple (*Acer platanoides* L.) and japanese pagoda tree (*Styphnolobium japonicum* (L.) Schott). Each tree poses risk to site users and properties due to its age, frequent occupancy rate and noted tree defects.

A starting point of the research was visual tree assessemnt where a detailed inspection of crown and branches, trunk, roots and root collar of each tree was carried out in accordance with the method of visual tree assessment ('VTA') developed by Mattheck and Breloer (1994). The results obtained by visual tree assessment are recorded into field tree risk assessment form. To examine the trees by acustic tomography the ARBOTOM (Version 5, Rinntech, Germany), an impulse tomograph developed for assessment of the interior state of trees was used. Acustic tomographic images exported from the Arbotom confirmed the presence of internal defects at 11 trees and it ranges from 0,5% at one silver linden tree up to 67% at japanese pagoda tree of damaged wood across circumference of measured cross section.

Key words: tree defects, VTA, acustic tomography

Acknowledgements: This research was supported through the project "Analysis of the health status and safety risk of trees in the protected area "University City" by the method of acoustic tomography with a proposal for sanation measures" funded by the Ministry of Scientific and Technological Development, Higher Education and Information Society, contract number: 19.032/961-125/19.

ANALYSIS OF QUALITY OF PRIMARY FOREST ACCESSIBILITY

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ABSTRACT

A quality of primary forest accessibility can be the best represented by primary forest relative accessibility The accessible forest area by primary forest traffic infrastructure is determined by bounded area around primary forest traffic infrastructure whose width depends on relief and slope of terrain. Today, in the area with steep and variable slope of terrain for width of bounded area around primary forest traffic infrastructure is used targeted geometrical extraction distance of timber, and in the area with mild and uniform slope of terrain is used width of area that make accessible primary forest traffic infrastructure. Both parameters depend on targeted density of primary forest traffic infrastructure. The GIS enables determination of accessible forest area and also insufficient accessible areas inside of forest area. Spatial distribution of insufficient accessible areas is the significant for spatial distribution of the new routes of primary forest traffic infrastructure. The research is done into area of MU Prosara. The base of planning of primary forest traffic infrastructure is targeted density of primary forest traffic infrastructure which is 21 m/ha and based on it, it was calculated targeted geometrical extraction distance (225 m) and width of forest area that make accessible by primary forest traffic infrastructure (476,19 m). They were used as the width of bounded area around primary forest traffic infrastructure. On that occasion, it was determined that grade of primary relative forest accessibility is poor (from 29 to 31%) in the both case. However, the differences between percent of accessible forest area by primary forest traffic infrastructure have arisen because for calculation of targeted geometrical extraction distance was used factor of reduction of real targeted extraction distance to geometrical. It is reason because of these two parameters should be used for different terrain conditions of some forest area.

Key words: relative forest accessibility, primary forest traffic infrastructure, GIS, DTM

УНИВЕРЗИТЕТ У БАЊОЈ ЛУЦИ
ШУМАРСКИ ФАКУЛТЕТ
FACULTY OF FORESTRY
UNIVERSITY OF BANJA LUKA

THEMATIC AREA 5
Innovative value chains and sociological aspects in forestry and related sectors

TEMATSKA OBLAST 5
Inovativni lanci vrijednosti i sociološki aspekti u šumarstvu i povezanim sektorima

CURRENT STATUS OF WILD BOAR (*SUS SCROFA* L.) IN THE REPUBLIC OF SRPSKA

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ABSTRACT

Wild boar is one of the most widespread and most attractive hunting species in the hunting grounds of the Republic of Srpska. According to the current Law on Hunting ("Official Gazette of RS", No. 60/09) it is in the group of unprotected species of game, but a bylaw ("Official Gazette of RS", No. 43/21) stipulates that females and piglets are hunted from July 1 to January 15. This paper analyzes the dynamics of the number and the rate of use of wild boar populations in the period 2016-2020. We used available data of the Ministry of Agriculture, Forestry and Water Management (www.vladars.net) and Institute of Statistics of the Republic of Srpska (Bulletin Forestry, www.rzs.rs.ba).

The area occupied by wild boar is about 833,000 ha, which is 33.8% of the total hunting area in the Republic of Srpska, more precisely 89 hunting grounds or 90%. Official data indicate that its estimated population in the spring of 2020 was 8,330 individuals, or 96.2% of the estimated optimal number for the territory of the Republic of Srpska. The largest number of individuals was found in sports and recreational hunting grounds managed by hunting associations (6,875 individuals or 82.5%). During the period 2016-2020, the rate of use of wild boar populations ranged from 21.2-28.3% of the estimated spring count. While the total planned harvesting is 20,060 individuals, its realization is about 50% (10,128 individuals). It can be concluded that the management of wild boar should be improved, especially the realization of the planned harvesting.

Key words: management, population, hunting ground, harvest

VIEWS ON WOMEN IN THE FORESTRY SECTOR IN SERBIA: FEMALE FORESTRY STUDENTS', FOREST PROFESSIONALS' AND FOREST OWNERS' ATTITUDES

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ABSTRACT

Women are an important human resource since they bring in different perspectives and contribute to efficient solutions in the forestry sector. The aim of this research is twofold: 1) to investigate motivation to choose a career in the forestry sector and 2) to identify the training needs and interests of female forestry students and forest professionals. A mixed-methods approach was applied in this research. Quantitative data were collected in the period March-May 2021 by online surveys with 32 female forestry students and 64 female forest professionals and private forest owners. Qualitative data were collected in June 2021 by structured interviews with 4 private forest owners and 9 forest professionals. The most important factors that motivated them to work in the forestry sector are interesting and varied work; "*I like to be in the forest*", meaningful work in nature or resource management; meaningful work that fulfills a social and sustainable purpose; friendly working environment. Both groups of respondents have similar training interests. Most are interested in training related to nature conservation and forest protection. Other interesting topics are forest adaptation to climate change (among female forest professionals and forest owners) and silviculture and forest maintenance (among female students). Most students (81.3%) and forest professionals (64.1%) would participate in a mentoring program for women in forestry. Interviewees believe that both genders can be placed in any job in forestry. Nevertheless, women more often focus on ecology, nature conservation, or work in nurseries, etc., because some other aspects of forestry require hard physical work. However, they highlighted that continuous education is necessary to strengthen the position of women in the forestry sector.

Key words: women in forestry; forestry career; training needs

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THE INFLUENCE OF ACETIC ACID PRETREATMENT ON THE CHEMICAL COMPOSITION OF THE NARROW LEAVED ASH WOOD

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ABSTRACT

The introduction of chemical pretreatments may improve digestibility and rationalize the use of chemical constituents of wood. The pretreatments are known to change the chemical and other properties of wood, and its final effects depends both on applied reagents (oxidants, alkalis, acids) and treatment conditions (chemical concentration, temperature, duration of treatment).

The main goal of this research was to evaluate the influence of acetic acid pretreatment on the chemical composition of Narrow leaved Ash. The pretreatments of wood particles (0.5 - 1 mm) were performed in autoclaves, at the temperature of 100 °C, during 60 minutes. The acetic acid solutions had three different concentrations: 3% (KT3), 6% (KT6) and 9% (KT9) based on oven dry wood weight. After the treatment there was a reduction in wood mass of: 6.09% (KT3), 5.92% (KT6) and 4.99% (KT9).

The acetic acid treatments have decreased the content of extraneous components for 46-54% (dissolved in toluene/ethanol mixture) and 76-85% (dissolved in hot water), and the mineral content decreased for 77-81%. Lignin content decreased slightly (0.7-2.3%), while the cellulose content slightly increased (1-2%). However, when calculating for the mass loss, the cellulose was slightly decomposed during the treatment. The noticed increase in cellulose content is due to the loss of extraneous materials and the change in mass ratios of wood constituents. FTIR spectra confirmed no significant changes in the ratio of structural constituents of wood after the treatments. The concentration of acetic acid did not significantly affect the chemical composition of treated samples.

Key words: pretreatment, acetic acid, chemical properties, Narrow leaved Ash

THE INFLUENCE OF PARTICLEBOARD DENSITY AND DEPTH OF THE PREBORED HOLES ON THE RESISTANCE TO AXIAL WITHDRAWAL OF SCREWS

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ABSTRACT

The aim of this work was to evaluate the resistance to axial withdrawal of screws from the edge of the particleboards samples in regard to the different prebored hole depths, and in regard to the change in particleboard density and especially the density of the middle layer. The parallel shank screws were used having nominal diameter of 4 mm and thread pitch of 2 mm.

As expected, statistical comparison between the general density of particleboard and the density of its middle layer has shown "strong" correlation (r = 0.7827).

The results for the screw withdrawal resistance showed no significant difference in regard to the in-plane direction (longitudinal and perpendicular). The correlation between the screw withdrawal resistance and the particleboard density was more pronounced in the case of longer prebored depths (25 and 30 mm), then for the shallower insertion of screws (15 and 20 mm).

Regression analysis showed very strong linear dependence between the screw withdrawal resistance and the prebored depth.

Key words: particleboards, density, wood screws, withdrawal resistance, hole depth

TRANSVERSE STRESS WAVE VELOCITY IN NORTHERN RED OAK TREE: ASSESSMENT OF THE WOOD QUALITY

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ABSTRACT

In this paper, the transverse wave velocity was investigated, as well as the possibility of assessing the quality of wood in northern red oak trees using the velocities of transverse stress waves. Stress wave velocity was recorded using a 2D acoustic tomograph with appropriate sensors and equipment. The recordings were made on a total of 18 sections on 9 trees from three northern red oak sites in Serbia. Based on the obtained results, it was concluded that the orientation of the annual ring in regard to the direction of sound propagation affects its speed. It was determined that the average stress wave velocity at the cross-sections is 1660 (1159-2350) m/s. However, it is higher in the tangential direction compared to the radial one. The relative difference between the reference and the measured speed was used to assess the quality of the wood. This relative difference indicates the amount of decay between the two sensors. The largest number of cross-sections had a speed loss of up to 10%, but there were also cross-sections with a speed loss of more than 30% in the radial direction. This result shows us that there are defects and damages in this direction that will reduce the strength of the wood, and thus narrow the field of use of wood from this part of the tree.

Key words: red oak, acoustic tomography, stress wave, assessment, transverse section

ANTIMICROBIAL ACTIVITY, TOTAL PHENOLIC AND FLAVONOID CONTENT OF METHANOL EXTRACTS FROM *PINUS HELDREICHII* CHRIST.

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ABSTRACT

Pinus heldreichii Christ. (Bosnian Pine) is a subendemic and relict high-mountain pine naturally occurring in the Balkan Peninsula and the southern Italy. The present study investigates antimicrobial activity, total phenolic and flavonoid content in leaves, bark, and wood methanolic extracts of *Pinus heldreichii*. Agar well diffusion method was used to evaluate the antimicrobial activity of plant extracts. Activity of extracts was tested against Gram-positive: *Enterococcus faecalis* ATCC®TM 19433, *Staphylococcus aureus* subsp. *aureus* ATCC® 6538TM, *Staphylococcus epidermidis* ATCC® 12228TM, *Bacillus subtilis* subsp. *spizizenii* ATCC® 6633TM and Gram-negative bacteria *Escherichia coli* ATCC® 8739TM and the yeast *Candida albicans* ATCC® 10231TM. Ampicillin was used as positive control for bacterial strains and nystatin for Candida albicans. Methanol was used as negative control. All tested extracts were highly efficient against tested microorganisms except against *E. coli*. Bark extracts exhibited strong antibacterial activity against *Enterococcus faecalis, Staphylococcus aureus, Staphylococcus epidermidis, Bacillus subtilis* and the yeast *Candida albicans* with similar efficiency as used control antibiotic. According to our research leaves, bark, and wood extracts of *Pinus heldrechii* were extremely rich in phenolic compounds. The highest total phenols concentration of 184.46 mg / gDW was recorded for the bark. Furthermore, leaves had the highest content of flavonoids, while slightly smaller concentration was recorded in wood and bark extracts. In conclusion, this study confirms bioactive and antimicrobial potential of this pine species.

Key words: Bosnian Pine, plant extracts, polyphenolics, bioactive properties

POLYPHENOLICS CONTENT AND ANTIMICROBIAL ACTIVITIES OF *PICEA ABIES* (L.) KARST. EXTRACTS

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ABSTRACT

Among the coniferous species, Norway spruce (*Picea abies* (L.) Karst.) is one of the most important trees in Europe with economic and ecosystem values and long use in traditional medicines. Different plant parts of this species (developing shoots, i.e., sprouts, and older needles) have traditionally been used for medicinal purposes due to the high content of vitamins and antioxidants. The objective of this study was to determine total phenolic and flavonoid contents and antimicrobial activities of leaves, bark and wood methanol extracts of *Picea abies*. The antimicrobial activity was performed by disc diffusion assay against five reference bacterial strains including Gram-negative and Gram-positive bacteria and one fungal strain. Extract of *Picea abies* bark contained the highest concentration of total phenolics (184.46±1.72 mg GAE/g), while extract of leaves had the highest concentration of flavonoids (8.75±0.71 mg CE/g). The methanol extract exhibited considerable inhibitory activity against the tested microbial strains. The largest diameters of inhibition zone (21 mm) were recorded against *Staphylococcus aureus* using bark extracts. These findings show that the spruce bark might be an important source of bioactive compounds that may lead to new natural products with important therapeutic uses.

Key words: Norway spruce, flavonoids, phenolics, bioactive compounds

NORWAY SPRUCE; FLAVONOIDS; PHENOLICS, BIOACTIVE COMPOUNDS

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ABSTRACT

Essential oils of lavender (*Lavandula angustifolia* Mill.) and thyme (*Thymus serphyllum* L.) at different concentrations (0, 10, 20 and 30 µg/mL) were tested against mint (*Mentha spicata* L.), lemon balm (*Melissa officinalis* L.), tomato (*Lycopersicon esculentum* Mill.), cucumber (*Cucumis sativus* L.) and acacia (*Robinia pseudoacacia* L.). Seeds were germinated at 25°C in petridishes containing three layers of filter papers soaked with distilled water or a given essential oil in particular concentration. Experiments were carried out in four replicatess. Both essential oils exhibited a dose-dependent inhibition activity against the seed germination and seedling growth of *Lycopersicon esculentum* and *Robinia pseudoacacia*, and less inhibitory action on *Mentha spicata*. On the other hand, *Melissa officinalis* was the most resistant to the tested essential oils. Seedling growth studies showed that both essential oils had a significant effect on the growth of all test species at the highest tested concentration (30 µg/mL).

Key words: allelopathy, essential oils, seed germination, seedling growth

ESSENTIAL OILS CONTENT, COMPOSITION AND ANTIOXIDANT ACTIVITY OF LEMON BALM (*MELISSA OFFICINALIS* L.) FROM SERBIA

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ABSTRACT

The present study aimed to determine whether light modification (plants grown under pearl shade nets with a 40% shaded index or in an un-shaded open field) could improve the quantity and quality as well as the antioxidant activity of lemon balm (*Melissa officinalis* L.) essential oils (EOs).

The EOs were isolated by Clevenger-type hydrodistillation and their antioxidant potential was estimated by using the DPPH assay. Their qualitative and quantitive composition were determined by GC/MS and GC/FID analyses. The yields of EOs after 120 min of hydrodistillation were 0.44 mL/100 g and 0.57 mL/100 g for un-shaded and shaded plant material, respectively. The main components of the lemon balm EOs were geranial (34.0% and 32.8%); neral (21.3% and 24.9%) and piperitenone oxide (17.2% and 16.7%) for un-shaded and shaded plant material, respectively. The essential oil obtained from the aerial parts of lemon balm grown under shading field condition has shown better antioxidant activity in comparison to the one obtained from the plant grown in an un-shaded field (EC50 values of 3.43±0.010 mg/mL vs. 12.85±0.199, respectively). Our data show that shade nets could be incorporated into the protected cultivation practices currently used for producing lemon balm. Plants grown in full sunlight field not just showed lower essential oil yield but also lower antioxidant activity. It is evident that the modification of light intensity can act as a physiological tool via shade nets to improve the phytochemical quality and antioxidant activity of plants. This plant species tolerates shading well, so it is recommended to grow them under shading nets.

Key words: Lemon balm, *Melissa offcinalis* L., Essential oil, Antioxidant activity

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STUDY OF THE ANTIBACTERIAL ACTIVITY OF *ALLIUM URSINUM* L. ON APATOGENIC BACTERIA

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ABSTRACT

Allium ursinum L. is populary known as sremush, crijemush, wild or bear onion. It is used in the diet as a vegetable (salad and spice) and in human medicine as an aid. Resistance of bacteria to antimicrobial substances (antibiotics and chemotherapeutics) is one of the most significant problems in public health. The problem of antimicrobial resistance is related to pathogenic bacteria and zoonotic agents, but this resistance also burdens apathogenic bacteria that transmit resistance genes through the food chain.

The aim of this study was to examine the antimicrobial activity of *Allium ursinum* L. on the growth of apathogenic bacteria isolated from food of animal origin and determine the type of action on the tested isolates. The plant material used in this paper is a fresh leaf of *Allium ursinum* L. harvested on the slopes of the Kruševo Brdo mountain, Kotor Varoš municipality, Republic of Srpska, Bosnia and Herzegovina. Sremush leaves were chopped, sunflower oil was added and a thick mass of sremush was diluted with distilled water in a ratio of sremush:water 80:20% v/v. The agar diffusion method was used to examine the antibacterial activity. Antibacterial activity was tested on 10 bacterial coagulase strains of negative staphylococci isolated from food of animal origin, from the collection of the Laboratory for Microbiology of food, feed and water of the Public Institution Veterinary Institute of Republic of Srpska "Dr Vaso Butozan" Banja Luka.

The results of the analysis indicate good inhibitory properties of *Allium ursinum* L. on 8 out of 10 tested apathogenic bacteria with an inhibition zone from 9.67 mm to 45.00 mm. Bactericidal activity was confirmed in four isolates, and bacteriostatic in two isolates. Given that the contribution of apathogenic microphlores from food of animal origin in the transmission of antimicrobial resistance through the food chain is not fully known, that the results indicate that *Allium ursinum* L. has good antibacterial properties, future studies should focus on more bacteria.

Key words: *Allium ursinum* L., antibacterial activity, resistance

VIBURNUM OPULUS L. LEAVES - PROMISING SOURCE OF PHENOLIC COMPOUNDS, MACRO- AND MICROELEMENTS

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ABSTRACT

Viburnum opulus L. is primarily known through its various cultivars. The most common is 'Compactum'. European Cranberrybush has showy creamy-white inflorescences in spring, red berries throughout autumn, and bold texture with raisin-like fruits in winter. The genus *Viburnum* is known to contain triterpenoids, diterpenoids, sesquiterpenes, iridoids, and polyphenols, therefore the biological activities of *Viburnum opulus* L. could be attributed to these compounds. The objective of this study was to determine phenolic compounds, macro- and microelements in the ethanolic *Viburnum opulus* L. leaf extract. In order to evaluate this plant material as promising plant material, the composition of the extract was determined by UHPLC-MS method, while the content of macro- and microelements was analyzed by ICP-OES technique.

Plant material was harvested during the flowering period (June), in the forest area below the Ostrozub mountain (Zeleničje, Nature Reserve, Serbia). Air-dried leaves of *Viburnum opulus* L. was used for obtaining the ethanolic extract by maceration.

Analysis of the extract using the UHPLC-MS method proved the presence of 22 components of which 10 components were identified (quercetin diglycoside, chlorogenic acid, routine, quercetin-3-O-glucoside, kaempferol-3-O-rhamnosyl galactoside, kaempferol-glucoside, dicaffeoylquinic acid (two isomers), pheophorbide b, methoxy derivative of pheophorbide b).

Ten elements were identified in the ethanolic *Viburnum opulus* L. leaf extract (Bi, Ca, Cu, Fe, In, K, Mg, Na, Pb, Zn). The results show that the extract contain a high content of potassium, sodium, magnesium and calcium, while other elements are present in smaller quantities. Based on the obtained results, it can be concluded that ethanolic *Viburnum opulus* L. leaf extract is a potential source of phenolic components and minerals.

Key words: *Viburnum opulus* L. leaves, Phenolic compounds, Macro-and microelements

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THE HARDNESS OF SERBIAN SPRUCE WOOD

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ABSTRACT

The aim of this paper is to evaluate the hardness of Serbian spruce wood in the axial, radial and tangential directions and its dependence on wood density. Hardness is a crucial mechanical propriety of wood and it positively correlates with density. In addition, it depends on the anatomical direction and can vary by up to 50% within the same species.

The test samples were taken from nine trees from natural stands and six trees from plantations in the Republic of Srpska. The hardness of the wood was tested by the Brinell method on 375 test samples. For trees from plantations, the determined average value of transverse hardness is 32.57 MPa, and for trees from natural stands it is 41.42 MPa. The average value of wood hardness in the radial direction for trees from plantations is 15.20 MPa, and for trees from natural stands is 17.08 MPa. The hardness of wood in the tangential direction for trees from plantations is 14.41 MPa, and for trees from natural stands 17.47 MPa. Regression analysis showed that there is a correlation between the hardness and the density of Serbian spruce wood, and it is strong when it comes to the correlation between wood density and hardness in the axial and tangential directions and the average correlation between wood density and hardness in the radial direction.

Key words: *Picea omorika*, plantations, natural stands, Republic of Srpska

THE INFLUENCE OF THE EXTRACION TECHNIQUE ON THE YIELD, COMPOSITION AND ANTIOXIDANT ACTIVITY OF THE ETHANOLIC EXTRACTS FROM GUELDER-ROSE LEAVES (*VIBURNUM OPULUS* L.)

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ABSTRACT

The genus *Viburnum* L. (Caprifoliaceae) is represented with 4 deciduous shrubs species in Turkey. Guelder-rose (*Viburnum opulus* L.) is grown as ornamental plant in many countries and the dried fruits consisting of phenolic glucosides, tannins and some organic acids were used for complaints of uterine cramps, colicky pains in pelvic organs. Previous phytochemical studies on *V. opulus* have shown the presence of different natural compounds including iridoids, iridoid glucosides, lantanoside, flavonoids, saponins, tannins, arbutin, ursolic acid, flavones and anthocyanins.

The goal of this study was to compare two extraction techniques for obtaining the yields of the extractive matter, total phenolics and flavonoids content of guelder-rose leaves as well as to determine the antioxidant activity of obtained extracts. Air-dried guelder-rose leaves were used in this investigation. Plant material was harvested during the flowering period (June), in the forest area below the Ostrozub mountain (Zeleničje, Nature Reserve, Serbia). Two extraction techniques: maceration and ultrasonic extraction, were used to obtain the extractive matters from guelder-rose leaves. The yield of extractive matter, total phenolic and total flavonoid contents, as well as antioxidant activity of ethanolic extracts obtained from the plant material by different extraction techniques were studied. Total phenolic content and total flavonoid content were determined according to the Folin-Ciocalteu method and by the complexation reaction with AlCl3, respectively. The antioxidant activity of the extracts was assessed by DPPH, FRAP and FIC test.

The extract obtained by the maceration contained the high yield of extractive matter (28.0 g/100g of plant material), total phenolics (323.4 mg GAE/g of plant material) and flavonoids (20.0 mg RE/g of plant material) as well as antioxidant activity determined by all tests. The use of ultrasound reduced both, the extraction time due to the positive effect of cavitation events and the antioxidant activity of the extracts due to the decrease of total phenolics and flavonoids content. Identification and determination of the structure of individual phenolic compounds in the guelder-rose leaves extracts will be the aim of our further investigation.

Key words: Maceration, Ultrasonic extraction, Guelder-rose, Viburnum opulus L., Antioxidant activity

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