



The Soil Re-Union Science for Healthy Soils

4th International and
16th National Congress
of the Serbian Society
of Soil Science



Serbian
Society of
Soil Science



THE BOOK OF ABSTRACTS

Vrdnik, Fruške Terme, Serbia,
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Soil ReUnion: Science speaks – a call to united action

Humanity faces a triple crisis: climate change, biodiversity loss, and pollution. The international community is working intensively to address these challenges, and science confirms that the *wise use of soil* remains one of the most effective levers for protecting ecosystems and advancing climate action. Soil is, more than ever, at the center of global attention, both a joy and a responsibility for all of us who care for it.

The Soil ReUnion Congress, though not a massive world assembly, carries big ideas. Its ambition, as an initial spark, is to contribute to the global effort of responding to the triple crisis, through a triple unification, bringing together: sectors, regions, and disciplines around soil.

Agriculture, in particular, is increasingly recognized as a field that can both mitigate and adapt to climate change through regenerative practices - creating an entire *generation of regeneration*. This transition requires practical knowledge, faster research, and innovative approaches such as Living Labs, since we no longer have time for a “trial and error” approach. And let us not forget: 95% of the world’s food comes from soil, and despite technological advancements, there is no energy sustainable alternative that could ever fully replace agricultural land.

Our congress brings together scientists, decision-makers, business representatives, and global initiatives to contribute voices, ideas, and perspectives that can enrich the broader movement for soil protection. Its impact is designed to extend beyond the event itself - creating a unique community of like-minded professionals through a vibrant social program, project presentations, and our innovative π to π format: project-to-project speed blind dates.

The congress goals provide a clear framework - and we warmly invite you to find your place within it, connect with others, and make the most of every opportunity it offers, including:

- transferring scientific knowledge to bridge science, industry, and policy;
- creating a platform for dialogue to enable cooperation and co-creation of future strategies; and
- establishing thematic networks to ensure ongoing knowledge exchange and advance soil protection beyond the event.

Welcome - and thank you for being part of this shared contribution!

Dr Jordana Ninkov, president of Organization committee

Dr Snežana Jakšić, president of Program committee

Dr Jovica Vasin, president of Scientific committee and president of Serbian Society of Soil Science

EXCERPT FROM THE CONGRESS PROGRAMME

This extract from the official Congress Programme captures the spirit and concept of the Congress. The complete and detailed programme has been published separately.

Duration: 20–23 October 2025

Venue: Fruške Terme Hotel, Vrdnik, Serbia

Congress Centre: IV Floor, Wing B

Monday, 20 October 2025

Late afternoon

Registration

Fireside chat and interactive discussion

Dinner

Welcome party

Tuesday, 21 October 2025

Morning session

Registration

Official ceremonial opening of the Congress

Pause, Project exhibitions tour

Pause, Poster viewing session

Plenary lectures – Keynote speakers

Parallel oral presentations

Lunch

Pause for forest walk or relaxation

Afternoon session

Interactive workshop on innovative techniques in soil analysis and nutrient management (Sponsors' exhibition)

π to π (Project-to-Project) speed blind date

Dinner

Social gathering

Wednesday, 22 October 2025

Registration

Parallel oral presentations

Pause, Poster viewing session

Poster section with three-minute talks

Lunch

Assembly of the Serbian Society of Soil Science

Pause for forest walk or relaxation

Gala dinner

Thursday, 23 October 2025

Expert and tourist excursion – one-day

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(in alphabetical order)

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**DEVELOPMENT AND IMPLEMENTATION OF SOIL
POLICIES AND STRATEGIES: AT NATIONAL,
REGIONAL, AND INTERNATIONAL LEVELS**

THE ROLE OF EU MISSION SOIL DEAL FOR EUROPE AND ITS IMPACTS IN THE WESTERN BALKANS REGION

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ABSTRACT

The Soil Deal for Europe mission main goal is to establish 100 living labs and lighthouses to lead the transition towards healthy soils by 2030. Life on Earth depends on healthy soils. They are the foundation of the food systems. Furthermore, they provide clean water and habitats for biodiversity while contributing to climate resilience, support cultural heritage and landscapes and are the basis of the EU's economy and prosperity. The need to establish the soil mission comes from the fact that EU soils are under the threat of degradation. Soil is a finite resource, meaning its loss and degradation is not recoverable within a human timespan. It is estimated that 60 to 70% of the in Europe are unhealthy due to current management practices, pollution, urbanisation, and the effects of climate change (EC, 2020).

Living labs are collaborations between multiple partners that operate and undertake experiments on several sites at regional or sub-regional level. Individual sites could be e.g. farms, forest stands, urban green or industrial areas, enterprises and other entities, where the work is carried-out and monitored under real-life conditions, regardless of the land size, tenure (land ownerships) or the type of economic activity.

Lighthouses, in contrast, are defined as "places for demonstration of solutions, training and communication that are exemplary in their performance in terms of soil health improvement". They are individual, local sites (one farm, one forest exploitation, one industrial site, one urban city green area, etc.) that either can be part of a living lab or be situated outside a living lab.

Moreover 2.8 million potential contaminated sites (only 24% are inventoried) posing major health risks and 65-75% of agricultural soils possess nutrient inputs at levels risking eutrophication of soils and water and affecting biodiversity. Cropland soils are losing carbon at a rate of 0.5% per year; that figure is 50% for peatlands drained that are losing much more carbon contributing to the climate crisis. 24% of land is under the impacts of unsustainable water erosion rates, while 25% of the land is at high or very high risk to desertification in Southern, Central and Eastern Europe

according to data presented in 2017. The costs associated with soil degradation in the EU exceed 50 billion € per year.

The supportive legislation framework in the EU is fast filling the gaps that for many years brought to the worrying effects mentioned above. Among the most important policy and legislation instruments are the Soil Strategy and upcoming Soil Monitoring and Resilience Law (previously known as Soil Health Law), the European Soil Observatory and the Mission that altogether will build an effective framework for soil protection and restoration. The EU Soil Observatory will establish a monitoring system based on the Land Use/Land Cover Area Frame Survey (LUCAS) that collects each four years soil samples on a grid-based system throughout the EU. Should be mentioned that in 2015 LUCAS soil sampling was conducted for the first time also in the Western Balkans and the results of this survey are forthcoming, including North Macedonia.

The Mission Soil Deal for Europe will lead the transition towards healthy soils by implementing the following actions:

- funding an ambitious research and innovation programme with a strong social science component
- putting in place an effective network of 100 living labs and lighthouses to co-create knowledge, test solutions, and demonstrate their value in real-life conditions
- developing a harmonised framework for soil monitoring in Europe
- raising people's awareness on the vital importance of soils

The 8 Mission Soil Deal for Europe objectives:

1. reduce desertification
2. conserve soil organic carbon stocks
3. stop soil sealing and increase re-use of urban soils
4. reduce soil pollution and enhance restoration
5. prevent erosion
6. improve soil structure to enhance soil biodiversity
7. reduce the EU global footprint on soils
8. improve soil literacy in society

The Mission will support the EU's ambition to lead on global commitments, notably the Sustainable Development Goals (SDGs), and will contribute to the European Green Deal targets on sustainable farming, climate resilience, biodiversity, and zero-pollution. It is also a flagship initiative of the long-term vision for rural areas. More in detail the mission has established the following goals:

By 2030:

- 25% of land under organic farming
- Reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50%

Reduce fertilizer use by at least 20%

Reduce nutrient losses by at least 50%

Reduce by 30% microplastics released into the environment

Reduce net greenhouse gas (GHG) emissions by at least 55% compared to 1990 levels

By 2035

- the EU should aim to reach climate neutrality in the land use, forestry & agriculture sectors

By 2050

- all EU soil ecosystems are in healthy condition
- Europe is the first climate neutral continent

Funding opportunities are available and a total of 134.5 million Euros have been allocated for the Call 2024 for a total of about 18 new projects to be funded.

Western Balkans countries have a lot to learn from the EU research being done in soils. Efforts are under way to harmonise the LUCAS 2015 soil survey and the first results are available and finally published.

Key words: EU soil mission, restoration, biodiversity, monitoring, sustainability

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SOIL PROTECTION IN EUROPE BASED ON EU AND NATIONAL DOCUMENTS: THE EXAMPLE OF THE CZECH REPUBLIC

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ABSTRACT

The paper analyzes key documents at international and national levels, valid in the agricultural sector for the planning period 2023 – 2027, which are focused on supporting European farmers, ensuring food security in Europe, while operating a sustainable and competitive agricultural sector. During their preparation and publication, supports within the Common Agricultural Policy (CAP) were merged into one strategic document, which is the CAP Strategic Plan (SP). This is designed to support the sustainability and competitiveness of agriculture and contribute to the fulfillment of the European Green Deal, particularly the Farm to Fork Strategy and the EU Biodiversity Strategy for 2030. In the CAP SP, member states bear greater responsibility for achieving goals defined at the EU level compared to previous programming periods. For this purpose, all member states had to submit their CAP Strategic Plans, which contain relevant indicators. In the case of the Czech Republic, these relate particularly to carbon sequestration, soil protection, sustainable nutrient management and pesticide use, and last but not least, organic farming when managing land. Assessment of soil quality/health is also important throughout the system. Therefore, a significant role will be played in the future by the currently approved directive – Soil monitoring law, whose aim is to establish a framework for monitoring all soil in the European Union, improving its health and preventing its degradation. According to the directive, member states will establish a monitoring framework with soil descriptors and criteria for healthy soil condition set at EU level or at member state level, or other possible descriptors without criteria.

In order for farmers to receive financial support from individual interventions, they must comply with Good Agricultural and Environmental Conditions (GAEC), designated in the Czech Republic as Good agricultural and environmental condition of the soil (with the Czech abbreviation DZES). Within DZES, one of the priorities is soil protection, including protection against erosion. The new eco-payment Strip cropping also relates to soil protection. The structure of DZES, agri-environmental climate measures and other payments related to soil protection is the subject of this presentation

with emphasis on soil quality and protection against erosion, which belongs in the Czech Republic, but also globally, to the most significant degradation factors affecting not only soil quality and production, but also a number of non-production functions in the landscape. Accelerated erosion influenced by anthropogenic factors intensified in the Czech Republic in the post-war period during the collectivization of agriculture, together with other problems in the landscape (e.g., in water management or in reducing biodiversity). Solving this situation therefore requires carefully designed landscape restoration and sustainable agricultural systems to mitigate damage to soil and other environmental components based on national and European legal norms. Many of these also account for climate change scenarios, which may significantly influence these processes and related measures in the future. Based on analysis of erosion processes and landscape connectivity, we are working on measures that can reduce overall erosion risk and contribute to increasing biodiversity in the landscape. One possibility is strip cropping, where based on developed methodology and measures already implemented in practice, the lecture will present its effects related to reducing erosion processes within this organizational measure, which also includes non-productive areas that influence strengthening landscape biodiversity and protecting water resources.

Key words: soil protection law, erosion, soil quality, measures, strip-cropping.

ACKNOWLEDGMENT

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NATIONAL-SCALE SOIL GEOCHEMICAL SURVEY OF ARMENIA

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ABSTRACT

The widespread interest in soil resources is emphasized by their importance in achieving several Sustainable Development Goals (SDGs) and fulfilling the objectives of the European Union's Soil Mission. Moreover, information on various soil properties is essential for implementing data-driven actions toward soil security. In regions lacking sufficient soil data, the characterization of soil quality and the selection of strategies to improve soil health may be biased or ineffective. Among the various aspects of soil, its chemical composition is particularly crucial for understanding and characterizing many soil-related processes, as well as gaining insights into soil health. Therefore, generating data on soil chemical composition is especially vital in developing countries, including the Republic of Armenia (RA). This study aims to highlight the efforts undertaken in Center for Ecological-Noosphere Studies of the National Academy of Science of RA to conduct a national-scale soil survey and to provide insight into the stages of regional geochemical studies toward the establishment of the country's first soil geochemical atlas. In recent years, significant progress has been made in the geochemical characterization of soils in several regions of RA. However, the national-level soil survey remains incomplete (Fig.1).

Two regions - Tavush and Syunik (24.3% of the country's territory), which are important for agriculture and mining, are still undergoing soil sampling activities. A regular 5 × 5 km sampling grid is used, and a bulk sample is obtained by mixing five subsamples collected from the central portion of each grid cell using the envelope technique. As part of these soil surveys, soil samples bank has been established.

The soil samples preserved in this bank are being used to determine various chemical (Na-U, pH etc.), biological (soil organic matter), and physical (soil texture) indicators, ensuring a comprehensive characterization of the soil environment. Element concentrations in soil are determined using X-ray fluorescence and ICP-OES/MS spectrometry.

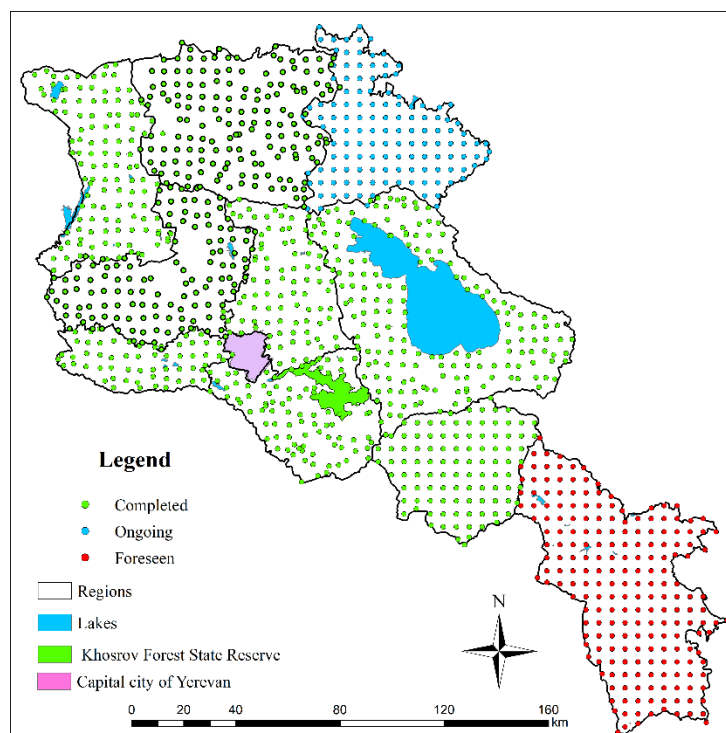


Figure 1: Spatial distribution of soil sampling sites and area under investigation

The ongoing efforts to develop Armenia’s first soil geochemical atlas mark a critical step toward enhancing soil data availability and supporting sustainable land management. By systematically characterizing the chemical, biological, and physical properties of soils, this initiative forms a solid basis for scientifically justified decision-making aligned with both national priorities and global sustainability goals. Completing the national soil survey will not only fill essential data gaps but also empower stakeholders to implement targeted strategies for improving soil health and achieving long-term soil security across the whole country.

Key words: environmental geochemistry, chemical elements, geochemical atlas, geospatial mapping.

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LOSS OF ARABLE LANDS IN SERBIA: DEVELOPMENT OR DAMAGE?

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ABSTRACT

In recent decades, we have observed the effects of climate change on soil degradation processes, and in synergy with intensive agricultural production or poor management, this can lead to severe damage to soil fertility. Such agricultural areas can be repaired by melioration measures and restored to their original state over a longer period of time. However, it becomes problematic when the soil, the basic natural resource on which all plant and animal life is based, is permanently lost. The increase in population requires higher food production, which is largely provided from agricultural land and to a lesser extent from the substrate. On the other hand, the development of mankind through mining, construction, transportation and industry is at the expense of agricultural land. The question arises to which limit one should go and what kind of soil quality should be "sacrificed" in order to ensure the development of a country (nation) without jeopardizing agricultural production. The aim of this paper is to examine the change in land use and the trend of decrease in arable lands in Serbia using data from the 2012 and 2023 agricultural census and remote sensing data downloaded from the FAO platform "OpenForis" for a period of 25 years by districts.

It was found that there is an obvious change in land use from agriculture to forest in all districts of Serbia. This is most pronounced in the South Banat district in Vojvodina, in Pčinjski in central Serbia and in the Prizren district in Kosovo and Metohija. A decrease in arable land was also recorded in the districts of Južnobački and Južnobanatski in Vojvodina, then in the districts of Pčinj, Belgrade and Zaječar in central Serbia and in the district of Kosovo. Most of the permanently lost land, on which buildings, roads, mines, etc. were built, is located in the districts of Belgrade, Juznobački and Kosovski. According to the data from "OpenForis", the arable land has decreased by 257,763 hectares. Of this, 178,559 hectares were converted into forest land. The total permanent land loss amounts to 75,273 hectares. It can therefore be concluded that almost all the land that was not converted to forest land was permanently lost. According to the agricultural censuses from 2012 to 2023, the utilized arable land decreased by 198,049 hectares and the unused land even

decreased by 253,702 hectares. It should be noted that 7,140 hectares are lost every year. The biggest problem is that the most fertile soils around Belgrade and Novi Sad are being lost for construction purposes, as well as near Požarevac, Lazarevac and Bor for mining.

Although the loss of land is unavoidable for the needs of social development, measures can still be taken not to build on the most fertile soils, and use land of lower fertility, instead. For example, the construction of an industrial zone should not be planned on Chernozem, but on soils of a lower cadastral class, such as heavy, poorly permeable black soils, sirozem, or sandy or shallow soils, etc. The role of the Serbian Society of Soil Science should be more visible and influential in the adoption of spatial plans, both at the level of local self-government and at the regional and national level.

Key words: soil loss, land use, OpenForis, plannig

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CAPACITY BUILDING FOR CONTAMINATED SITE MANAGEMENT IN BOSNIA and HERZEGOVINA AND SERBIA

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ABSTRACT

Addressing soil contamination in the Western Balkans is hindered by insufficient legal and institutional frameworks, limited financial and human resources, and the absence of systematic site investigations. Public awareness and remediation activities remain low, highlighting the urgent need for integrated strategies, increased investment, and stronger community engagement to mitigate environmental and health risks. Establishing a comprehensive registry of contaminated sites across Western Balkans requires national authorities to identify potentially polluting activities, compile inventories, carry out on-site investigations, and assess risks to human health and the environment.

To contribute to these efforts, the United Nations Environment Programme (UNEP), under its mandate to support the implementation of the 2030 Agenda for Sustainable Development and relevant Multilateral Environmental Agreements on pollution, has intensified efforts in South East Europe to address pollution-related challenges. In alignment with the UNEA initiative *“Towards a Pollution-Free Planet”*, UNEP and the Italian Ministry for Ecological Transition signed a Donor Agreement in January 2019 to establish the *South East European Sub-Regional Platform to Beat Pollution (SEEPP)*. The platform aims to promote innovative partnerships for pollution prevention, enhance transboundary cooperation in policy development, and facilitate the exchange of knowledge and best practices across the region.

Building upon these regional efforts, UNEP, with financial support from the Italian Government, launched the project *“Strengthening the Capacity in the Management of Contaminated Sites in Bosnia and Herzegovina and Serbia to Reduce Pollution into the Environment”* for implementation during

2023–2026. The project seeks to strengthen institutional capacities and technical expertise in the Western Balkans to identify, prioritize, and manage contaminated sites. It further aims to support the development of evidence-based policies for pollution control and environmental protection. Key objectives include improving legal and institutional frameworks, enhancing the management of contaminated sites, and fostering regional cooperation through the exchange of environmental information and best practices. The main goal is to reduce pollution, protect human health, and safeguard water resources and other environmental receptors.

Key words: Western Balkans, soil contamination, contaminated sites

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SOIL GENESIS, CLASSIFICATION AND HERITAGE

PARENT MATERIAL ORIGIN AS A FACTOR IN FORMATION OF BRUNIC ARENOSOLS

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ABSTRACT

Brunic Arenosols are zonal soils widely distributed across postglacial landscapes of Central European lowlands. The presence of rusty-colored horizons enriched in the products of weathering (Bw horizons) is the most distinguishing feature of these soils, while their physical and chemical characteristics, as well as their generally low fertility and productivity, are strongly determined by sandy substrates of varied origin.

Although the Brunic Arenosols have been intensively studied over the last decades, particularly in Germany and Poland, there are many gaps in the knowledge. There is no consensus among soil scientists regarding the mechanisms of their formation. Some authors have emphasized the role of periglacial environments and frost weathering, whereas others highlighted importance of forest vegetation as a nutrient pump. Another interesting, albeit poorly explored, aspect is the role of the origin and age of parent material. The role of this factor seems to be important considering the widely reported variability of Brunic Arenosols in terms of morphology, chemistry, and trophic status.

Considering large importance of the issue, we undertook a broad study on the role of parent material origin as a factor influencing development and properties of Brunic Arenosols in young-glacial landscape of northern Poland, representing temperate oceanic climate. The studies covered 74 locations of Brunic Arenosols (Fig. 1). The soils have developed from sands of various origins and represent different landforms, including aeolian covers (A), kames (K), eskers (E), sandurs (S), river supra-flood terraces (T), and moraines (G). One soil pit was dug in each location recognized as representative (i.e., the soil representing the most typical morphology). The soil profiles were described using the WRB standards, sampled from horizons and analyzed using standard procedures in soil science. The data obtained were explored statistically to quantify the effects of parent material origin as a factor of heterogeneity of Brunic Arenosols.

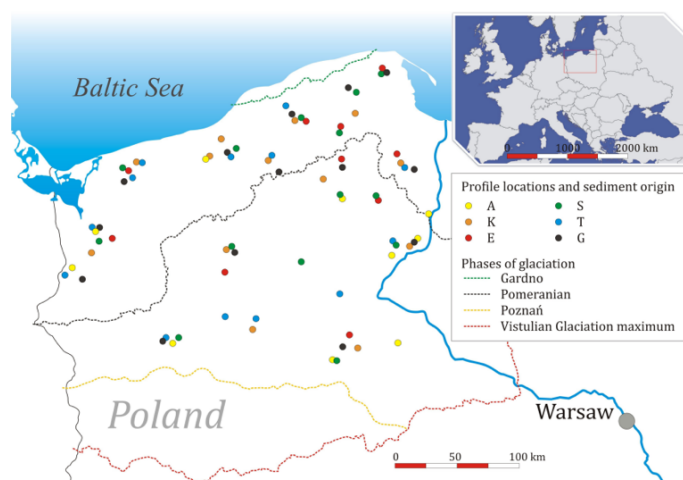


Fig. 1. Location of the soils and origin of their parent materials (A – aeolian sediments; E – eskers; G – glacial deposits; K – kames; S – sandurs; T – supra-flood terraces).

The studies confirmed large role of parent material origin as a factor influencing development and properties of Brunic Arenosols. Its role was well reflected in the morphological features, such as the depth of the solum, and the thickness of the Bw horizon and its color saturation. Soils developed from materials directly deposited by the melting ice sheet and those developed from materials strongly transformed by water and wind differed the most. Low intensity of transport favored the development of deeper profiles and a stronger color saturation. The soils were usually acidic or strongly acidic, which is typical of forest Brunic Arenosols, showing some significant variation in subsoil based on origin of the parent material. Many statistically significant differences affected by parent material origin were noted for major nutrients. Additionally, there was a clear variation in the content of Fe (total and pedogenic forms), as a key element in brunification. Those soils developed from aeolian sediments differed most from the other soils in this term. The soils were generally characterized by low sorption capacity, which was significantly influenced by the origin of the parent material. Moreover, this study confirmed large variability of Brunic Arenosols and their continuum affected by parent material origin.

Key words: pedogenesis, Brunic Arenosols, parent material, landscape evolution, soil properties

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SOIL CLASSIFICATION OF SLOVENIA 2025

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ABSTRACT

Soil classification is the systematic categorisation of soils based on their pedogenetic, morphological, physical, chemical and nowadays also biotic and functional properties in order to understand the potential use and limitations of different soil types. At the national level, soil classification provides a standardised framework for (more) sustainable land management and serves as a guide for agricultural policy, forestry, urban planning, environmental protection and climate change mitigation. Soil classification is the basis for soil mapping at any scale. Despite advances in digital soil mapping and modelling of soil properties, soil classification and soil maps remain important documents of national soil resources.

The origin of the older Slovenian Soil Classification (SSC) is linked to the development of the Yugoslav Soil Classification (YSC), which was based on lithological, chemical, physical and morphological soil properties and the principles of soil genesis. Although there was an official YSC, slightly different soil classifications were applied in the former Yugoslav republics. The soil taxonomies of the new states are developed and improved independently and have therefore become more diverse.

The digital soil map of Slovenia at a scale of 1:25,000 (DSM25) was finalised in 2000. The DSM25 uses the SSC, although the SSC has never been published in a comprehensive and official form. The DSM25 has been in use for 25 years. Unfortunately, Slovenia is not rich in good and fertile soils. Our soils are often shallow and sandy or hydromorphic and clayey and generally very vulnerable and exposed to natural and human degradation. Above all, land consumption by housing, industry and infrastructure development is the main reason why good soils should be identified and preserved for future generations. There was an urgent need to update the DSM25 and create more detailed soil maps for agricultural land. In parallel, there was a growing need in part of the Slovenian soil research community to update and further improve the SSC.

In 2015, the International Year of Soils, activities to update and improve the SSC continued and accelerated in 2024, when the Ministry of Agriculture, Forestry and Food commissioned the new national soil mapping project. Two new digital maps will be produced: the improved and more detailed 1:25,000 digital soil map (DSM2026), covering the entire country, and a better scale soil map of agricultural land (ASM). Both are to

be based on a new and improved Soil Classification of Slovenia (SCS2025).

The paper presents the structure of SCS2025, soil groups and soil types, their forms, primary properties and associated soil quality parameters. The main differences between SSC and SCS2025 are explained. The SCS2025 is already integrated into the eTLA soil information system and is used for the formation of DSM2026 and ASM mapping units as well as for the reclassification of legacy soil profile data. The SCS2025 will be published in printed form by the end of 2025, DSM2026 and ASM delivered in 2026.

Keywords: soil maps, soil information system

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**PHAEOZEMS FORMED ON LOOSE PARENT MATERIALS IN
SERBIA: POSSIBLE POSITION IN NATIONAL SOIL CLASSIFICATION**

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ABSTRACT

Phaeozems cover around 190 million of ha worldwide. In Europe, their distribution is evident as discontinuous areas in Central Europe, where also Serbia belongs. Phaeozems in World Reference Base (WRB) for Soil Resources are eutric soils having mollic horizon and no secondary carbonates, unless very deep. The term Phaeozems does not exist in National Soil Classification System (NSCS) in Serbia as soil type, or at the lower systematic levels, but the soils with these characteristics exist. Therefore, their presence can be enrolled within other soil types. Usually, deep Phaeozems formed at unconsolidated parent materials like loess or alluvial and deluvial sediments may be encountered in genetic sense between Chernozems and Eutric Cambisols, whereas other soils with mollic horizon formed on hard parent materials could also match the criteria required for Phaeozems.

The aim of this work was to compare the results of national and international classification of 18 soil profiles investigated at the toeslopes of Mountain Vukan, East-Central Serbia. Soils are mainly formed on alluvial deposits, they are thick, with moderately high humus content, developed humus-accumulative horizon, and also rich in bases. In WRB these soils are classified as Phaeozems but NSCS classified them as different subtypes of Chernozems and Eutric Cambisols. WRB classification identified two Calcaric Cambic Chernic Phaeozems which correspond to Calcaric Chernozems of NSCS. Among nine Cambic Chernic Phaeozems of WRB, there are five Leached Chernozems and four Eutric Cambisols of NSCS. Among five Cambic Phaeozems of WRB there are three Leached Chernozems and two Eutric Cambisols in NSCS. Two Eutric Cambisols in WRB system correspond to Eutric Cambisols of NSCS. Oppositely, the

results show that eight Leached Chernozems of NSCS are classified as Phaeozems, six Eutric Cambisols of NSCS are classified as Phaeozems, and two Calcaric Chernozems of NSCS are classified as Phaeozems.

The important criteria required to differentiate between Chernozems and Phaeozems in WRB is the presence of secondary carbonates. In Serbia, Calcaric Chernozems in majority of cases have secondary carbonates and they correspond mainly to Chernozems of WRB, but without secondary carbonates they can correspond to Calcaric Phaeozems. Leached Chernozems in NSCS can be classified as Chernozems in WRB only if they have secondary CaCO₃ concentrations in intermediate horizons, whereas Brownized Chernozems in NSCS are potentially the closest soils to Phaeozems. However, in some cases they do not fulfill criteria required for mollic horizons in terms of colour and thickness, and therefore they might be classified as Eutric Cambisols.

The importance of Phaeozems is outstanding because they are naturally fertile soils used in agricultural production due to their thickness and good water-holding capacity, physical and chemical properties. These soils in Serbia probably cover more than 400,000 ha and are used for intensive agricultural production and are being degraded. Further evolution/ degradation of these soils can go into direction of "loosing criteria" required for mollic horizon. From the classification point of view, these soils may further develop to Eutric Cambisols and Luvisols. Oppositely, some Chernozems may evolve/degrade into Phaeozems.

Key words: phaeozems, WRB, soil color, mollic horizon, chernozems, secondary carbonates, Serbia

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CLASSIFICATION OF CHERNOZEM SOILS UNDER WHEAT IN BARE (BRANIČEVO PROVINCE, SERBIA)

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ABSTRACT

According to the official local soil classification system (Škorić et al., 1985), Chernozem is a soil type within the order of automorphic soils and the class of humus-accumulative soils, with an A–AC–C profile. Chernozems are divided into subtypes according to the parent material: (i) loess and loess-like sediments, (ii) carbonate eolian sand, and (iii) alluvial deposits; varieties according to the stage of evolution: (i) calcareous, (ii) decarbonated, (iii) brunified, (iv) calcareous oxygleyic, (v) decarbonated oxygleyic, (vi) brunified oxygleyic, and (vii) salinized and alkalinized; and forms according to depth: (i) shallow, up to 40 cm; (ii) moderately deep, 40–80 cm; and (iii) deep, >80 cm.

It is important to note that not all Serbian Chernozems fulfill the criteria for Chernozems in the WRB 2022 classification, which requires the presence of secondary carbonates at a depth no greater than 50 cm below the mollic horizon.

The aim of this study was to provide a detailed classification of soils from three profiles in Bare (44° 38' 19" N, 21° 19' 19" E), Braničevo District, northeastern Serbia, using the local (Škorić et al., 1985) and international (WRB 2022) classification systems.

According to Škorić et al. (1985), all studied soils were classified as the subtype Chernozem on loess and loess-like sediments, with an A–AC–C soil profile. Variations in carbonate content and the thickness of the A (humus-accumulative) genetic horizon resulted in these soils being further classified into different forms and varieties. Profile 1, with a calcareous A horizon (<40 cm), was classified as form – Shallow, variety – Calcareous. Profile 2, with a non-calcareous A horizon also <40 cm, was classified as form – Shallow, variety – Decarbonated. Profile 3, with a slightly deeper non-calcareous A horizon (41 cm), was classified as form – Moderately deep, variety – Decarbonated.

According to WRB 2022, all analysed soil profiles contained chernic and mollic horizons, but no calcic horizon, and were formed on unconsolidated

parent material. No diagnostic properties were identified in the studied soils, while the determined diagnostic materials included calcaric material, mineral material, and soil organic carbon (SOC). All soil profiles correspond to the Phaeozems Reference Soil Group (RSG). Profiles 1 and 3 were classified as Chernic Calcaric Phaeozems (Humic, Loamic), while profile 2 did not fulfill the criteria for the Calcaric qualifier; all other principal and supplementary qualifiers were the same as in profiles 1 and 3.

Although the studied profiles are classified as Chernozem according to the national system (Škorić et al., 1985), their classification within the WRB system places them in the Phaeozem RSG, highlighting the importance of comparative studies that connect national and international classification systems and provide valuable insights for soil taxonomy and harmonization.

The studied soil profiles do not fulfill the WRB criteria for Chernozems due to the absence of secondary carbonates, which are leached to a somewhat greater depth, likely caused by the slightly more humid climate (mean annual precipitation 670 mm, 30-year average).

Key words: WRB, soil classification, Chernozem, Phaeozem

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SOIL CHARACTERISTICS OF SOME CLIMATE-ZONAL OAK FORESTS IN SERBIA

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ABSTRACT

Oak forests are among the most important forest types in Serbia, making understanding their ecological conditions essential for effective management. The degradation of hilly-mountainous oak forests in Serbia is primarily the result of human activities. Historically, improper forest management has led to a decline in forest quality, weakened tree health, changes in the natural composition of tree species, and a regression in the natural succession of vegetation. Given the complexity of regenerating hilly and mountainous oak forests, it is crucial to conduct systematic research on the key factors influencing this process (including soils) to support successful and sustainable forest restoration efforts.

This study was conducted in *Quercetum frainetto-cerris typicum*, typical climate-zonal forests in Serbia, on tree different localities: Cer, Žiča and Vračevšnica. One soil profile was examined in each locality to identify the soil types and determine their properties.

Three different soil types were determined: Luvisol on Cer, Planosol on Žiča and Cambisol on Vračevšnica.

The analyzed properties of the Luvisol are as follows: soil reaction (pH in H₂O) is 5.70; humus content is 1.45% (all average values). The texture class is silty clay loam. The analyzed properties of the Planosol are as follows: soil reaction (pH in H₂O) is 5.48; humus content is 1.84% (all average values). The texture class is silty loam. The analyzed properties of the Cambisol are as follows: soil reaction (pH in H₂O) is 5.79; humus content is 1.81% (all average values). The texture class is silty clay loam.

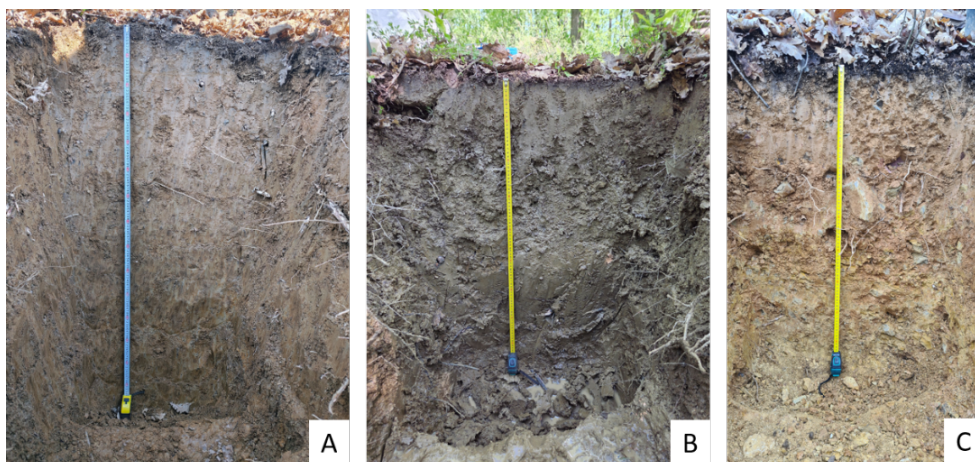


Figure 1. Soil types: A- Luvisol; B- Planosol; C- Cambisol

The studied soils, in general, have good physicochemical properties for successful forest restoration. When appropriately managed, they offer excellent conditions for the growth and development of oak species.

Key words: forest soils, climate-zonal oak forests, Serbia, Luvisol, Planosol, Cambisol

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**PRACTICES ON INTANGIBLE CULTURAL HERITAGE REGISTER
RELATED TO NATURAL RESOURCES ALONG THE DANUBE**

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ABSTRACT

A methodological approach was developed in 2021 to protect intangible cultural heritage (ICH) — specifically, domain knowledge and practices related to nature and the universe — through the creation of national registers for the traditional medicine and agriculture sectors. These registers include bearers, practitioners, and “living human treasures” within the EU’s Danube region.

The following international frameworks served as the basis for this methodology. These include UNESCO (Convention for the Safeguarding of the ICH, 2003; Convention on the Protection and Promotion of the Diversity of Cultural Expressions, 2005), FAO (Globally Important Agricultural Heritage Systems, GIAHS), WHO (Global Traditional Medicine Strategy), and the UN (2030 Agenda for Sustainable Development, Nagoya Protocol, Covenant on Economic, Social and Cultural Rights). Harmonized frameworks within the EU and the Danube Region are also considered, with particular emphasis on state aid mechanisms.

The methodology is further aligned with the WIPO Treaty on Intellectual Property, Genetic Resources, and Associated Traditional Knowledge (2024), as a result of 30 years of collaboration and harmonization between WIPO and UNESCO.

Each state community protects its ICH in accordance with the public

principles of its community, which is a challenge for safeguarding of ICH in a geographical area that often does not recognize administrative borders. Through case studies from six countries of the Danube Region, has been created an approach to harmonization and overcoming fragmentation in different public local frameworks.

The core values of the methodology include: (1) the national registry as the first phase of valorization of ICH for science, innovation, sustainable tourism, and as a resource for the sustainable development of local and regional communities; (2) the protection of this domain in the Danube Region, which serves as an example of good practice for the sustainability of other regions; (3) encouragement of cross-sectoral cooperation, inviting participation in a core group; (4) emphasis on the harmonization of linguistic concepts across different sectors; (5) highlighting the importance of the concept of “benefit sharing”; and (6) serving as a tool foreseen by the Second IPBES Global Assessment Report on Biodiversity and Ecosystem Services (2024).

Key words: traditional knowledge, natural resources, folk medicine, agriculture

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SOIL PHYSICS, MINERALOGY AND CHEMISTRY: ANALYTICS AND FUNDAMENTAL RESEARCH

WATER-DISPERSIBLE CLAY AND AN AGGREGATION/ ERODIBILITY INDEX IN A FLUVISOL IN WESTERN SERBIA

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ABSTRACT

Intensive agriculture is one of the main human activities that promote erosion and degradation of soil. Information on water-dispersible clay (WDC) and an aggregation/erodibility index (AI) are needed to assess the soil attributes that influence the susceptibility of soils to erosion in water. This study was conducted to determine the effects of long-term tillage (>100 years) on soil erodibility using a WDC and AI approach as well as soil attributes that influence erodibility. Nine locations in a Fluvisol in western Serbia were sampled for the analysis. At each location soil samples were collected at a depth of 0–15 cm. The object was to measure the WDC and AI and to determine some of the soil properties that influence them. WDC and AI (erodibility indices), were used as indicators of soil erodibility.

The soil studied is heavy textured with a sand (2–0.05 mm) fraction ranging from 5.59 to 13.11%, a silt (0.05–0.002 mm) fraction ranging from 37.66 to 44.55%, and a clay fraction (< 0.002 mm) ranging from 36.51 to 47.25% in the entire investigation area. The pH is in the moderate to slightly acidic range (pH 5.86–6.21), the humus (organic matter) content is medium (2.49–3.37%) and the cation exchange capacity (T) is high (28.63–38.31 cmol_e kg⁻¹). The WDC (5.00–7.13%, mean 5.76%) was low while the AI (82.38–88.79%, mean 86.06%) was high in the studied Fluvisols. The correlation coefficients (*r*) for WDC and AI versus humus, clay and T were in the interval 0.376–0.451, indicating the positive influence of humus and clay content and T on the erodibility indices investigated. The WDC correlated strongly positively with silt (*r* = 0.504) and pH (*r* = 0.502). Moderately negative correlations were observed between pH and AI (*r* = –0.305). The *r* value for WDC and AI versus sand content was –0.407 and –

0.301, respectively. Based on values of the erodibility indices (WDC and AI), it can be concluded that the erodibility of these long-term tillaged Fluvisol is low. Consequently, management practises that decrease WDC and increase humus content may control the possible degradation of soils.

Key words: cropland, soil organic carbon, water dispersible clay, aggregation index, erodibility, erosion

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THERMAL PROPERTIES OF CLOMAZONE SORBED ONTO INORGANIC AND ORGANICALLY MODIFIED CLAY MINERALS

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ABSTRACT

Results presented here are an attempt toward a better understanding of the thermal properties of the clomazone/clay complex. Montmorillonite (clay) was modified with organic complexes such as HDTMA (hexadecyltrimethylammonium bromide), and the surfactant/clay ratio was selected in accordance with clay CEC values. Saturation of cation exchange capacity (CEC) was 25%, 50%, 75%, and 100%. Thermal analysis of samples is performed using the TG/DTG method.

The TG/DTG analysis of Na-montmorillonite revealed three distinct mass loss phases. The initial phase is associated with the removal of surface-adsorbed water and dehydration of interlayer hydrated Na⁺ and Ca²⁺ cations. Two forms of interlayer water were identified: water directly coordinating exchangeable cations, forming their hydration shells, and water indirectly bound with higher mobility.

In HDTMA-modified montmorillonites, four distinct thermal events were observed: water desorption, decomposition of the HDTMA complex both on the external mineral surfaces and within the interlayer space, dehydroxylation of aluminosilicate structures, and finally, oxidation of residual carbon compounds in the interlayer region.

The HDTMA-montmorillonite samples containing sorbed clomazone exhibited increased mass loss between 200 and 350°C compared to clomazone-free samples, indicating decomposition of the pesticide. Additionally, the total mass loss was greater for clomazone-loaded HDTMA-montmorillonite, further confirming the pesticide's presence within the modified clay structure.

Key words: montmorillonite, clomazone, thermogravimetric analysis (TG), derivative thermogravimetry (DTG).

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NATURALLY OCCURRING RADIONUCLIDES AND ¹³⁷Cs IN SOIL PROFILES OF TWO SOIL TYPES IN EAST-CENTRAL SERBIA

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ABSTRACT

The characteristics of soils formed at the contacts of different geomorphological units can be very heterogeneous. This applies particularly to situations where geogenic processes and anthropogenic measures have affected soil formation. The aim of this work was to investigate soil characteristics and radionuclide concentrations in soils formed the foothills and toe slopes of Mt. Vukan, East-Central Serbia. The area of more than 200 ha is characterized by a geomorphologically simple form and mild slopes, but by intensive geogenic processes that occurred in the past. Namely, it represents the transition zone between the soils formed under strong impact of colluviation and the soils formed on the old alluvial terraces. The investigated Calcaric Chernozem (Solimovic) is moderately rich in colluvial material and it is formed on loess-like sediments with more than 15% of CaCO₃. The soil sequence consists of a developed A-horizon, a transitional horizon, and unconsolidated parent material. The soil is moderately alkaline and rich in CaCO₃ which varies with depth due to pronounced leaching. The investigated Eutric Cambisol is formed on unconsolidated alluvial material with more than 35% of clay content. It is moderately acidic in topsoil and slightly acid in subsurface cambic horizon, which contains on average 6% more clay than the A-horizon.

The activity concentration of radionuclides was measured throughout the entire soil profile at all depths and horizons analyzed. The results of the activity concentration of the naturally occurring radionuclides in the soil were in the range of 31–68 Bq kg⁻¹ for ²³⁸U, from 1.7–3.6 Bq kg⁻¹ for ²³⁵U, 30–48 Bq kg⁻¹ for ²²⁶Ra, 34–60 Bq kg⁻¹ for ²³²Th, and from 330–590 Bq kg⁻¹ for ⁴⁰K. The anthropogenic radioisotope ¹³⁷Cs was also detected, but only in topsoil horizons in the range between 6.2–17.0 Bq kg⁻¹, whereas its activity at greater depths was below the minimum detectable activity concentration. The external gamma dose rate in the air at 1 m above the

ground due to natural radionuclides in the soil and the annual effective dose equivalent (AEDE) are calculated using the activity concentration values (A_{Ra} , A_{Th} , A_K) from the first 20 cm soil depth, assuming equilibrium conditions in the decay chains of ^{226}Ra and ^{232}Th . The AEDE values of 87.2 μSv for the Calcaric Chernozem and 91.5 μSv for the Eutric Cambisol were higher than the worldwide average, but in accordance with the values reported for the wider area of central Serbia. A similar conclusion can be drawn for the gamma dose rate values which were 71.7 $nGy h^{-1}$ in Calcaric Chernozem and 74.6 $nGy h^{-1}$ in Eutric Cambisol, indicating radioecologically safe conditions.

Key words: radioactivity, ^{137}Cs , gamma spectrometry, Chernozem, Eutric Cambisol

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TEXTURE OF URBAN SOILS OF BELGRADE

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ABSTRACT

Urban soils differ significantly from natural and agricultural soils due to the direct impacts of urbanization, including heterogeneous land use, construction, industrial activity, and waste disposal. These anthropogenic influences cause substantial physical disturbances, leading to pronounced vertical and horizontal variability in soil properties, particularly texture. Unlike natural soils, whose texture is largely derived from parent material and remains relatively stable, urban soils may experience rapid and intense textural changes. Since soil texture controls key functions such as water retention, nutrient cycling, and pollutant filtration, it plays a critical role in supporting ecosystem services.

This study investigates soil texture variability in urban soils of Belgrade across four land use types (parks, industrial complexes, traffic junctions, and urban forests) with the aim of quantifying the impact of anthropogenic land use change on soil texture. Composite samples were collected from two layers (0–10 cm and 10–40 cm) using a steel auger. The comparative analysis revealed higher proportions of coarse sand (2.0–0.2 mm) in the soils of industrial complexes and traffic junctions—by 9.45% and 8.69% in surface layers, and 11.35% and 7.48% in subsoil layers, respectively compared to urban forests (0.97%, 0.87%). A similar trend was observed for fine sand (0.2–0.06 mm), with industrial zones (16.95%, 20.96%) and traffic junctions (18.0%, 18.16%) showing elevated levels relative to urban forests. In contrast, both coarse silt (0.06–0.02 mm) and fine silt (0.02–0.002 mm) were lower in these land use types across both layers, although the differences were less pronounced. No statistically significant differences were found in the clay fraction among the various land use categories. These findings indicate that the type of urban land use significantly influences the distribution of sand and silt fractions, while clay content remains largely unaffected. Urban land use notably influences soil texture, especially sand and silt distribution, with industrial and traffic areas showing greater disturbance. In contrast, clay content remains relatively unaffected, indicating its stability under varying land use conditions.

Given its critical role in determining soil functionality, the assessment of soil texture is essential for sustainable land management, particularly in addressing environmental challenges such as land degradation and climate

variability. Therefore, soil texture should be systematically integrated into environmental assessments and urban planning processes. Municipal authorities are strongly encouraged to incorporate texture analysis when formulating sustainable land use strategies and environmental protection policies for the city of Belgrade.

Key words: urban soils, texture of urban soils, anthropogenic impact

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SOIL PHYSICAL RESPONSE TO WINTER COVER CROP INTEGRATION IN SOYBEAN PRODUCTION

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ABSTRACT

This study examines the effects of different production systems and winter cover crops on soil physical properties, focusing on bulk density in soybean production. The experimental design included two farming systems, low-input production and organic production and three cover crop treatments: rye, a mixture of pea and oat, and a control with no winter cover crops. Samples were collected over three consecutive years (2020, 2021, and 2022) prior soybean harvest. Soil physical properties, particle density (2.14 – 2.72 g/cm³) and dry bulk density (1.11 – 1.67 g/cm³), had varied over years, and it was influenced by selection of cover crops. The results indicated that both cover crop type and production system significantly influenced soil bulk density. First year (2020) had the highest values for both observed parameters. Decrease in bulk density indicates better aeration and lower soil compaction, which was observed during 2021 and 2022. Use of cover crops, especially the pea and oat mixture, significantly contributes to the reduction of soil compaction over the three-year period, as reflected in the continuous decrease of bulk density compared to the control. The findings suggest that integrating winter cover crops, particularly in organic and low-input systems, can positively affect soil physical properties by reducing soil compaction and enhancing soil porosity.

Key words: soil, bulk density, soybean, cover crops

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ROLE OF DISSOLVED ORGANIC MATTER NATURE ON GEOGENIC NI DYNAMIC UNDER CHANGING SOIL REDOX CONDITIONS

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ABSTRACT

This study examined the effects of dissolved organic carbon (DOC) nature on solubility of geogenic nickel (Ni) as soil redox status (E_H) changes from anaerobic to aerobic conditions following floods. The investigated soil was typical for Serbia's agricultural areas impacted by serpentine minerals. Total Ni in the soil was 131 mg kg⁻¹. An automated biogeochemical microcosm system was used to simulate the alteration of E_H from reducing to oxidizing conditions at redox-windows of approximately 100 mV. Three microcosms (MC) served as replicates; each received a wheat straw inoculation at the start of the experiment to accelerate the microorganisms' growth. The addition of straw mirrors the real field conditions in soil following the plowing of harvest residues. The soil slurry was sampled at each redox-window and analyzed for soluble Ni, Fe, Mn, and DOC. Absorbance at 254 nm was measured and used for calculation of the specific ultraviolet absorbance (SUVA₂₅₄) as an indicator of DOC composition.

During the experiment, E_H changed from -195 mV to 561 mV. Concentrations of soluble Ni varied in the range 92–260 µg L⁻¹. Soluble Ni correlated significant negative with E_H ($r = -0.872$, $p < 0.05$), and significant positive with: DOC ($r = 0.925$, $p < 0.05$), soluble Fe ($r = 0.923$, $p < 0.05$), soluble Mn ($r = 0.748$, $p < 0.05$). We anticipated a positive correlation between soluble Ni and SUVA, taking into account the same trend in DOC and Ni dynamics with increasing E_H as well as the affinity of aromatic DOC to readily form complexes with trace elements. Opposite, there was a negative correlation between SUVA and soluble Ni ($r = -0.709$, $p < 0.05$). SUVA rose as E_H increased in our experiment, suggesting that there were more aromatic DOC compounds present under oxidizing than reducing conditions. This supports earlier findings that, under oxidizing conditions, more aromatic DOC may be produced by mineralization of organic material

mainly composed of cellulose, hemicellulose, and lignin, such as wheat straw. A negative correlation between Ni and SUVA suggested that the dynamics of Ni in our experiment were governed by other variables than DOC. The PCA (principal component analysis) showed that decrease of soluble Ni at high E_H can be attributed to precipitation or sorption to newly formed Fe oxides, whereas DOC was absorbed or complexed by newly formed Mn oxides. This explained low affinity of aromatic DOC for Ni which corroborate with earlier findings that SUVA does not provide information regarding the reactivity of DOC derived from different types of source materials.

We concluded that flooding of agricultural soils with high geogenic Ni may present a serious environmental risk, which lessens as soil Eh changes toward a more oxidizing state when water is withdrawn. During those events, DOC produced by the mineralization of hardly broken-down organic molecules plays a smaller role in Ni co-transport. This provides more information on the availability and solubility of Ni in relation to agriculture at specific areas and climate change.

Key words: nickel, soil, redox potential, wheat straw, SUVA

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ORGANIC AMENDMENTS AND PESTICIDE RETENTION IN SOILS

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ABSTRACT

To evaluate how organic soil amendments (OSAs) influence pesticide retention, batch adsorption experiments were carried out with sandy amended alluvial soil from the Danube River. Three organic materials were tested as amendments: biochar, obtained from *Miscanthus giganteus* pyrolyzed at 550°C; sediment, collected from the polluted Begej Canal (containing heavy metals and organic contaminants); and compost, derived from green waste in Novi Sad. Two pesticides with contrasting properties were selected: cypermethrin, a pyrethroid insecticide, and cyprodinil, a fungicide. The sorption tests were performed under controlled laboratory conditions (20±2°C), with equilibrium established after 72h. Sorption data were fitted with the Freundlich isotherm model, which showed well correlation ($R^2 = 0.989\text{--}0.999$). The Freundlich exponent (n) varied between 0.56 and 1.28, reflecting differences in sorption favorability depending on the applied amendment. Partition coefficients (K_d), determined at three relative equilibrium concentrations ($C_e = 0.01S_w$, $0.1S_w$, $0.5S_w$), ranged from 2.2 to 5.3, confirming the role of amendment type in regulating pesticide retention.

The results emphasize that pesticide retention is not governed by a single mechanism but rather by the chemical nature of both the pesticide and the amendment. While cyprodinil sorption was promoted through specific interactions, cypermethrin retention was driven mainly by hydrophobic forces. These variations underline the complexity of pesticide–soil amendment interactions and the importance of selecting amendment strategies tailored to the properties of individual pesticides.

Overall, the study demonstrates that biochar, sediment, and compost can substantially enhance pesticide sorption in soils, thereby reducing their potential mobility and leaching to groundwater. Such insights are essential for the design of sustainable soil management practices that both mitigate environmental contamination and preserve soil health.

Keywords: organic soil amendments, pesticide sorption, groundwater protection

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EFFICIENCY OF DOLOMITE WASTE IN RECLAMATION OF ACID SOILS

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ABSTRACT

Acid soil needs to be limed repeatedly as the bases added with lime are washed out of the soil in the humid northern hemisphere. The mining of dolomite rock for road construction produces large quantities of waste-by-product that can be used as lime material for the remediation of acidic soils. In 2015, a microfield experiment was launched in the Soil Remediation Laboratory of the Agrophysical Research Institute (Russia, St. Petersburg) to test the possibility of using large particles of dolomite chippings as a long-acting ameliorant stored in landfills. Dolomite particles with a size of 5-7 and 7-10 mm were investigated for 16-years, which were used in deliberately excessive doses.

A 10-variant micro-field experiment was carried out in polyethylene vessels without bottom (S = 1 m², depth 25 cm, weight – 300 kg of soil per vessel). The crops grown (peas and mustard) are sensitive to liming and characterized by a high demand for calcium and magnesium.

Increasing the dolomite grains from 5-7 and 7-10 mm to 3 full doses (3Hy) led to a significant increase in the recovery effect. Over the course of 16 test years, these ameliorants were able to keep the pH_{KCl} value of the soil in the medium and slightly acidic range.

The application of dolomite granules of 5-7 and 7-10 mm at a dose of 5 Hy enhanced the reclamation effect at pH values corresponding to slightly acidic and almost neutral values throughout the duration of the experiment.

The application of dolomite screenings at 5-7 and 7-10 mm in deliberately excessive doses can be considered as a technique that allows

the soil acidity to be kept constant over a long period of time, thus postponing the time for repeated liming.

The clustering of the individual test variants was carried out according to their effect on the pH_{KCl} value over the entire test period of 16 years.

Key words: micro-field experiment, dolomite waste, liming, acid soil

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THE EFFECT OF LIMING ON SOIL FERTILITY AND PLANT PRODUCTIVITY

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ABSTRACT

In a four year laboratory-pot experiment conducted on highly acidic sod-podzolic sandy loam soil, a comparative study was conducted of the fertilizing value and ameliorative properties of calcareous materials of carbonate nature (dolomitized limestone flour, dolomite flour, crushed stone screenings, chemically pure salt CaCO₃), ameliorants of silicate nature (blast furnace slag and shale ash) and brucites (ameliorants of hydroxide nature) with different content and ratio of CaO:MgO, introduced at a dose of 0.4 Hy (hydrolitic acidity)

Table 1. Chemical composition of ameliorants of various chemical nature

Ameliorant	CaO %	MgO %	SiO ₂ %
CaCO ₃ chemically pure	56.0	0	–
Conversion chalk (CC)	50.7	1.7	–
Dolomitized limestone flour (DLF)	44.7	4.3	–
Dolomite flour (DF)	30.4	21.0	–
Crushed stone screenings (CSS)	27.0	17.3	–
Blast furnace slag (BS)	39.7	19.7	38.5
Shale ash (SA)	42.1	4.2	27.1
Brucite (A category)	3.0	59.9	4.7
Brucite (C category)	11.4	49.7	5.1

It was found that the maximum effect on the change in pH, hydrolytic acidity and the content of mobile aluminum was achieved in the year of liming. Over the course of three years of plant cultivation, soil acidification was observed. However, the soil acidity indicators in limed variants do not reach the values in variants without liming.

Liming contributed to the enrichment of the soil with exchangeable cations of calcium and magnesium. The more of these elements in the composition of ameliorants, the higher their concentration in the soil. No reduction in calcium and magnesium reserves in the soil after three periods of plant cultivation was established

Liming led to the precipitation of mobile manganese in the soil already in the year of melioration. Starting from the second year of the experiment, an increase in the concentration of this element in the soil was established in all variants of the experiment. Regardless of the type of use of the ameliorant, liming had a restraining effect on the growth of the concentration of mobile manganese in the soil. The increase in the manganese content in the soil of the meliorated variants continued even three years after liming. The exceptions were the "control" variants, blast furnace slag, and brucite category A, where the manganese content remained at the same level.

In the year of the experiment, the introduction of lime-containing materials did not affect the content of mobile iron in the soil after harvesting rape. After two vegetation periods of plant cultivation, a tendency for the concentration of iron in the soil to increase was noted, which ceased after harvesting barley.

Based on the total productivity of plants over 4 years of the experiment, all variants can be arranged in the following ascending order: Control (without fertilizers) > Azofoska (Background) > Background + CC by 0.4 Hy > Background + DF by 0.4 Hy > Background + CSS by 0.4 Hy > Background + DLF by 0.4 Hy > Background + Brucite (cath. C) by 0.4 Hy > Background + DF by 0.4 Hy > Background + CaCO₃ > Background + SA by 0.4 Hy > Background + Brucite (cath. A) by 0.4 Hy.

Key words: sod-podzolic soil, acid-base properties, chemical melioration, carbonate, silicate and hydroxide ameliorants, plant productivity

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SOIL BIOLOGY AND ECOLOGY: SOIL BIODIVERSITY, SOIL ECOSYSTEM SERVICES

ECOFUNCTIONALITY OF SOIL ORGANIC MATTER: A NEW PARADIGM FOR SOIL SUSTAINABILITY

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ABSTRACT

Soil organic matter (SOM) plays a key role in maintaining soil productivity through its positive impact on physical, chemical, and biological soil processes. It supports vital ecosystem functions such as carbon sequestration, nutrient provision, and biodiversity. Despite its importance, current research on SOM tends to emphasize its chemical properties, often overlooking its broader ecological functions.

As global soils face mounting pressures and declining productivity, a paradigm shift is needed – one that redefines the conservation, management, and use of SOM in terms of its ecofunctionality. This concept encompasses the relationship between the characteristics of organic inputs and the specific ecosystem functions they sustain.

To move in this direction, we must first define the key traits of organic amendments that promote desired outcomes such as enhanced carbon storage, improved nutrient cycling, or disease suppression. Equally important is identifying which ecological functions require targeted improvement. In this context, SOM should not only be evaluated for its contribution to soil fertility, but also as a proxy for the health and resilience of the soil ecosystem—providing habitat, supporting biodiversity, enabling biogeochemical cycles, and contributing to soil formation and primary productivity.

In conclusion, ensuring long-term soil sustainability demands a shift in focus from chemical composition toward ecological function. Only by understanding and preserving soil ecofunctions can we truly safeguard this vital resource.

Key words: soil organic matter, ecofunctionality, ecosystem preservation

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SOIL MICROBIAL PROPERTIES ACROSS DIFFERENT LAND USE TYPES OF VOJVODINA PROVINCE

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ABSTRACT

Soil microorganisms participate in the processes of soil formation and in the processes necessary for soil ecosystem to function. Both arable and non-arable lands host diverse microbial communities that contribute to nutrient cycling, organic matter decomposition, carbon storage, plant growth regulation, and overall soil health and fertility. The abundance and diversity of soil microorganisms can vary considerably depending on the different land use patterns; however, the intricate drivers of these variations are not fully understood.

The aim of this research was to examine the microbial abundance and activity across seven land use types of Vojvodina Province. The soil collection included 1090 samples of croplands, 93 samples under forestlands, 80 samples under grasslands, 37 samples under gardens, 27 samples under orchards, 4 samples under vineyards, and 39 samples of non-arable lands. Soil samples were collected from the depth of 0–30 cm. The number of different systematic and physiological groups of microorganisms was determined using the indirect dilution method, while the activity of the dehydrogenase enzyme was assessed spectrophotometrically.

Investigated land use types generally had moderate to high microbial abundance and activity. The highest total bacteria, ammonifiers, and free nitrogen-fixing bacteria were observed in non-arable lands. Actinobacteria and azotobacters were most abundant in soils under gardens, whereas the most intensive development of fungi was observed in soils under vineyards. Moreover, the highest dehydrogenase activity was recorded in non-arable lands, followed by forestlands and grasslands. The microbial community differences among land use types may be associated to a great extent with various soil properties, particularly the soil pH, humus, and nutrient content. In addition, vegetation type may be an important factor promoting the number and activity of soil microorganisms, as well as minimal anthropogenic disturbance and beneficial interventions such as organic management and reduced tillage.

Key words: dehydrogenase, land usage, microbial number, soil health

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NATURE BASED SOLUTIONS TO RESTORE SOIL BIOLOGICAL QUALITY: INSIGHTS FROM A FIELD PLOT STUDY

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ABSTRACT

Soil contamination is increasingly prevalent due to urbanization and industrialization, often involving improper disposal of hazardous waste, which leads to a decline in soil health and ecosystem functioning. Nature-based remediation strategies, such as phytoremediation, are gaining attention as sustainable alternatives to conventional methods, offering economic and energy efficiency. These approaches leverage energy crops and their associated microbial communities to degrade, stabilize, or volatilize soil pollutants.

This study was conducted at the experimental field of the Regional Landfill Subotica-Bikovo to evaluate the effects of *Arundo donax* cultivation combined with sewage sludge application on soil biological properties. Soil samples were collected at two vegetation stages (March and October) from three plots and two soil depths (0–30 cm, 30–60 cm). Soil enzyme activities, functional bacterial group counts, and 16S rRNA gene copy numbers (by dPCR) were measured to assess microbial activity and biomass.

Results showed that surface soil (0–30 cm) exhibited significantly higher enzyme activities and bacterial counts compared to the deeper layer, with phosphatases and dehydrogenase showing up to four- to sixfold greater activity. Nitrogen-fixing and ammonifying bacteria were dominant, while nitrifiers and denitrifiers occurred at moderate levels. Fecal coliforms were detected in both depths, whereas *Salmonella* was present in only in surface layer in most cases. The abundance of 16S rRNA gene copies was higher in soils under *A. donax* and in cultivated soils compared to fallow soils, indicating enhanced microbial biomass due to plant cover and sludge treatment. The highest number of gene copies (3.5×10^9) was detected in the sample of soil under *A. donax*, and the lowest number of gene copies (7.42×10^7) was detected in soil sample from fallow land.

Overall, the combination of energy crop cultivation and organic soil amendments improved microbial activity, biomass, and nutrient cycling, particularly in the surface horizon. These findings suggest that integrating phytoremediation with circular economy principles can effectively restore soil biological and overall quality and support sustainable management of contaminated sites.

Key words: energy crops, enzyme activities, microbial communities, phytoremediation

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REPRODUCTION OF THE EARTHWORM *EISENIA FETIDA* IN SOILS AMENDED WITH SULFUR-LOADED ACTIVATED CARBON

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ABSTRACT

In the context of advancing circular economy practices in agriculture, this study assessed the soil-ecotoxicological safety and biological effects of sulfur-loaded activated carbon as a by-product of biogas desulfurization in agricultural biogas plants. Following OECD Guideline 222, a standardized earthworm reproduction test using *Eisenia fetida* (Savigny 1826) was conducted to evaluate adult survival, biomass development and reproductive output over eight weeks. Alongside the spent activated carbon (applied at two concentrations), three reference amendments (a mineral fertilizer containing magnesium, calcium, and sulfur, an organomineral microgranular fertilizer, and an alkaline humic acid extract) were included for comparison.

All test amendments showed no negative effects on survival or biomass. Instead, significant increases in juvenile production were observed across all treatments compared to the control ($p < 0.001$), with the organomineral fertilizer producing the highest reproductive output.

Differences between the optimal concentration of the sulfur-loaded activated carbon for plant growth (0.1% in soil) and a fivefold higher concentration were reflected in a 13% lower reproduction rate at the higher concentration, which was not statistically significant. Furthermore, variability in reproduction was lower at the 0.1% carbon level (SD = 38.6) compared to the treatments with 0.5% carbon (SD = 82.8).

Among the different treatments, a significant negative correlation between adult body mass gain and reproductive output was observed ($r = -0.57$, $p = 0.0036$), indicating a classical life-history trade-off.

The observed effects are likely driven by microbial stimulation, particularly during the early test phase, with spent activated carbon potentially acting as a microbial habitat, a nutrient source for sulfur, potassium, and sodium, and/or a redox-active biostimulant. These findings support the safe reuse of spent activated carbon in agricultural applications

and highlight its potential role in promoting soil biological activity within circular agricultural systems.

Key words: OECD 222, life cycle, humic substances, microgranular fertilizer, biogas, biostimulants

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MICROBIAL COMMUNITY IN ALFALFA RHIZOSPHERE IN RESPONSE TO INCREASED NICKEL CONCENTRATION

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ABSTRACT

Rhizosphere is a very active region containing many microorganisms involved in complex biological and ecological processes. Under adverse conditions such as trace element pollution, the rhizosphere of plants can modify the soil conditions and the effects of pollutants, promote plant growth and alleviate stress in plants. Alfalfa establishes effective nitrogen-fixing symbiosis with rhizobia. Besides nitrogen fixation, inoculation with rhizobial strains can result in promotion of the metal bioaccumulation within the root nodules in contaminated soil. Trace elements in the soil could be immobilized via their adsorption and/or accumulation in the plant roots and/or by bacteria in rhizosphere, resulting in reduction of their toxicity. To evaluate the effect of rhizobial inoculation of alfalfa on soil properties, two locations with different Ni content in the soil 195 mg/kg and 52 mg/kg, as well as 6 different rhizobial strains were tested. Concentrations of trace elements, total and available forms, as well as other chemical soil parameters were determined at the beginning and at the end of the vegetation period. Furthermore, the abundance and activity of specific groups of soil microorganisms in soils under the field experiment were evaluated: soil respiration, total number of microorganisms and the number of specific groups of soil microorganisms including fungi, Actinomycetes, oligonitrophiles, *Azotobacter* and ammonifiers.

Multivariate analysis of variance revealed a significant interaction between location and rhizobial strain used as inoculum on the total number of microorganisms, as well as number of specific groups of microorganisms including fungi, Actinomycetes and oligonitrophiles in the first and second year of the experiment, indicating that the effect of rhizobial treatment depended on the location. The soil properties also varied among treatments and the two locations. Some rhizobial treatments increased the soil respiration rate, total number of microorganisms in soil, as well as the number of one or more specific groups of microorganisms including oligonitrophiles, fungi, Actinomycetes, *Azotobacter* and ammonifiers, compared to the control.

Key words: alfalfa, soil quality, trace elements, microbial community

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NATIVE *BACILLUS THURINGIENSIS*: A PROMISING BIOCONTROL AGENT AGAINST WIREWORMS

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ABSTRACT

Wireworms, the larval stage of click beetles (*Agriotes lineatus*), represent a persistent threat to cereal crops, particularly wheat. Their subterranean lifestyle, prolonged life cycle, and wide host range make them especially difficult to manage through conventional control strategies. Chemical treatments often show limited efficacy due to uneven soil distribution, restricted translocation, and growing concerns over environmental and non-target effects. As such, sustainable and biologically-based alternatives are urgently needed. One promising avenue in integrated pest management is the use of entomopathogenic bacteria, particularly *Bacillus thuringiensis* (*Bt*). This Gram-positive, spore-forming bacterium is known for producing insecticidal crystal proteins (Cry toxins) during sporulation, which have been widely applied in the control of lepidopteran, coleopteran, and dipteran pests. The *cry11* gene encodes a δ -endotoxin typically active against dipteran larvae, yet recent studies suggest it may have broader insecticidal potential depending on the strain and target species. In this study, we investigated the presence of the *cry11* gene in three native *B. thuringiensis* soil isolates (BHC 2.4, BHC 4.5 and BHC 4.7) using polymerase chain reaction (PCR), with the aim of identifying strains with potential bioinsecticidal activity against wireworms. The *cry11* gene was successfully detected in strain BHC 2.4, highlighting its potential as a candidate for further biological testing and application in wireworm management. Our findings contribute to the growing body of research focused on the development of locally adapted, environmentally friendly biopesticides. Further bioassays and field trials will be necessary to confirm the efficacy of *cry11*-positive strains against wireworm populations in wheat agroecosystems.

Key words: *Bacillus thuringiensis*, *cry11*, wireworms, wheat, biocontrol

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APPLICATION OF *METHYLOBACTERIUM SYMBIOTICUM* SB 23 IN CORN PRODUCTION UNDER TWO LEVELS OF NITROGEN

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ABSTRACT

The application of plant growth-promoting microorganisms represents a promising strategy for enhancing crop productivity and sustainability. *Methylobacterium symbioticum*, a naturally occurring endophytic bacterium, has shown the ability to stimulate plant growth, improve nutrient uptake, and increase tolerance to environmental stress. This bacterium enhances corn growth by stimulating biological nitrogen fixation and improving the plant's ability to utilize available N more efficiently. The aim of this study was to examine the effectiveness of *Methylobacterium symbioticum* SB 23 (MS) in corn production under two levels of nitrogen in the agroecological conditions of Vojvodina.

The field experiment was conducted in 2022 using a randomized block system design in four replicates. The experimental plot is classified as Calcic Chernozem soil. Following treatments were investigated: 1. Control without N fertilization; 2. 170 kg N ha⁻¹; 3. 170 kg N ha⁻¹ + MS; 4. 85 kg N ha⁻¹; 5. 85 kg N ha⁻¹ + MS; 6. MS. Standard agrotechnical measures were applied on all experimental plots. The biostimulant containing *Methylobacterium symbioticum* SB 23 (Utrisha N, Corteva Agriscience Biologicals) was foliar applied at the 5–7 leaf stage of corn at a dose of 300 g ha⁻¹ (200 L water ha⁻¹).

Table 1: The average weight grain per cob, average number of columns per cob, average number of rows per cob, and total grain yield.

Treatments	Weight of the grain per cob [g]	Number of columns per cob	Number of rows per cob	Grain yield [kg ha ⁻¹]
Control	145,38	16,19	32,38	8 126
170 N	159,56	15,95	33,55	8 920
170 N+MS	162,23	15,75	34,22	9 069
85 N	154,25	15,78	32,63	8 623
85 N+MS	157,31	16,05	33,65	8 794
MS	149,73	15,92	32,57	8 370
*LSD _{0,05}	11,52	0,52	2,06	644

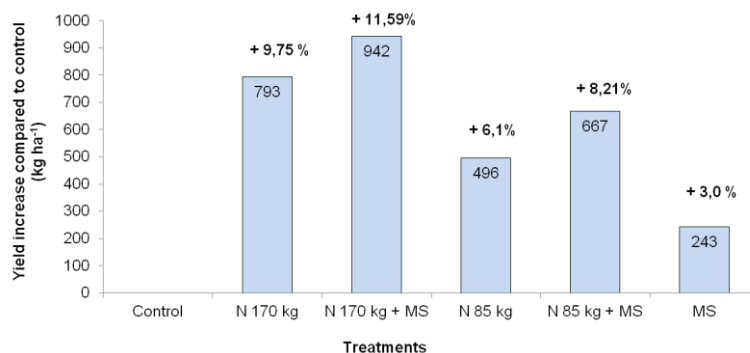


Chart 1. Yield increase (%) compared to control

The results indicate that the application of *Methylobacterium symbioticum* SB 23 in combination with N fertilization can significantly enhance corn grain yield. Notably, the use of MS allowed for improved efficiency of N utilization, suggesting the potential to reduce N inputs while maintaining or even increasing productivity. Such practices can enhance the sustainability of crop production by lowering the environmental footprint of mineral fertilizers and supporting long-term soil and ecosystem health.

Key words: biostimulant, plant growth-promoting bacteria, sustainable agriculture, biofertilizer

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THE EFFECT OF PRE-INOCULATION ON WHEAT SEED PROTECTION

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ABSTRACT

Pre-inoculation of seeds allows farmers to avoid daily inoculation, to focus on sowing and protecting seeds in the earliest period of seed germination. By using pre-inoculated seeds, farmers save time during sowing and reduce manpower requirements. Pre-inoculated seeds maintain bacterial viability for as long as possible, and this depends on a number of factors. The long-term viability of bacterial cells on pre-inoculated seeds depends on the bacterial species and the ability of the bacteria to survive in specific conditions, as well as the adhesive substances and cell protectors in the inoculant formulation. Inoculation is more common with liquid fertilizers than with inoculants that act as biopesticides. In this study, the bacterial strain *Priestia megaterium* BHC 5.5 was used for pre-inoculation of wheat seeds and protection of seedlings against *Fusarium poae*. In our previous research, the bacterial strain BHC 5.5 showed the ability to suppress the growth of the phytopathogenic fungus *F. poae*. Two hundred wheat seeds were soaked in a bacterial suspension (50 mL, 10^9 CFU mL⁻¹) for 5 minutes and then allowed to air dry. The dried seeds were stored at 22°C for periods of 0, 1, 2 and 3 months. Pre-inoculated seeds (20 seeds per treatment) without and with *F. poae* infection were placed monthly in Petri dishes on moist filter paper. Infection of pre-inoculated seeds was performed by placing the seeds in a Petri dish with *F. poae* for 10 minutes. In addition, the germination of uninoculated and infected uninoculated seeds was done in same manner. Petri dishes were kept for one week in a transparent sealed box. Final seed germination percentage (FG %) was calculated: germinated seeds in samples / total planted seeds x 100. The relative seed germination index (RSGI%) was calculated as follows: germinated uninfected pre-inoculated seeds/ germinated infected pre-inoculated seeds x 100. In each month, the pre-inoculated wheat seeds showed FG of 100%, except for the germination of seeds stored for two months (90%). The final seed germination percentage of the infected pre-inoculated seeds were 90%, 85%, 70% and 55% of the seeds stored for 0, 1, 2 and 3 months, respectively. The RSGI of the infected pre-inoculated seeds was the same as the FG for seeds stored for 0, 1 and 3 months. For

the pre-inoculated seeds for 2 months, the RSGI was 77%. The FG of the infected seeds was only 40%.

Pre-inoculation of wheat seeds with the bacterial strain *P. megaterium* BHC 5.5 provided protection to the seeds and increased germination from 40% to 85% in the treatment where the pre-inoculated seeds were stored for one month. Pre-inoculation two months before sowing also showed satisfactory results in wheat seed protection. Further research will include the development of inoculant formulation with BHC 5.5 as a biocontrol agent in the protection of pre-inoculated wheat seeds.

Key words: pre-inoculation, wheat seed, *Priestia megaterium*, seed germination, *F. poae* biocontrol, seed protection

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MICROBIAL COMMUNITIES IN SUSTAINABLE SOYBEAN PRODUCTION SYSTEMS UNDER WINTER COVER CROPPING

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ABSTRACT

Cover cropping is a cornerstone practice in sustainable agriculture, offering numerous benefits that support soil health. In organic and low-input production systems, where the synthetic inputs are minimized, cover crops provide key ecosystem services, including the addition of organic matter, promotion of nutrient cycling, and improvement of soil structure. Cover crops also shape soil microbial community composition due to diverse root exudates and decomposition products. The increased diversity of beneficial microorganisms, triggered by cover crops, could aid the main crop's rhizosphere as a hotspot of complex interactions between plants, soil, and microorganisms. Better understanding and optimizing these interactions is needed to empower agro-biodiversity and crop performance in the face of climate change.

This research aimed to assess the impact of winter cover crops, namely peas and oats (P+O) and rye (R), on rhizosphere microbial communities of soybeans grown under organic (OP) and low-input production (LIP). The effect of cover crops was compared to the plots with only soybeans (control). Trials were established according to a complete block design in four replications. Soil was slightly alkaline, Calcareous Chernozem but differed in the content of humus (medium – OP, low - LIP) and available phosphorus (poor - OP, optimal - LIP). Extreme drought and high temperatures during the experimental year (2022) were unfavorable for major field crops, including soybean. Rhizosphere samples were collected at full flowering (R2) and full maturity (R8) of soybean, and the values from two samplings were averaged. Microbial abundance was determined using the indirect dilution plate method, while dehydrogenase and β -glucosidase activity were analyzed spectrophotometrically.

Cover cropping significantly increased total microbial number (P+O), ammonifiers (R, P+O), and β -glucosidase activity (P+O, R) in the soybean rhizosphere. A shift in abundance of fungi (P+O), actinomycetes (R), and dehydrogenase activity (R, P+O) was also observed. Moreover, total

microbial number and β -glucosidase activity varied significantly depending on the production system, with OP in advance of LIP. Similarly, abundances of ammonifiers and actinomycetes were higher in OP compared with LIP, while the opposite was observed for N-fixers, fungi, and dehydrogenase. This research indicated that integration of cover crops in sustainable production systems could influence the rhizosphere environment of the main crop differentially, promoting the beneficial microbial communities involved in nutrient cycling and organic matter decomposition. This could potentially mitigate the negative effects of drought on desirable microbiological processes in the soil and contribute to the overall productivity and resilience of soybean production.

Key words: agro-biodiversity, drought, rhizosphere microorganisms, soil cover, soybean

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NEW BRADYRHIZOBIUM STRAINS ENHANCE SOYBEAN NODULATION IN SOILS OF DIFFERENT FERTILITY

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ABSTRACT

The legume–rhizobia symbiotic N₂ fixation is considered the most efficient and important process in crop production. Besides their potential to reduce atmospheric nitrogen, rhizobia accomplish various PGP (Plant Growth Promoting) activities such as phosphate solubilization, siderophore and phytohormone production, thus improving nutrient availability, soil structure and fertility, and crop productivity. Utilizing rhizobial inoculants is a low-cost and highly efficient approach that reduces inputs of synthetic fertilizers while promoting sustainable agricultural and environmental stability. To improve inoculation success, it is crucial to continuously investigate native rhizobia populations as an inexhaustible source of superior strains with an enhanced adaptability to specific agricultural environments. This research aims to characterize *Bradyrhizobium* strains with high plant growth-promoting properties for potential use as bioinoculants for soybean.

Bradyrhizobium japonicum strains (33) were obtained from the collection of the Laboratory for Microbiology of the Institute of Field and Vegetable Crops. These strains were originally isolated from root nodules collected from different soybean cultivars and locations in Vojvodina province. The qualitative estimation of *Bradyrhizobium* strains for phosphate solubilization and mineralization ability and siderophore production was performed *in vitro* on appropriate media. The Salkowski reagent colorimetric method was used for quantitative determination of indole-3-acetic acid (IAA). Based on PGP traits, 10 strains were selected for the inoculation experiment in pots to examine the effect on soybean root nodulation in soils of high and low fertility. In a full bloom stage of soybean, the number and dry weight of nodules were assessed.

This study revealed that all strains synthesize IAA, with concentrations ranging from 8.97 µg/mL to 41.17 µg/mL. Isolates Bj2, Bj4, Bj6, and Bj8 produced the highest amount of IAA. Among tested strains, 12 showed phosphate mineralization and only five phosphate solubilization abilities. However, the solubilization and mineralization activities varied, with the

highest diameter of the halo zones formed in strains Bj1, Bj4, Bj7, Bj18, and Bj24. The appearance of yellow-orange zones indicated siderophore production in 16 *Bradyrhizobium* strains, and the best producers were Bj1, Bj2, Bj6, Bj12, and Bj21. All strains were able to successfully induce nodulation on soybean roots in both high- and low-fertility soils. However, inoculation with Bj1, Bj2, Bj4, Bj6, Bj7, and Bj8 achieved the highest score according to the nodulation scale.

Although this research confirmed promising PGP and symbiotic potentials of indigenous *Bradyrhizobium* strains, extensive field studies are required to evaluate their efficiency for further bioinoculant development.

Key words: *Bradyrhizobium*, inoculation, nodulation, PGP properties, soybean

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OPPORTUNITIES AND LIMITATIONS OF MICROBIAL INOCULANTS IN MAIZE: INSIGHTS FROM NINE YEARS OF FIELD TRIALS

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ABSTRACT

The application of biostimulants in the form of microbial inoculants (MIs) has been an intensively studied topic for decades. In agricultural practice, however, the adoption of MIs has progressed at a much slower pace. A major reason is the considerably higher inconsistency of their effects on yield, soil microbiomes, and nutrient regimes under field conditions compared to the many promising results obtained under laboratory or greenhouse settings.

To fully exploit the potential of MIs, predictors are needed that allow for a more reliable assessment of their effects under practical conditions. Our data from nine years of field trials at five different study sites with MIs in silage maize cultivation highlight the crucial relevance of microbial analyses beyond standard soil analytics. Traditional soil analysis, focusing solely on nutrients and water, proved insufficient as a predictor of MIs' effects on yield. Instead, the composition of the autochthonous soil microbiome determined the outcome of MIs application. In particular, the relative abundances of *Firmicutes*, *β-Proteobacteria*, and total fungi emerged as the most important predictors in our recent experiments.

Furthermore, we observed that the combined use of MIs with in-furrow starter fertilizer frequently neutralized or even reversed the positive effects of inoculant application. Drought conditions further exacerbated these negative interactions or led to the complete absence of measurable effects.

With this contribution, we aim to discuss both the opportunities and limitations of MIs application and to emphasize the need for developing effective microbial soil analytics that go beyond conventional nutrient analyses and give due attention to microbial parameters.

Key words: plant-growth promoting bacteria, biostimulants, soil microbiome, drought

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SOIL FERTILITY AND PLANT NUTRITION: ORGANIC MATTER, NUTRIENTS CYCLE, PLANT NUTRIENT STATUS

COMPARISON OF INSTRUMENTAL METHODS (UV-VIS AND ICP-OES) FOR DETERMINATION OF AVAILABLE SOIL PHOSPHORUS

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ABSTRACT

Phosphorus is a vital biogenic element whose availability in soil plays a key role in agricultural productivity. Determination of plant-available phosphorus is therefore a standard component of agrochemical soil testing, essential for assessing fertility and providing fertilization recommendations. In the Republic of Croatia, the AL extraction method is most commonly applied. This study compares two analytical techniques: UV-VIS spectrophotometry and ICP-OES for quantifying plant-available phosphorus in soil, while also evaluating the influence of soil physicochemical properties on measurement outcomes.

A total of 165 soil samples were analyzed, representing nine systematic soil units across seven soil types. Results revealed high variability among samples. The actual soil pH (H₂O) ranged from 4.77 to 8.75, potential acidity (pH KCl) from 3.27 to 7.91, organic matter content from 0.83% to 11.8%, clay content from 1.83% to 58.86%, and cation exchange capacity (CEC) from 7.01 to 65.87 cmol(+) kg⁻¹. Phosphorus availability, expressed as P₂O₅, ranged from 2.14 to 186.3 mg/100 g (UV-VIS) and from 1.65 to 188.8 mg/100 g (ICP-OES). A strong positive correlation was observed between the two analytical methods (Chart 1.).

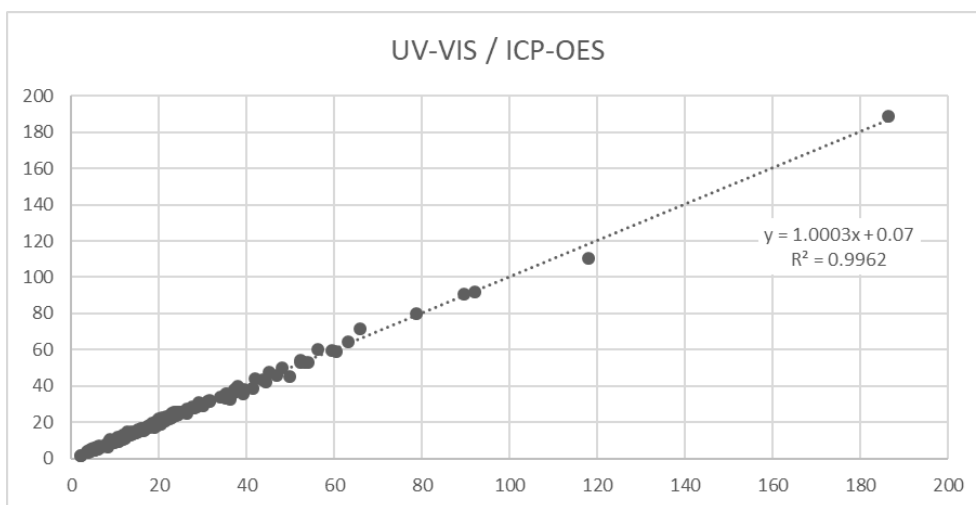


Chart 1. Correlation of UV-VIS and ICP-OES methods for available phosphorus determination

These findings confirm that both UV-VIS and ICP-OES are suitable techniques for determining plant-available phosphorus in soils. However, ICP-OES offers advantages in terms of analytical speed, standardization, and interlaboratory comparability, thereby representing a valuable tool for modern soil fertility diagnostics.

Key words: soil analytical techniques, method comparison, soil fertility

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ATR-FTIR SPECTROSCOPY AS A COMPLEMENTARY METHOD FOR IDENTIFYING ARTIFICIAL FERTILIZERS

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ABSTRACT

Complementary analytical methods are crucial for the qualitative assessment of mineral fertilizers commonly applied in agriculture. In this study, both reference substances and fertilizer samples were analyzed using the ATR-FTIR technique. Pure compounds such as ammonium sulfate, potassium sulfate, and calcium sulfate heptahydrate were first recorded as standards to establish a reference spectral library. Fertilizer samples were ground to a fine powder (<1 mm) and placed on the diamond crystal surface for spectral measurement. The obtained absorption spectra enabled identification of the main components present in the fertilizers and provided a clear comparison with the standard spectra. Although the method allows only qualitative determination of compounds, comparison with the recorded standards provides valuable insights into the composition of the investigated samples. This approach is particularly useful when rapid screening of fertilizers is required without the need for time-consuming wet chemistry analyses. The results demonstrate that ATR-FTIR spectroscopy can serve as a reliable complementary method for routine fertilizer testing, ensuring both quality control and detection of possible adulteration or impurities. Furthermore, when combined with conventional laboratory techniques such as titrimetry, AAS, or ICP-OES, the method contributes to a more comprehensive and accurate characterization of fertilizer composition, ultimately supporting sustainable agricultural practices.

Key words: fertilizers, ATR-FTIR spectroscopy, spectral standards, qualitative analysis

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FERTILITY OF LIGHT CHESTNUT SOILS OF KAZAKHSTAN AND ITS CHANGES UNDER LONG-TERM APPLICATION OF FERTILIZERS

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ABSTRACT

The southeastern region of Kazakhstan is one of the country's major agricultural areas. The diversity of natural and climatic conditions in the region determines its division into several natural-economic zones. The studied foothill light chestnut soils are located at elevations of 700–1000 m above sea level in the foothill desert-steppe zone and occupy an area of about 28 million hectares. Annual precipitation ranges from 250 to 350 mm.

The foothill light chestnut soils are characterized by a low content of humus (2–3%) and total nitrogen (0.10–0.20%), as well as by a relatively narrow carbon-to-nitrogen ratio in humus (C:N = 7–10).

The research focused on assessing the anthropogenic transformation of irrigated light chestnut soils as a result of the systematic application of fertilizers. The most valuable information in this regard comes from long-term stationary experiments, which were established as early as 1961.

Studies have shown that with the long-term cultivation of crops in an eight-field sugar beet rotation without the application of fertilizers, the humus content in the arable layer decreased by 0.37% compared to the initial level, and in the subarable layer by 0.34% (Tab. 1). With the systematic application of a complete mineral fertilizer, the humus content in the upper soil layer by the end of the fifth rotation decreased by only 0.10% compared to the initial level and amounted to 2.50%, while in the lower layer it decreased by 0.15%. When a complete mineral fertilizer was applied together with 60 t/ha of manure once per rotation, the humus content in the upper soil layer increased by 0.09% compared to the initial level and reached 2.69%. In the lower soil layer, the humus content also decreased during this period, but to a lesser extent than in the unfertilized variant (Tab. 1).

Phosphorus is one of the most important nutrients for plants, and its deficiency negatively affects crop growth, yield, and drought resistance. Low levels of available phosphorus in southeastern Kazakhstan soils significantly limit crop productivity. In a stationary experiment, the initial content of available phosphorus in the upper soil layer was 24.0 mg/kg. After five crop

rotations without fertilization, it decreased by 7.1 mg/kg in the upper and 5.5 mg/kg in the lower layer. With systematic mineral fertilization, phosphorus pentoxide reached 39.7 mg/kg in the upper 0–20 cm layer, and 52.3 mg/kg when mineral and organic fertilizers were combined, with increases also noted in the 20–40 cm layer.

Table 1: Change in Humus Content in Irrigated Light Chestnut Soils under Long-Term Systematic Application of Fertilizers (over 40 years)

Variant	Humus content in soil layers					
	0–20 cm		20–40 cm		20–40 cm	
	[%]	±	[%]	±	[%]	±
Initial content	2.60	-	2.50	-	2.55	-
Third rotation						
Without fertilizers	2.27	-0.33	2.17	-0.33	2.22	-0.33
NPK	2.53	-0.07	2.34	-0.16	2.44	-0.11
Manure 60 t/ha + NPK	2.83	-0.03	2.47	-0.03	2.65	0.10
Fifth rotation						
Without fertilizers	2.23	-0.37	2.19	-0.34	2.20	-0.35
NPK	2.50	-0.10	2.35	-0.05	2.57	-0.01
Manure 60 t/ha + NPK	2.69	0.09	2.45	-0.05	2.57	0.02

Light chestnut soils are well supplied with exchangeable potassium, but long-term cultivation without potassium fertilizers decreases its content. By the fifth rotation, fertilization increased potassium by 76 mg/kg in the upper and 54 mg/kg in the lower layer, while mineral fertilizers with manure raised it by 240 and 247 mg/kg, respectively. Fertilizers improved the nutrient regime of irrigated light chestnut soils, raising crop productivity in the sugar beet rotation.

In recent years, more attention has been given to diagnosing and systematizing anthropogenically disturbed soils. This research direction is driven by the environmental crisis from irrational chemical use in agroecosystems and the growing role of soil cover as a regulator of natural-economic ecosystems.

Key words: light chestnut soil, fertilizers, humus, phosphorus, potassium

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SPATIAL VARIABILITY OF SOIL PROPERTIES UNDER FRUIT ORCHARDS IN THE KUMANOVO REGION

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ABSTRACT

This study presents the results of soil analyses conducted on 22 samples collected from 11 locations under fruit orchards in the Kumanovo region. The orchards included various fruit crops (apples, pears, plums, peaches, apricots, cherries, sour cherries, walnuts, and hazelnuts). Samples were taken at depths of 0-30 cm and 30-60 cm, corresponding to the primary rooting zone of fruit trees. The analyses focused on key soil properties: mechanical composition, pH of the soil solution, carbonate content, humus, total nitrogen, available forms of phosphorus (P_2O_5) and potassium (K_2O), and electrical conductivity. Data on natural soil forming factors such as parent material, relief, and climate were also collected. Due to deep plowing, an anthropogenic P-horizon was formed, classifying the soils as Rigosols. Laboratory analyses were performed using standardized methods in an accredited laboratory (Soil and Fertilizer Laboratory L-04, Faculty of Agricultural Sciences and Food). The soils at 0-30 cm depth were predominantly sandy clay loam (37%), with smaller proportions of sandy loam (9%), clay, clay loam, and sandy loam (each 18%). At 30-60 cm, clay and sandy loam were each present in 28% of samples, followed by clay loam and sandy clay loam (18%), and loam (8%). Humus content ranged from low to moderate, with mean values of 2.29% (0-30 cm) and 1.42% (30-60 cm). Soil reaction varied from neutral to strongly alkaline. Elevated electrical conductivity values indicated excessive fertilization, supported by high levels of available P_2O_5 and K_2O . The classification used for these properties was cited from Mitkova & Markoski (2022). Carbonates were absent in only two samples; in the rest, $CaCO_3$ content ranged from 2.10% to 19.99% (0-30 cm) and 2.40% to 20.41% (30-60 cm), classifying the soils as weakly to highly calcareous according to Penkov (1996). All results were statistically processed, and spatial distribution maps of the analyzed properties were generated.

Key words: Rigosols, mechanical composition, chemical properties, distribution maps.

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SOIL FERTILITY AS ONE OF THE ELEMENTS OF YIELD STABILITY AND ECONOMIC JUSTIFICATION IN CROP PRODUCTION

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ABSTRACT

Climate, soil properties, and soil management practices are key factors that affect plant production and overall soil fertility and health. Various activities within intensive agriculture, such as excessive use of chemical fertilizers and removing crop residues, degrade soil quality, alter soil organic matter contents, lead to nutrient losses, and contribute to other obstacles to environment and human well-being. Tailored fertilizer recommendations for desired crop yield, based on knowing the exact status of soil nutrients, are crucial in achieving higher and more stable yields for specific conditions, along with efficient resource use, reduced negative environmental impacts and economic costs.

This research presents the current status of soil fertility in the agroecological regions of the AP Vojvodina: Bačka (three districts) and Banat (three districts). As key yield determinants, the content of readily available phosphorus and potassium, and humus content were analyzed. The presented results are from the *Agroveles* company database.

Adequate phosphorus levels (15 – 25 mg 100 g⁻¹ soil) were recorded on 24.11% areas in Northern Bačka and 44.62% areas in Western Bačka, as well as on 12.38% and 56.92% areas in Central Banat and Southern Banat, respectively. The highest phosphorus surplus was recorded in South Bačka on 50.50% areas. In North Banat, harmful phosphorus levels were determined on 30.12% of the tested areas. Very low and low phosphorus levels were recorded on 20.95% and 24.76% areas in Central Banat, respectively. Also, very low phosphorus level was observed on 1.54% areas in Western Bačka, and low level on 10.64% areas in Northern Bačka.

In Banat, the adequate potassium content (15 – 25 mg 100 g⁻¹ soil) was observed on 11.35% and 72.31% areas in Northern and Southern districts, respectively. Moreover, the highest surplus of potassium was recorded in the Northern Banat on 64.72% of the examined areas. In Bačka, the adequate levels of potassium were observed on 21.92% and 46.10% areas in Western and Northern Bačka, respectively. Within the investigated areas,

the harmful level of potassium ranged from 9.93% in Northern Bačka to 25.71% in Central Banat.

High humus content, above 4%, was recorded on plots with applied manure and/or plowed crop residues. The most areas with high humus content (63.32%) was registered in South Bačka. Conversely, very low humus content, less than 1%, was determined in soils where these measures were not applied. The majority of these areas (0.76%) were registered in Western Bačka.

These results highlight the importance of monitoring soil fertility and improving soil management through balanced fertilization and organic matter incorporation as the basis for high yields, sustainable, environmentally friendly, and economically justified agricultural production.

Key words: fertilizer recommendations, nutrient levels, crop productivity

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DOES ORGANIC AGRICULTURE AFFECT SOIL QUALITY ON CHERNOZEM?

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ABSTRACT

Agricultural soils are affected by applied agrotechnical measures, resulting in change in soil health. Conventional agriculture, usually is linked to intensive tillage, application of different range of chemical protection products, and mostly only mineral fertilizers, resulting in high crop yield. However, organic farming practices includes reduced tillage, wide range of soil protection measures, as growing cover crops, intercrops and use of organic fertilizers and microbial preparations that positively affect soil health, specially on low quality soils. The aim of this research is to compare the effect of organic and conventional agriculture on Chernozem soil in comparison to soil fertility 15 years later.

Soil samples was collected from 10 location under conventional and organic farming in Vojvodina, Serbia, in two periods; first in 2005/6 and second in 2019/20.

Soil on the all farms belongs to loam/clay loam Chernozem. In order to determine the impact of production systems on soil fertility, for each investigated farm we selected plots in organic production (3-5 per site) and conventional production (1-2 per site). If there were no plots with conventional production system on the organic farm for comparison, samples were taken from the nearest neighboring farms. Soil samples were taken from the surface layer of soil (0-20 cm).

Soil analyses were done in the laboratory of the Department of Field and Vegetable Crops, Faculty of Agriculture in Novi Sad. We used the following methods for the determination of basic soil fertility parameters: SOC content was determined by Tjurin, modification Simakov, contents of available phosphorus and potasium by AL method. Statistical data was performed using two-factorial analysis of variance using Statistica. The first factor was year and the second was system of production (organic and conventional).

Significant differences in soil fertility between organic and conventional production, in average for all sites were not determined in 2005/2006. A short period of time (2-4 years) from switching to organic production was

not long enough, that the positive effects of organic production are reflected in soil fertility.

The results of soil fertility analyzed 15 years later have not shown significant differences in soil parameters compared to initial status, except pH values, which is lower on both organic and conventional farms 15 years later. Regarding SOC, there is a trend in its accumulation under organic farming systems due to use of organic fertilizers, reduced tillage and specific crop rotation with legumes, intercrops etc. On the other hand SOC under conventional farming is reduced but not significantly.

In conclusion, organic farming production showed that soil fertility parameters are maintained or to some extent improved due to agrotechnical measures that are oriented to sustainable soil use.

Key words: organic farming, conventional farming, chernozem

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INOCULANT FORMULATION: EFFECTS OF ZEOLITE ADDITIVES ON ALFALFA AND RHIZOBIAL SYMBIONT

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ABSTRACT

Inoculants containing rhizobial bacteria are bio-inoculants which represent microbiological N fertilizer and they contain selected highly effective and highly competitive rhizobial bacteria placed in suitable carrier. The role of carrier is to maintain the viability and efficiency of bacteria used as active agent and to increase the shelf life of inoculant. The most widespread formulation consists of peat as the rhizobia carrier and formulations of inoculants using zeolites as additives are common. Nanogranulation of the zeolite by increasing its surface would enhance its water and nutrients retention efficiency in the layer of the inoculant on inoculated seeds, making the bacteria more resistant to desiccation causing nano-carriers superiority over other carriers. In this study, 15 different inoculants were tested, five highly efficient nitrogen-fixing rhizobial *Ensifer meliloti* strains named 218, 225, 252, 4148s and 4193cs in three different peat carriers, including peat carrier with regular zeolite, zeolite nanoparticles, or CaCO₃. The initial number of rhizobial cells of all strains exceeded 10⁹ in all formulations. After one month of storage at room temperature the number did not differ significantly among strains and formulations but after two months the number was the higher in formulation with zeolite nanoparticles >10¹⁰ for strains 252 and 4148s. This trend continued in the next 6 months. The nodulation ability and efficiency of inoculants was confirmed in the nodulation test with alfalfa after three and six months of storage, indicating good performance of all evaluated inoculant formulations, with the most performant nano zeolite as an additive.

Key words: alfalfa, soil quality, zeolite, peat, carrier

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THE ROLE OF ZEOLITES AND ORGANO-MINERAL FERTILIZERS IN SUSTAINABLE SOIL FERTILITY MANAGEMENT

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ABSTRACT

Soil represents an irreplaceable resource whose fertility and health directly determine the sustainability of agroecosystems, yet in Serbia and the surrounding region it is increasingly threatened by severe degradation processes. Analyses reveal a significant decline in soil organic matter, acidification, erosion, and contamination, all contributing to reduced productivity and substantial economic losses. It is estimated that nearly 80% of agricultural land is affected by some form of degradation, while climate change further exacerbates these trends. Under such conditions, the introduction of sustainable fertility management strategies is essential, relying on the preservation of soil organic matter, the integration of organic and mineral fertilization, crop rotation, and precision agronomic practices.

This study devotes particular attention to zeolites, natural aluminosilicates whose unique porous structure markedly improves both the physical and chemical properties of soils. Their exceptional water retention capacity enhances crop resilience to drought, while their high cation exchange capacity allows for nutrient binding and gradual release, thereby reducing nitrogen and phosphorus losses. Furthermore, zeolites play an important ecological role by adsorbing heavy metals and contaminants, contributing to agroecosystem safety.

Organo-mineral fertilizers represent an innovative tool that combines the advantages of mineral and organic components, ensuring a controlled release of nutrients, long-term humus accumulation, and the improvement of soil structure. Within this framework, the study highlights organo-mineral formulations with zeolite, such as ZeoPullus and ZeoGrape, whose application leads to yield increases and enhanced soil microbial activity. Of particular importance is their synergy with zeolites, which ensures more efficient nutrient use, humus stabilization, and improved soil resistance to environmental stressors.

Although the results of applying zeolites and organo-mineral fertilizers are highly promising, it is important to note that their effects may vary depending on soil type, application rate, climatic conditions, and cultivated crop. Integrated use of zeolites and organo-mineral formulations constitutes

a key strategy for restoring soil fertility and ensuring the long-term sustainability of agriculture in Serbia and the wider region, with the potential to significantly enhance productivity and resilience to climate-induced challenges.

Key words: soil fertility, zeolite, organo-mineral fertilizers, sustainable agriculture

REBUILDING THE NITROGEN CYCLE WITHOUT EXTERNAL INPUTS: THE LOGINEKO MODEL

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ABSTRACT

Nitrogen (N) is the principal yield-limiting nutrient in agricultural systems, with management challenges being particularly important in organic production and most pronounced in livestock-free systems, where no manure or other animal-origin amendments are applied. Designing efficient N-cycling strategies is therefore essential for sustaining yields and maintaining long-term soil fertility.

Our initial nitrogen management strategy relied on green-manure winter pea (*Pisum sativum* L.) terminated at full flowering. This practice increased subsequent wheat yields by 38.8% to 120% compared with unfertilized controls. However, in the semi-arid conditions of northern Serbia, incorporating large biomass in late spring depleted soil moisture reserves, making it impossible to establish a second commercial crop in the same season due to unfavourable precipitation distribution.

To address these constraints, we shifted focus to winter-hardy grain legumes, mainly field pea and faba bean (*Vicia faba* L.), valued both for high-protein yields and residual N benefits to subsequent non-legumes. Within this redesigned model, diverse rotations combine strong BNF legumes with crops of varying nitrogen demand and rooting depth. We established a functional rotation system with several crop sequences; one example is winter pea–winter cereal (e.g. wheat, oats)–winter flax–chickpea–sunflower. Cereals following legumes act as high N-demand crops and contribute to weed suppression by limiting emergence and reducing the seedbank. On average, the grain harvest of oats removes about 74 kg N ha⁻¹, while flax (*Linum usitatissimum* L.) removes around 41 kg N ha⁻¹, providing high-value oilseed with a lower nitrogen drain.

Secondary legumes such as chickpea (*Cicer arietinum* L.), genetically distinct from peas and faba beans, reduce the risk of legume fatigue by breaking the presence of closely related legumes in the rotation. Despite limitations in symbiotic performance with native *Mesorhizobium* strains, chickpea contributes 30–60 kg N ha⁻¹ through crop residues. This residual nitrogen is particularly valuable for the following deep-rooted sunflower (*Helianthus annuus* L.) crop, which not only scavenges nutrients from deeper soil horizons and disrupts weed cycles, but also serves as a high-

value cash crop positioned at the end of the rotation to capitalize on improved nutrient availability and reduced weed pressure.

Soil management practices are adapted to Pelic Vertisols (>80% total clay, <5% macropores, k-Darcy 10^{-5}), with periodic subsoiling to improve mineralization, infiltration, and rooting, and moldboard ploughing once every five years to incorporate surface residues containing pathogen inoculum into deeper layers. All crop residues are returned to the soil to sustain organic matter inputs and stimulate biological nutrient cycling. Efficient integral weed control, requiring consistent and disciplined application in every production season, is a cornerstone practice for minimizing nitrogen competition and sustaining high nitrogen use efficiency (NUE).

From 2021 to 2025, soil mineral N (NO_3^- -N, NH_4^+ -N) was monitored across rotation phases and sites on more than 8,000 samples. Although short-term N-min assessments often showed modest values, reflecting the transient nature of mineral N pools in organic systems, yields of our key crops showed a consistent upward trend over this period. Ordinary Least Squares regression analysis revealed a positive yield trend for both sunflower and wheat over the analyzed period. Wheat yields, analyzed over the dataset from 2021 to 2025, exhibited an annual increase of approximately 375.7 kg ha^{-1} . For sunflower, based on the dataset from 2021 to 2024 (the 2025 harvest has not yet started), the yields showed an average annual increase of approximately 164.4 kg ha^{-1} . By 2024–2025, crop yields matched or exceeded EU conventional benchmarks, and positive yield trends across key crops confirmed that residual N from grain legumes, combined with carefully structured crop sequences and full residue recycling, has removed nitrogen as a limiting factor in our model, ensuring sustained productivity without any external N inputs.

Beyond yield stability, this rotation model directly addresses the accelerated decline of soil organic carbon (SOC) observed in Serbian agricultural soils. By maintaining continuous organic matter inputs, integrating crops with complementary nutrient demands and rooting patterns, and applying tillage only when strategically justified, the system enhances nutrient cycling efficiency, improves soil structure, and supports long-term carbon sequestration. These results confirm that even under semi-arid conditions on heavy clay Vertisols, a strategically designed, livestock-free organic farming system can achieve strong agronomic performance. Future work will prioritize detailed measurement and verification of environmental sustainability outcomes.

Key words: livestock-free, organic, crop rotation, grain legumes.

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THE INFLUENCE OF EXCESS NITROGEN IN THE SOIL ON THE YIELD OF OILSEED RAPE

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ABSTRACT

The decline in the content of organic matter in the soils of Vojvodina (the northern part of the Republic of Serbia) represents their most important degradation process. In the absence of organic fertilizers for the soil, the application of various industrial composts is considered as a possible solution to stop this degradation process.

Disposal of sewage sludge in municipal waste landfills is the least favorable option for several reasons (occupation of the capacity of the landfill itself and loss of valuable organic substances found in the sludge). The composting process at the Regional landfill begins with the mixing of sludge created by the purification of wastewater from the city of Subotica and shredded green waste (wooden biomass) collected from public city areas. Compost material goes through a mesophilic phase (25-45 °C), a thermophilic phase (up to 65 °C, with turning and aeration), cooling phase and ripening phase. The tested compost has > 30% organic matter and is free of dangerous and harmful substances.

An agricultural soil of the Chernozem type, locality Bikovo, in the area of the Subotica Regional Landfill (N 45°58'37", E 19°47'54") was sampled and tested. All examined soil properties exhibited values typical of this soil type, except for content of mineral nitrogen, which reached markedly high levels (194.7 kg/ha in the 0–30 cm layer, 118.1 kg/ha in the 30–60 cm layer, and 50.2 kg/ha in the 60–90 cm layer, totalling 363 kg/ha).

An experiment with three variants (Ø – without added compost, I - with 7.5 t/ha of added and plowed compost and II - with 15 t/ha of added and plowed compost) was set up on the plot in four repetitions.

The winter oilseed rape variety Zlatna (group "00") was used in the trial. Throughout the vegetation period, the plants remained in good condition, with vigorous growth and timely advancement through all phenological stages. Harvesting was done with a plot combine harvester ZÜRN 150. Achieved yields by variety are shown in Chart 1.

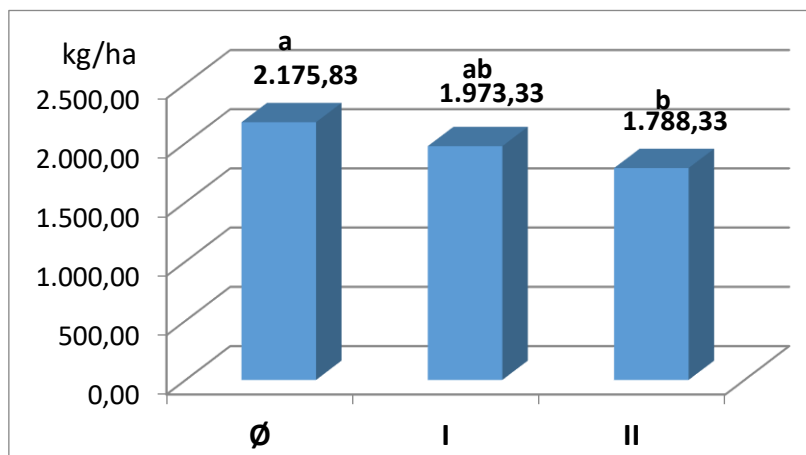


Chart 1. Rapeseed yield by varieties of applied compost

The yield of rapeseed on the control variant (without compost application) was statistically significantly higher (at the significance level of 0.05) compared to variant II. This is explained by the laying down of the plants as a symptom of excess nitrogen in the nutrition, which was more pronounced on variants I and II. Due to this phenomenon, the harvester could not cover all the plant mass with the header, which resulted in congestion and significant losses of rapeseed seeds. These results of the experiment indicate the importance of balanced nutrition of oilseed rape with nutrients, especially nitrogen as a yield carrier.

Key words: excessive soil nitrogen, laying of plants, oilseed rape

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IMPACT OF WINTER COVER CROPS AND MANAGEMENT ON SOIL NITRATE IN MAIZE PRODUCTION

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ABSTRACT

The introduction of cover crops into the agroecological practice of sustainable agriculture represents an important and increasingly accepted method for improving soil fertility and quality. However, the selection of appropriate crops is a key factor in ensuring sufficient nitrogen availability for the subsequent main crop.

The aim of the study was to determine the effect of the type of winter cover crop, the method of their utilization, and different soil depths on the content of available NO_3^- in the soil. The research was conducted at the experimental field of the Institute of Field and Vegetable Crops in Novi Sad, at the Rimski Šančevi location. The experiment was set up as a randomized block design. The winter cover crops consisted of a combined intercrop of triticale (*xTriticosecale* Wittm. ex A. Camus) and winter pea (*Pisum sativum* ssp. *arvense* L.) (T+P), a sole winter fodder pea crop (*Pisum sativum* ssp. *arvense* L.) (P), and a control without winter cover crops (\emptyset). The experiment with winter cover crops was divided into two blocks. In the first block, the cover crops were chopped and plowed under, while in the second block they were mowed using a rotary mower and the biomass was removed for ruminant feed. The preceding crop was soybean. The sowing of winter cover crops was done in early November, and their mulching and plowing under were performed in the last week of May. After plowing and soil preparation, maize (NS4051) was sown in early June, and soil sampling for determining nitrate nitrogen (NO_3^-) content was performed at three depths (0–30; 30–60; 60–90 cm) in the second half of July, four weeks after the incorporation of cover crops.

The three-factor ANOVA showed that cover crop type had a highly significant effect ($p < 0.001$), while utilization method was not significant. Soil depth showed borderline significance ($p \approx 0.065$), with higher values in the 30–60 cm layer. Significant interactions occurred between crop type and utilization method, and between type and depth. The highest nitrate N to 90 cm was in P-plowed (147.2 kg ha^{-1}), and the lowest in T+P-plowed (77.8 kg ha^{-1}). Soybean as a preceding crop with pure pea provided dual N

contributions, while T+P reduced immediate availability but promoted gradual mineralization.

Frequent N monitoring is recommended to support sustainable, fertilizer-reduced maize production using cover crops.

Key words: cover crops, green manure, winter pea, triticale

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Original scientific paper
Poster presentation

SUSTAINABLE GROWING MEDIA: HYDROCHAR FROM GRASSLAND BIOMASS AS A PEAT ALTERNATIVE

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ABSTRACT

Bog peat is a limited resource, but still forms the main component for the production of growth media. Due to the negative impact of peat use on the carbon footprint of ecosystems and the landscape, demand for peat substitutes is increasing. The objective of the substrate producers is to use regional, ecologically beneficial substrates that can be achieved through hydrothermal conversion by providing the process of converting biomass into peat-like properties. This method was investigated with materials originating from landscape conservation as starting material with the aim of using the generated peat substitute in culture experiments.

The hydrothermal carbonization of the biomass from extensive grassland was first carried out in preliminary experiments on a laboratory scale by varying the temperature and holding time. Hydrothermally carbonized plant residues (hydrochar) were obtained on the basis of three different temperatures (150 °C, 170 °C, 190 °C) and their chemical properties were analyzed. In the study, three different mixtures of a commercial growing medium with addition of 10, 20 and 30 % v/v of hydrochar were examined.

The substrate chemical properties of the hydrochar mixtures differed only slightly. The hydrochar mixtures, a pure peat substrate and a peat substrate mixed with wood fibres, were used for substrate hydraulic, chemical and phytotoxic experiments. In addition, extensive cultivation and storage experiments of the described admixtures of the various varieties produced with Chinese cabbage, impatiens and daisies were carried out. Comparable plant growth could be observed for some of the tested qualities, but fungal and odour problems leave room for improvement, especially in terms of post-processing.

The relationship between the growth of plants and soil chemical properties have been studied and presented. It was found that the chemical analyzes showed no dominant influence on the growth behaviour. Presumably, the hydrothermally carbonized material fixed the added nitrogen.

Key words: HTC growing medium, peat substitute, hydrochar, soil chemistry

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CAN Zn AND Se BIOFORTIFICATION DECREASE Cd WHEAT GRAIN CONCENTRATION?

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ABSTRACT

Zinc (Zn) and selenium (Se) are an essential elements in the human and animal nutrition. Although wheat is an important source of Se and Zn for humans, their concentrations are often below the dietary requirements. Therefore, biofortification can be important practices to increase their grain concentrations. Beside positive effect of Zn and Se application on wheat grain concentrations, also, it can be seen as a measure to decrease of Cd concentration in grain, but the results are not consistent. There is not enough research on the effect of Zn and Se fertilization on the Cd grain concentration. Therefore, the aim of this research was to examine the effect of Zn and Se foliar application to wheat grain biofortification, and to Cd grain concentration.

The field experiment was set up on Chernozem, on two locations in Serbia, in two consecutive years. Beside control, four treatments were applied: Se, Se+urea, Zn, Zn+urea.

The results show that biofortification had no effect on the wheat grain yield. However, the wheat biofortification was successful in the increase of Se and Zn in grain concentrations, in two experimental years, on both locations. In addition, Zn foliar application decrease the Cd wheat grain concentration in average on two locations and two years.

The results indicate that Zn biofortification can decrease grain Cd concentration, but additional research is needed to include different wheat varieties and different agroecological conditions.

Key words: microelements, foliar fertilization, zinc, selenium

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ENHANCING YIELDS IN PEAT-FREE MEDIA THROUGH SYNERGISTIC EFFECTS OF MICROORGANISMS AND ORGANIC FERTILIZERS

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ABSTRACT

The future of plant production will be shaped by the ecologically justified renunciation of peat as part of growing media and by a steadily growing proportion of ecological production processes. We investigated how combining microorganisms and organic fertilizers affects yields on peat-free growing media. An experiment was set up using a fully randomized block design, in which three vegetable species (lettuce, celery, Chinese cabbage) and a grass were grown on peat-free growing media in Mitscherlich vessels.

Chicken dry manure and hydrothermally carbonized sheep wool served as fertilizers. *Bacillus amyloliquefaciens*, mycorrhizal fungi, and *Bacillus amyloliquefaciens* combined with mycorrhizal fungi were selected as microorganisms.

This resulted in a total of 48 vessels per plant species. With the exception of celery, all species showed high yield increases when the application of organic fertilizers was combined with the application of bacteria and/or mycorrhizal fungi.

Our results suggest that a combination of microorganisms and organic fertilizers is a promising approach for increasing yields of a variety of plants, when using peat-free growing media for plant production.

Key words: *Bacillus amyloliquefaciens*, mycorrhiza, organic fertilizer, hydrothermal carbonisation

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NUTRIENTS LEACHING IN A MAIZE STOVER BIOCHAR AMENDED SOIL

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ABSTRACT

Agricultural productivity is severely impeded by soil nutrient leaching, especially in tropical areas like Ado-Ekiti, Nigeria, where intense rainfall promotes nutrient loss. This study examined the impact of maize stover biochar (MSB) on nutrient leaching and soil fertility.

Pyrolyzed MSB was produced at an average of 460 °C and a leaching column experiment was conducted using soil amended with MSB at rates of 0, 2, 4, and 6 ton ha⁻¹, simulating rainfall over 90 days. The collected leachate and soil samples (before and after the experiment) were analyzed to determine pH, electrical conductivity (EC), and the concentrations of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg).

Results show that MSB application significantly increased the leachate volume, with the highest volume recorded at 6 ton ha⁻¹, indicating improved soil porosity and drainage. Leachate analysis revealed elevated pH (7.45-9.41), EC (0.005-0.283 dS m⁻¹), P (5.09-81.05 mg l⁻¹), K (107.84-6348.04 mg l⁻¹) and Mg (62.50-135.00 mg l⁻¹) concentrations, with P and K leaching peaking at 60 days. The leachate volume for Ca reduced with MSB rates. Post-experiment soil analysis shows increased pH (6.20-8.35), EC (0.060-3.090 dS m⁻¹), total organic carbon (0.49-0.97 g kg⁻¹), total N (0.03-0.15 g kg⁻¹), available P (4.14-34.40 mg kg⁻¹), exchangeable K (0.10-1.89 cmol kg⁻¹), Ca (0.85-0.93 cmol kg⁻¹), Mg (0.34-0.87 cmol kg⁻¹) and water retention (1.99-16.08 %) with increasing MSB rates.

The MSB improved soil fertility, however, higher application rates increased nutrient leaching risks due to the soil's sandy texture. Long term biochar application on various soil types and economic feasibility is recommended.

Key words: maize stover biochar, nutrient leaching, tropical soils

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Original scientific paper
Poster presentation

DETERMINANTS OF RYEGRASS YIELD IN COMMERCIAL GROWING MEDIA: NUTRIENTS AND HYDRAULIC TRAITS

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ABSTRACT

Growing media are made for horticultural use as a mixture of various organic and mineral components. In this study, a total of 34 commercially available growing media were tested for the performance of biomass growth in ryegrass. The aim of the study was to determine which properties of growing media have a greater influence on the performance of grass plant growth. Specifically, the effects of chemical and hydraulic characteristics on ryegrass growth were examined. These results are intended to help in subsequent investigations to find alternative mixing components for the substitution of peat.

The variables for the hydraulic assessment were the water capacity in the slightly plant-related area, the air capacity and the capillary water increase. The hydraulic parameters were measured with the HYPROP system (HYdraulicPROPerTy Analyzer). The chemical properties (carbon, nitrogen, phosphorous, potassium, magnesium,) were determined by analyzing the total and plant-available nutrients. Additionally, substance loss was determined during the vegetation period. Effects of the chemical and hydraulic properties on ryegrass biomass growth were tested via multiple regression analysis.

Ryegrass biomass growth varied widely over the different growing media. The multiple regression showed that substrate loss, plant-available nitrogen (Nav) and phosphorus (Pcal) were significantly associated with increases of yield. Overall, the model explains 44.6% of the variance of Yield. Nav explains 21%, loss 13% and Pcal almost 10% of the variance. Moreover, substance loss was significantly correlated with biomass growth. We also found a higher biomass yield on peat-rich substrates compared to

peat-free substrates. These results show in conclusion that commercially available potting soils vary strongly in their content and properties, and confirm the importance of peat for horticulture. Further studies are needed to quantify the importance of chemical and hydraulic properties under consideration of the peat content.

Key words: growing medium, cultivation trials, soil chemical properties, hydro-physical properties

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SOIL WATER MANAGEMENT: DRAINAGE, IRRIGATION AND WATER QUALITY

EFFECTS OF DIFFERENT IRRIGATION METHODS ON LETTUCE YIELD, WATER USE EFFICIENCY AND WATER STRESS INDEX

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ABSTRACT

The introduction of efficient irrigation methods and the creation of optimal cultivation conditions have become the most important goals of modern agriculture in order to ensure the sustainable and rational use of water resources.

This study investigated the effects of regulated deficit irrigation (RDI) on the yield, water use efficiency and water stress index (CWSI) of lettuce (*Lactuca sativa* L.). The study was conducted in a greenhouse in the period from November 2023 to February 2024. Lettuce of the variety Cindarella (Meridiem Seeds) was planted at a spacing of 25 cm in gutters 0.4 m wide, 0.4 m deep and 10 m long, filled with Free Peat substrate with known water-physical and chemical properties. Two irrigation methods were used: a new method, Responsive Drip Irrigation (RDI), which delivers water according to the needs of the plants, and the Standard Drip Irrigation (SDI) method, which served as a control.

Plant growth and the amount of water applied using the two irrigation methods were continuously monitored throughout the experiment. Every 7 to 10 days, the temperature of the lettuce canopy was measured using remote sensing techniques and a thermal imaging camera (FLIR T335). The thermal images were processed using FLIR Tools software and the resulting data were used to calculate the Crop Water Stress Index (CWSI) according to the method described by Idso et al. (1981). At the end of the experiment, the yield was measured (fresh and dry weight in g·m⁻²) and the water use efficiency (WUE) was calculated as the ratio between the yield and the total amount of irrigation water applied.

The average lettuce yield was significantly higher in the RDI treatment (7271.7 g·m⁻² fresh weight and 208 g·m⁻² dry weight) than in the SDI treatment (4699.2 g·m⁻² fresh weight and 160 g·m⁻² dry weight). In the RDI treatment, the plants used the water more efficiently (7.5 g·L⁻¹) than in the SDI treatment (6.4 g·L⁻¹), which corresponds to an improvement of 15%. The average CWSI value in the RDI treatment was 0.0, while the average CWSI value in the SDI treatment was 0.3, indicating that the plants suffered from water stress.

The results of this study show that the application of the new irrigation method (RDI) resulted in higher yield, improved water use efficiency and lower CWSI in lettuce grown under protected conditions. The application of RDI irrigation could be one of the solutions for the sustainable use of water resources. It is recommended to conduct further tests with different soil types, substrates and crops.

Key words: responsive drip irrigation, water use efficiency, crop water stress index

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WATER PROPERTIES OF DIFFERENT TYPES OF HYDROMORPHIC SOILS

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ABSTRACT

In the study, the water characteristics of the following types of hydromorphic soils were investigated: Fluvisol, Humofluvisol, Humogley, and Eugley. The formation of these soils is related to the process of fluvial sedimentation, which also affects the distribution of these soils from the riverbed through the alluvial plain, as well as their granulometric composition.

The results show that water retention at all three pressures is lowest in Fluvisol, increases in Humofluvisol and Humogley, and is highest in Eugley. Observing physiologically active water, it can also be concluded that it has the lowest content in fluvisol soil, the highest in Humogley, while Humofluvisol and Eugley soils have medium content.

Data on hydraulic conductivity or permeability coefficient (Darcy coefficient) indicate that Fluvisol has high permeability, Humofluvisol medium, Humogley low, and Eugley very low permeability.

The height of water that can rise in the soil due to capillary forces, which is significant in dry conditions or at greater depths of groundwater, also varied, with the highest capillary rise in Fluvisol, medium rise values in Humofluvisol and Humogley, and the lowest value in Eugley soil.

Table 1. Water characteristics of soils

Soil type	Water retention (% vol.)			Physiologically active water (vol%)	Darcy coefficient (cm/sec)	Capillary rise (cm)
	0.33b	6.25b	15.0b			
Fluvisol	18.72	6.45	6.00	12.72	0.00751	27.18
Humofluvisol	35.96	16.72	14.30	21.66	0.00070	13.58
Humogley	39.88	20.00	17.36	22.52	0.00054	18.17
Eugley	45.50	28.00	26.85	18.65	0.00009	11.15

It should be noted that the investigated soils have different granulometric compositions, ranging from Fluvisol, which contains the highest proportion of total sand, through Humofluvisol, where the proportion of total clay slightly increases, to Humogley and Eugley, where the total clay fraction predominates over sand. The variation in the water characteristics of the presented hydromorphic soils is directly related to the proportion of granulometric fractions in these soils.

Key words: hydromorphic soils, water retention, physiologically active water, Darcy coefficient, capillary rise

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HERBICIDE RESIDUE CONCENTRATIONS IN THE WATERS OF THE DTD CHANNEL IN 2024 AND 2025

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ABSTRACT

Vojvodina is an agricultural region where numerous plant protection products are used. Also in Vojvodina there is a large network of melioration canals (navigable in length of about 600 km) which are more or less in use, but they are certainly places where agrochemicals accumulate. The aim of the work is to determine how much the application of plant protection products in agriculture affects the accumulation of these compounds in the surface waters of the canal network of Vojvodina. The paper presents the results of testing the presence of 41 herbicides (Mitić et al, *Environments* 2025, 12, 246) in the waters of the Danube-Tisa Danube canal system. 2024. Selected herbicides are still in use. In 2024, 100 water samples taken along the entire length of the Bogojevo-Bečej canal were examined, while in 2025, 90 samples were examined from the Vrbas-Bezdan, Odžaci-Sombor and Karavukovo-Bački Petrovac canals (Image 1). The samples were taken in 1 L glass bottles, preserved with formic acid and stored at +4 °C until analysis. Extraction was performed using solid-phase disk extraction on CDC Analytical Empore™ disks (Catalog number: 2215-C-18, lot 320005C) with a diameter of 47 mm. The herbicides were eluted from the disk with two portions of 5 ml of acetonitrile each, the obtained extract was evaporated in a stream of nitrogen and reconstituted with 1 ml of acetonitrile. The analysis was performed on HPLC-MS/MS VANQUISH CORE/TSQ Quantis Plus and on GC-MS/MS system Thermo Trace 1300/TSQ 9000 with confirmation of the identity of compounds based on the formed ions/daughter ions. The certified standards from Riedel-de-Haen were used for quantification.

The results showed that s-metolachlor was found in 100% and 97% of the water samples. In 2024 and 2025, the average concentrations of s-metolachlor were 0.037 µg/L and 0.091 µg/L, respectively. Trebutylazine was also found in 97% of samples in both years at concentrations of 0.0108 µg/L and 0.388 µg/L. In this study, among others, 9 Sulfonyl-urea herbicides, which are used in extremely low doses, were tested. The results

showed that in 2024 and 2025, nicosulfuron was the most abundant and was found in 76% and 36% of water samples, respectively. The second most common is amidosulfuron, which was found in water in 55% and 46% of the tested samples, respectively. Concentrations of sulfonyl urea herbicides and other compounds listed here were also tested in agricultural soil. It has been established that in 2024 amidosulfuron, nicosulfuron, s-metolachlor, triflusulfuron-meil, foramsulfuron, terbuthylazine and others ARE detected in significant concentrations in the soil, namely: 0.197 $\mu\text{g/L}$, 0.206 $\mu\text{g/L}$, 0.270 $\mu\text{g/L}$, 145.47 $\mu\text{g/L}$, 10.358 $\mu\text{g/L}$, 30,173 $\mu\text{g/L}$, respectively (Mitić et al, Environments 2025, 12, 246)

This research demonstrates that these compounds migrate from surrounding agricultural soil into surface water where they accumulate and have an unknown life cycle and fate.



Image 1: Map of the sampling area

Key words: herbicide residues, pesticide, water, soil

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APPLICATION OF INFORMATION TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN SOIL SCIENCE

AGROECOLOGICAL ASSESSMENT OF SOIL SPATIAL-TEMPORAL VARIABILITY FOR SMART FARMING AND LAND MANAGEMENT

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ABSTRACT

Agroecological assessment of soil spatial variability in the different scale from region to field, of soil regimes seasonal and inter-seasonal dynamics forms the information-methodical basis for smart farming (Chart 1.), land-use management and rational crop rotation (Chart 2.) due to their crucial role for crop yield and profit – even in case of most suitable for farming Black soils.

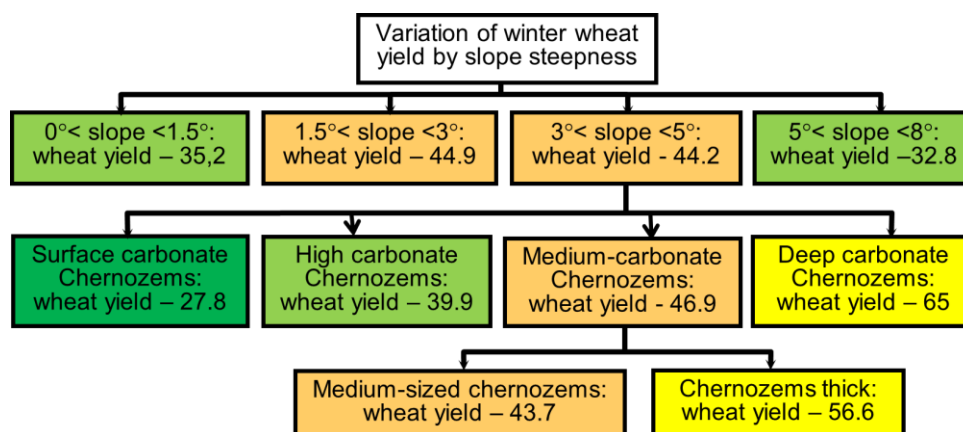


Chart 1. Regression tree of the agroecological factors influence on the winter wheat yield (dt/ha) within representative field on Chernozems in Kursk region

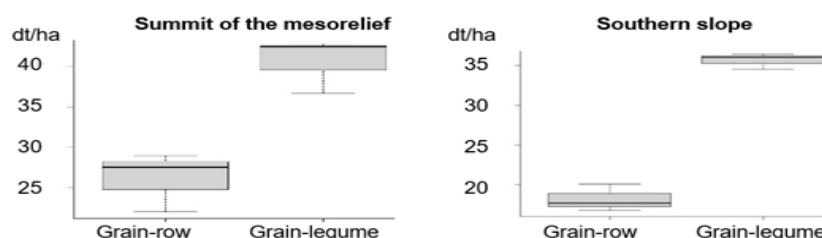


Chart 2. The effect of mesorelief and crop rotation on the spring durum wheat yield within representative field on Chernozems in Saratov region, RF

Mesorelief is usually the dominant unregulated limiting agroecological factor in Chernozems. Slope mesorelief determines the intensity of erosion processes, the thickness of humus horizons, the depth of carbonates, and reserves of soil productive moisture, on which wheat yield largely depend.

In the context of global climate change with the shift of the second summer maximum precipitation by 2-3 weeks in the arid regions of Volga region and the Southern Urals (Chart 3.), an effective means of minimizing agroecological risks of reducing durum wheat yields became to shift its sowing time by 1.5-4 weeks (Table 1). The effect of this turned out to be higher than the aftereffect of the use of micro fertilizers – both in 2022 with the average annual rainfall of the growing season, and in the dry year 2023.

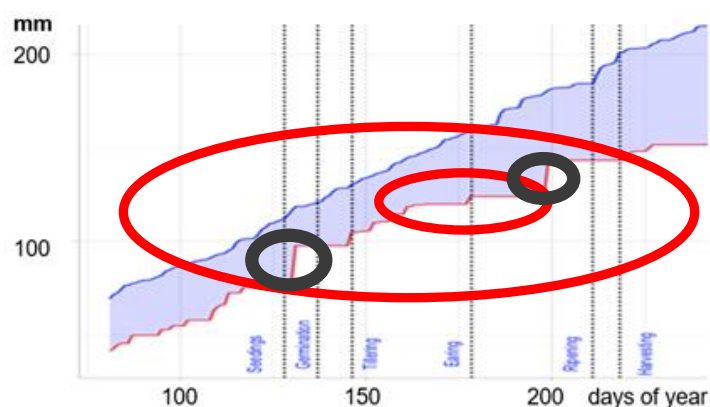


Chart 3. The seasonal precipitation cumulation curve in the Orenburg region in dry year seasons (red line) in comparison with decade average (blue line)

Table 1. The yield (dt/ha) of durum wheat varieties with two sowing periods and two variants of agrotechnology on Chernozems in the Orenburg region

Variety	A variant of zonal agrotechnology	Wheat yield by sowing time, dt/ha			
		2022		2023	
		7.05.22	4.06.22	7.05.23	17.05.23
Luch-25	Traditional	18.15	19.25	6.96	10.04
	With epsomite	19.48	22.05	8.87	11.37
Bezenchuk Golden	Traditional	21.11	23.22	9.10	14.17
	With epsomite	21.32	24.23	9.32	13.76

The results in 2022-2023 showed a statistically significant increase in yield by 2–5 dt/ha at later sowing – at the same level of technological costs.

Key words: agroecology, Chernozem, climate change, pedodiversity, smart farming

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**URBAN ENVIRONMENTALLY SENSITIVE AREAS (U-ESA)
MAPPING ON EXAMPLE OF THE CITY OF BRATISLAVA**

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ABSTRACT

For mapping of urban environmentally sensitive areas (U-ESA), soil sealed surfaces in the urbanized environment were identified, soil properties and quality, including green urban infrastructure were mapped and classified. As well as microclimatic conditions were modelled, especially in terms of the occurrence of urban heat islands (UHI). The U-ESA assessment methodology is based on a multi-criteria approach, in which several attributes were profiled: 1. mapping of land cover/land use and soil sealing using the extended nomenclature of the Urban Atlas 2012 for the city of Bratislava, 2. modelling the occurrence of urban heat islands (UHI) and their spatial distribution using the MUKLIMO model; 3. mapping of urban soils using the concept of pedo-urban complexes (PUC) and assessing their quality; 4. identification and classification of urban vegetation types; 5. overlapping and synthesis of results using GIS tools (© ESRI ArcGIS). Identification of urban environmentally sensitive areas (U-ESA). was carried out by overlaying raster layers of partial attributes. The main outputs: 1. geospatial information is the basis for a balanced spatial design and organization of plans and studies of cities in which environmentally sensitive areas are identified, 2. in densely built-up areas, deteriorating living conditions intensify, especially in the presence of urban heat islands (UHI) 3. soil sealing surfaces are one of the main causes of increased heat, but not entirely, polluted air and microclimatic conditions play a role. The most ecologically sensitive areas appear to be city centres which are characterized by dense historical buildings and impermeable or semi-permeable soil cover (more than 80%), where an increased effect of UHI and a reduced degree of availability of public green spaces can be observed, which is confirmed by the results of U-ESA mapping in the city of Bratislava (Fig. 1).

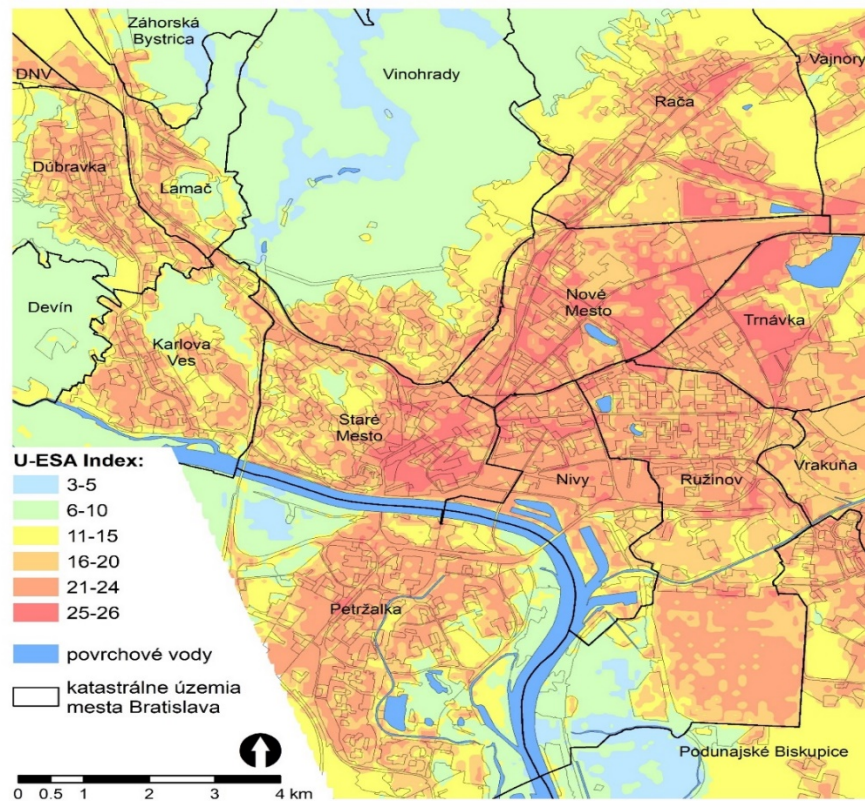


Fig. 1. Environmentally sensitive areas in urban environments (U-ESA) in terms of the impact of impervious areas, soil quality and urban green infrastructure as well as the occurrence of urban heat islands in the summer months

Key words: urban soil, urban heat islands, urban land development, environmentally sensitive areas

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GIS-BASED IDENTIFICATION OF FARMS IN NITRATE VULNERABLE ZONES IN MONTENEGRO

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ABSTRACT

The implementation of the Nitrates Directive in Montenegro requires the identification of Nitrate Vulnerable Zones (NVZs) and the mapping of agricultural activities within these zones in order to mitigate nitrate pollution and protect water resources. This paper focuses on the integration of administrative databases and geographic information systems (GIS) to identify farms and agricultural parcels located within NVZs, update NVZ boundaries, and assess the scope of agricultural activities subject to nitrate management measures. Data from the Directorate for Food Safety, Veterinary and Phytosanitary Affairs, the Directorate for Payments, the National Geoportal, and the Regional Livestock Selection Services were harmonized and analyzed using QGIS to identify the geographic overlap between NVZ boundaries and farm parcels. Expert consultations were conducted to refine NVZ borders and address inconsistencies.

The analysis revealed that 197 farms, each with more than 10 livestock units (LU), and comprising over 2,000 agricultural parcels covering approximately 629 hectares, are situated within NVZs in Montenegro. Updated maps were produced to visualize NVZ distribution within the country and at the municipal level, as well as in relation to ecological networks such as the Emerald sites. The results highlight the environmental importance of focusing nitrate management efforts in hydrogeologically sensitive zones, including karst aquifers and alluvial plains, where the risk of nitrate leaching to groundwater is highest.

The study revealed several challenges: outdated registries containing inactive or deceased farmers, incomplete records that prevented the identification of approximately 30 farms, and geo-referencing inconsistencies that impeded precise parcel mapping. These issues highlight the need for regular database updates, improved geospatial referencing, and better inter-agency integration, alongside direct communication with farmers to ensure awareness of NVZ obligations.

The findings provide a solid evidence base for the design and implementation of Montenegro's Nitrate Action Programme, underscoring the need for accurate technical tools as well as robust administrative systems. The recommendations highlight continuous improvement of databases, strengthening farmer outreach, and establishing adaptive monitoring to track water quality improvements. The paper demonstrates that GIS-based methodologies can effectively support environmental policy while exposing institutional challenges that must be resolved to achieve sustainable nitrate management in agriculture.

Key words: nitrates, GIS, agricultural parcels, water quality protection

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METHODOLOGICAL FRAMEWORK FOR SOIL ELECTRICAL CONDUCTIVITY MAPPING IN WHEAT NITROGEN MANAGEMENT

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ABSTRACT

The research is conducted within the framework of the project "*Precision Agriculture – Application of Remote Sensing in Rational Nitrogen Fertilization of Winter Cereals.*" The general objective of the project is to modernize agricultural production by introducing high-precision technologies and strengthening agricultural practices through collaboration between scientific institutions and farmers. The specific aim of this study is to optimize nitrogen application in wheat nutrition and reduce its negative environmental impact using precision agriculture technologies.

To achieve this goal, new technologies must be applied throughout the entire production cycle of wheat, from soil fertility sampling to harvest. This paper presents results of the validation of an EC mapper — a device measuring soil electrical conductivity (EC) — which is used for developing soil sampling schemes, one of the key phases in soil fertility monitoring systems. In precision agriculture, spatial variability assessment of soil properties serves as a basis for designing efficient soil sampling maps. Soil electrical conductivity depends on several factors, including soil texture (particularly clay content), salinity, and moisture. Measurements are carried out using an EC mapper towed or carried across the field along predefined paths. After data processing, a georeferenced map is generated, showing spatial variations in EC values. Different colors on the map indicate zones with varying textural composition, representing the first step in creating a precise soil sampling strategy.

One of the important factors influencing the accuracy of EC measurements is the distance between survey lines (i.e., spacing between passes of the EC mapper). While the device directly measures EC at a certain depth, intermediate values are obtained via interpolation between measurement points. In practice, in Vojvodina (Serbia), where Chernozems predominate, a spacing of 18 m is commonly used between adjacent survey lines, whereas different approaches exist in Croatia. In Bosnia and

Herzegovina, EC mapping has been sporadically applied so far, resulting in limited practical experience.

This study presents findings from EC mapping of an experimental field covering 5 hectares. The soil type will be determined based on pedological maps. On this field, wheat exhibits mosaic-like growth, with visible irregularities in plant development. The second and third nitrogen applications were performed using a precision spreader based on crop status data obtained via remote sensing.

Following harvest and yield mapping, EC measurements will be carried out using the EM38MK2-1 device at two depths: 0–30 cm and 0–60 cm, with a line spacing of 6 m. Based on the collected data, three EC maps will be created: (1) using data from 6 m line spacing; (2) 12 m line spacing; and (3) 18 m line spacing. The resulting maps will be compared with crop condition maps obtained during the growing season and the final yield map.

In areas where strong correlation between EC values and crop performance is observed, soil samples will be taken from two depths (0–30 cm and 0–60 cm) for mechanical composition analysis.

Key words: electrical conductivity (EC), EC mapping, precision agriculture, soil heterogeneity, nitrogen fertilization

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SPATIAL VARIABILITY OF SOIL FERTILITY BASED ON ELECTRICAL CONDUCTIVITY IN A SMALL-SCALE VINEYARD

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ABSTRACT

This study investigates spatial variations of soil fertility in terms of chemical properties, macro- and microelement content, and granulometric composition within a small vineyard (1.2 ha). The research was conducted during the 2020 growing season at the Experimental Field of the Faculty of Agriculture, University of Novi Sad, located in Sremski Karlovci. The vineyard, planted with the Grašac (*Riesling Italico*) variety, was subdivided into 20 quadrants to enable a spatially explicit characterization of soil variability. Soil samples were collected at two depths (0–30 cm and 30–60 cm). Laboratory analyses included pH (H₂O and KCl), organic matter (OM), total organic carbon (TOC), calcium carbonate (CaCO₃), cation exchange capacity (CEC), available phosphorus (P) and potassium (K), available micronutrients (Mn, Fe, Zn, Cu, B), and granulometric composition.

Spatial analyses were complemented by high-resolution geophysical measurements obtained with the Topsoil Mapper (Geoprospectors GmbH), which records soil electrical conductivity across four cumulative depth intervals, providing dense sensor datasets with pronounced spatial variability. Based on electrical conductivity, the vineyard was delineated into two management zones: Zone I (higher EC readings, 13 subplots) and Zone II (lower EC readings, 7 subplots).

Overall, the soil exhibited low levels of organic matter, available P and K, Zn, and B. Reduced fertility was consistently observed in Zone II across most parameters. Notably, available phosphorus and potassium tended to be higher in Zone II, although these differences were not statistically significant. Statistically significant differences between the two management zones were identified in several soil properties, including pH, CaCO₃, organic carbon, and the sand and silt fractions of the granulometric composition. The greatest variability was detected in the 30–60 cm soil layer.

Principal component analysis (PCA) highlighted strong correlations among key soil characteristics, including pH, CaCO₃, total nitrogen, CEC, TOC, clay content, and enzyme activity across the two management zones.

Further research is needed on vineyards at larger scales, where greater spatial variability is expected. The results underscore the potential benefits of precision viticulture and advanced soil analytics for vineyard management and winemaking.

Key words: soil fertility, spatial variability, electrical conductivity, vineyard

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INFLUENCE OF TOPOGRAPHIC SHADOWS ON REMOTE SENSING VEGETATION INDICES: A CASE STUDY IN TARA NP, SERBIA

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ABSTRACT

Vegetation indices obtained from optical satellite images enable assessments and monitoring of vegetation cover through an efficient and economically viable approach. Optical satellite images are based on capturing reflected solar radiation that can be blocked by surface topographic characteristics; an object can face away from the sun because of its own slope and aspect (self-shadowing), or one object can block the sunlight of another object (cast shadowing).

The topographic shadows can cause reduced values of remote sensing vegetation indices on high-relief terrains and their surroundings, which impacts the accuracy of the vegetation indices results within the affected areas.

This study evaluates the influences of topographic shadows calculated from a Digital Elevation Model (DEM), in conjunction with sun azimuth and altitude data, on remote sensing vegetation indices: Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI). The Copernicus DEM, as well as the Copernicus Sentinel-2 mission data from March 2025, are employed for research purposes. The research suggests excluding certain parts of the results obtained for vegetation indices due to the influence of topographic shadows within the study area (Tara National Park, Serbia).

Key words: remote sensing, topographic shadows, vegetation indices, NDVI

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DIGITAL TWIN OF AGROLANDSCAPE SOILS AS AN APPROACH FOR SCIENTIFIC AND APPLIED PROBLEM SOLVING

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ABSTRACT

Digital twins are one of the fastest growing areas in Computer Science, based on the convergence of advanced information technologies, including cyber-physical systems, computer modeling, the Internet of Things (IoT), and several others. However, despite the high potential of the technology, the use of digital twins in agriculture is still at an early stage of deployment (Soderstrom et al., 2016; Tekinerdogan et al., 2020; Verdouw et al., 2020; Sreedevi, 2020). The use of digital twins in agriculture has not yet made a quantitative leap for several reasons. On the one hand, agricultural processes are usually more complex than industrial processes in factories. This complexity is due not only to the high dimensionality of the data, but also to the fact that many variables that determine the behavior of the processes are stochastic in nature and cannot be managed or controlled. In addition, the large area where agricultural processes occur, combined with the heterogeneous conditions typical of these territories, requires spatial and temporal resolution of data, which is technically and economically impossible. The V.V. Dokuchaev Soil Science Institute launched a project to conduct fundamental scientific research and develop a concept and scientific justification for the regulatory and infrastructural support for collecting, processing, analyzing, storing and using data to model processes in soils to create their virtual images (digital twins) when designing agricultural systems. The project developed guidelines, including a standard for describing data and methods for obtaining them, a standard for describing the problems solved by a digital twin of soils, a standard for describing mathematical models for implementing an automated launch, a protocol for describing interaction schemes between data and models to solve problems. The design principles for creating digital twins of soils and soil cover, and the instrumental part of the physical image of the digital twin with the selection of the necessary sensors for measuring the physical and physicochemical state of the soil were developed. The development of a digital twin of soil is based on a digital platform (PaaS, platform as a service) for the life cycle of soil and soil cover models, models for processing, analyzing and forecasting

the state of soil and soil cover, including neural network models, data sets (collection, storage, marking) and services created on their basis. The platform ensures the use of data received from a set of soil condition measurement sensors (IoT), meteorological data, results of field and laboratory measurements of soil properties, and remote sensing data as information flows. In conclusion, a concept for managing production processes in crop production based on digital twins of soils and soil cover was developed.

Key words: soil modelling, soil management, artificial intelligence, agroecology

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SOIL AND CLIMATE ACTION: CARBON SEQUESTRATION, FOREST SOILS AND REGENERATIVE AGRICULTURE

ADAPTATION AND MITIGATION OF AGRICULTURE TO CLIMATE CHANGE

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ABSTRACT

Agriculture operates largely as an open-air factory without a roof, making it especially vulnerable to weather extremes. Climate change is driving an increase in natural disasters, including more frequent and severe events such as alternating heatwaves and droughts and very local strong intensive rains. These extremes are expected to become even more frequent and intense in the near future. In Croatia 2021, 2022, and 2024, droughts were the dominant natural disasters, while in 2023, severe storms and hail in July and August. While declaring a natural disaster is often the simplest response, it does not offer a long-term solution. In fruit growing, climate change has a particularly significant impact, notably the rise in winter temperatures. To survive winter, fruit trees enter a dormancy phase, which requires a certain number of chill hours at low temperatures. A lack of these conditions can reduce both yield and fruit quality. Fruit growers report that trees are entering vegetative stages earlier, while late frosts, now more frequent in April, pose a growing threat. Olive and grapevines also start vegetating earlier, but their growing periods are becoming shorter, reducing the quality of olive oil and wine. As a result, olive and grape harvesting are occurring earlier almost every year. Indigenous, native plant varieties are generally more resilient to climate variability; therefore, future crop selections should be based on genetically improved versions of traditional, autochthonous varieties.

The livestock sector is also indirectly affected by climate change. Rising temperatures are causing increasingly pronounced desertification processes in meadows and pastures, which indirectly leads to a decrease in the availability of quality feed for livestock and to erosion processes. Feed production and processing, along with enteric fermentation in ruminants, are the two main sources of emissions from livestock production. Interestingly, due to enteric fermentation, both conventional and organic livestock farming produce similar levels of greenhouse gas emissions. In arable and horticultural farming, organic agriculture shows significantly better results in adapting to and mitigating the effects of climate change.

Adaptation measures can be direct or indirect, short-term or long-term. Autonomous measures include changing crop varieties, adjusting sowing

and harvesting dates, and optimizing the use of fertilizers, pesticides, and soil improvers. Long-term measures involve structural adaptations such as changes in land use, diversification of production, cultivation methods, crop selection, and various soil management techniques (e.g., conventional vs. conservation tillage). Biodiversity enhances the resilience of ecosystems to changing conditions and climate-related stresses. As a key adaptation strategy, plant and animal species with resistance to high temperatures, drought, soil salinity, and pest and disease pressures should be prioritized. Accordingly, plant and animal breeders must intensify efforts to select and develop species with traits suited to climate anomalies.

Water management is becoming increasingly complex under climate change. It involves technical, infrastructural, economic, and sociological considerations. Agriculture must adapt to intense rainfall in late spring, summer, and early autumn, as well as prolonged summer droughts. Effective water management involves drainage systems, irrigation and the construction of facilities for collecting and storing water (water harvest) during the period of the year when there is a surplus.

Climate change is already causing, and will continue to cause, major shifts in entomological and herbological domains. Changes in the migration patterns, growth dynamics, and habitats of pests due to global warming have already been observed. There will also be changes in the prevalence of weed species and the extinction of certain plant species. All of this will, of course, impact the effectiveness of and approaches to plant protection. Furthermore, changes in cultivated crops will drive shifts in the distribution of pests and their natural predators. Soil tillage is a central measure in adapting to climate change. Conservation and regenerative agriculture offer strong potential to mitigate climate change impacts. Precision agriculture is based on managing the entire farming operation using information technologies, including satellite positioning and remote control of processes and machinery. These systems enable highly precise and efficient use of fertilizers, increased production under limited water availability, and improved efficiency per unit of cultivated area.

The academic community plays a key role in providing answers on how to adapt agriculture to and mitigate the impacts of climate change. Pressing challenges such as transforming production methods (including agrotechnical practices with alternative soil tillage techniques), developing new cultivars, adjusting sowing schedules, and regionalizing crop cultivation are critical issues that science must address. The scope and urgency of these problems are increasing, while the time available for solutions is shrinking. There are more questions than ever – and fewer answers.

Key words: agriculture, climate change, adaptation and mitigation measures

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CARBON FARMING – TWO YEARS OF EXPERIENCE

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ABSTRACT

Achieving an increase in organic carbon (C) in the soil has recently been the magic target for removing CO₂ from the atmosphere, increasing humus and soil fertility, and ensuring long-lasting yield resilience in agriculture. All of this should be subsumed under the term Carbon Farming (CF).

Politicians are pushing for quick and reliable results, are seeking to set up a system of incentives for farmers to use CF techniques, and want to prove that the climate crisis can be tackled with these instruments. In addition to feasibility and acceptability as criteria for farmers, the impact on carbon sequestration is crucial for the overall assessment of certain techniques.

Under pedological and climatic conditions of Central Europe, we conducted 37 field trials in nine different countries, exploring the short-term reaction from 2023-2024 of seven CF techniques. These ranged from additional organic fertilizers, via diversification of crop rotation, agroforestry, reduced tillage, to liming/gypsum effect, and others. Different techniques covered methods of adding additional external C material to the field, using on-site grown and photosynthesis derived plant C, and methods of avoiding C/CO₂ loss from the soil.

All our teams concentrated on the evaluation of total organic carbon values, but single working groups also focused on microbiological status, mineral associated organic matter (MAOM), root exudates, and root dry matter as specific sources of soil organic carbon (SOC). Furthermore, specific soil data like cation exchange capacity and base saturation rate were assessed.

Key findings indicate that, even over a short-term, different crops influence soil C sources via root mass ($p < 0.001$), root permanency ($p = 0.05$), use of rooting space, and root exudates ($p = 0.002$). The long-term positive impact of applied CF techniques on SOC development versus a slow but steady decrease of SOC through agricultural soil treatment as such is undoubtable. Additional biomass input from relocation of harvest residues showed influence on the C:N ratio ($p < 0.01$) and on the abundance of bacteria and fungi. The highly expected influence of specific root exudates on micro-organisms and in consequence on rhizosphere related MAOM have yet to be explored. Development of SOC is not necessarily positively correlated with above-ground biomass and yield, at least not on the short-term. Seasonal and climatic conditions showed to play a greater role than CF methods themselves ($p = 0.003$).

We conclude that the most promising carbon farming techniques showed to be 'additional organic fertilizers', 'diversification of crop rotation' and 'liming/gypsum effect'. Long-term trials are highly appreciated.

Key words: SOC, carbon farming, agriculture, Central Europe

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QUANTIFICATION OF SOIL CARBON WITH THE SOLI TOC® CUBE: THE IMPACT OF SAMPLE WEIGHT AND GRAIN SIZE ON PRECISION

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ABSTRACT

The need for soil carbon measurements is increasing as global efforts to combat climate change intensify. Soil health, soil fertility and climate change mitigation are drivers for ongoing analytical testing. Accurate and precise soil carbon data for applications such as carbon credit programs is crucial for transitioning from estimated based approaches to direct measurement technologies. This study evaluates the precision of soil carbon measurements using the Elementar soli TOC® cube, focusing on the critical factors of sample grain size and sample weight.

Two different soil sample series, ALP SRS-1810 and ALP SRS-2308, were analyzed according to the ISO 17505 standard for temperature-dependent differentiation of carbon fractions, including TOC, ROC, and TIC, without the need for time-consuming acid pre-treatment. Samples were ground and sieved to various grain sizes, from <2.00 mm down to <0.10 mm, and then analyzed in different weights ranging from 0.025 g to 1.0 g. Our results show a clear trend: precision, as measured by the absolute standard deviation (SD), significantly improves with decreasing grain size and increasing sample weight. However, the data also reveals a sweet spot that balances sample preparation effort with measurement precision.

Based on our findings, a sieve size of 0.25 mm to 0.50 mm combined with a sample weight of 0.1 g to 0.25 g provides a highly efficient and effective working range (Figure 1). This combination delivers very good to excellent precision (relative standard deviation, SD rel. < 1.80%) while minimizing the labor and time associated with excessive grinding and weighing. The soli TOC® cube's ability to handle this optimal range, along with its automated sample feeder, makes it an ideal instrument for high-throughput laboratory analysis, providing reliable and reproducible soil carbon data that exceeds required precision specifications.

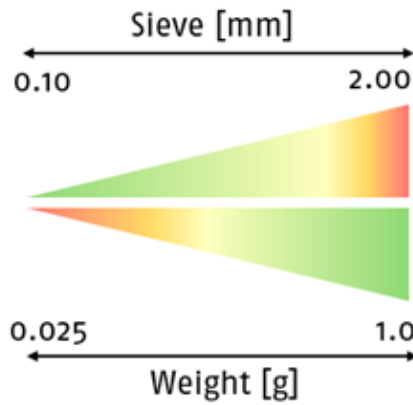


Chart 1. Depiction of the relationship between sample homogeneity and sample amount

Key words: Soil carbon, sample preparation, precision, carbon credits.

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The work was done in collaboration with Robert O. Miller technical director of the Agricultural Laboratory Proficiency (ALP) Program and experienced affiliate Professor with a demonstrated history of working in the higher education industry, skilled in Soil Chemical Analysis, Water Quality, Natural Resources, Compost, and laboratory Proficiency testing.

THE IMPACT OF LAND USE MANAGEMENT ON SOIL ORGANIC CARBON STOCK IN THE AREA OF MT. GOČ

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ABSTRACT

Forest ecosystems and forest soils play a significant influence in climate change adaptation and mitigation. Due to their high carbon storage potential, the soil plays a crucial role in regulating the global carbon cycle. Soils have the capacity to accumulate vast carbon reserves, making this one of their primary roles in the global carbon balance. Increased atmospheric CO₂ concentration can foster biomass growth, potentially leading to an increase in total carbon stored in the soil. Organic carbon is the most important indicator of soil quality. The assessment of soil conditions and quality within the territory of the Republic of Serbia is governed by laws and aligned with objectives defined in various national strategies.

The research was conducted within the Goč teaching and research base of the Faculty of Forestry, in separate experimental watersheds characterized by different soil and vegetation conditions. In the area of the ameliorative Unit B, three experimental watersheds were designated (R-I black pine, spruce, R-II meadow association, and R-III black pine plantation, while within the management Unit A, one experimental watershed was selected (Vaona under beech-fir forest). Soil samples were taken from a representative area as composite samples, each consisting of 5 individual samples, and forest floor samples were also collected. The goal is to determine the reserves of organic carbon in soils under black pine on previously degraded habitats, as well as in the soils of beech and fir ecosystems.

By comparing the organic carbon density from 30 years ago with the current values, it can be concluded that the organic carbon content has increased at all locations, with a particularly noticeable increase in the areas of Ravnina III and Ravnina II. This is mainly attributed to land use practices, as the process of pedogenesis has proceeded uninterrupted over the past 30 years under the black pine plantation. In Ravnina I, smaller differences in soil organic carbon density were observed, which were influenced by the necessary management practices. The least changes in organic carbon reserves were found in soil samples from the Vaona

watershed, under the mixed forest of beech and fir, which can be explained by the ecological and productive characteristics of the beech-fir mixed forest in Goč. The beech and fir forest potentially has a more stable and long-lasting humus layer, with microclimatic conditions and microbial activity further influencing carbon sequestration processes.

Key words: organic carbon, Goč, forest ecosystem, soil quality

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AGROECOLOGICAL RESULTS OF COMPOSTING IN THE REGIONAL LANDFILL SUBOTICA

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ABSTRACT

The Subotica waste management agglomeration represents the regionalization of waste: collection, treatment and disposal from the territory of seven local governments. The regional municipal waste landfill in Subotica, in accordance with Council Directive 1999/31/EC aims to reduce and gradually ban the disposal of biodegradable waste in landfills. Industrial composting is a controlled transformation: decomposition of organic matter by microorganisms and fungi into a stable humus material. The technology enables the produced compost to meet the European standards for compost preparation, and can be used after the accreditation process as a fertilizer for soil improvement. Regional Landfill Subotica, in cooperation with Institute of Field and Vegetable Crops, Novi Sad, in accordance with legal and strategic documents, implements a project of reuse of biodegradable waste (green waste, sludge from wastewater treatment plants) in order to produce a new product - compost. In this way, the amount of generated sludge, that will increase in the coming years, will not be deposited - sludge will get a new value. Analysis of samples of finished compost material determined the following characteristics shown in the tables (Tab 1 and Tab 2).

Table 1: Results of compost-basic quality analysis

Chemical parameters	% (m/m)
Total N % (m/m)	1.86
Total P ₂ O ₅ % (m/m)	3.76
Total K ₂ O % (m/m)	1.22
Organic carbon C % (m/m)	17.55
C/N ratio	10.81
Ash content % (m/m)	28.81
Organic matter % (m/m)	46.98
Moisture content % (m/m)	24.20
pH	7.69

Compost shows good results in terms of nutrient values, while analyses of ecotoxic elements are minimized and are below the maximum permitted amounts prescribed by the legal act.

Table 2: Results of compost ecotoxic parameters

Heavy metals	Determined Amount [mg/kg]	Maximum Allowed Amount [mg/kg]*
Cd	<MDL(1.5)	3
Cr	39.99	100
Ni	30.04	100
Pb	35.78	100
Hg	0.76	1

*Max. maximum allowed concentration according to the Rulebook (Official Gazette of the Republic of Serbia, No. 31/2017); dry mass plant nutrition and soil conditioners ("Fertilizers, soil improvers, other fertilizers and special products")

The production of compost from anaerobic stabilized sludge and green waste in industrial conditions is one of the ways of closing the ecological cycle, and providing the possibility of use in soil improvement with a clearly defined agro-ecological guideline.

Key words: anaerobic stabilized sludge, composting, nutrient values

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URBAN FOREST SOIL INDICATORS AS A TOOL FOR CLIMATE-SMART FORESTRY

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ABSTRACT

Climate-Smart Forestry (CSF) promotes adaptive forest management that maintains ecosystem functions and services while increasing the resilience of forests to climate change. Although this framework was primarily developed for mountain and rural forests, its application to urban forests (UF) is increasingly important. Urban forests, defined as tree-based ecosystems in cities, provide essential ecosystem services (ES) such as air purification, stormwater regulation, temperature mitigation, and social and cultural benefits. However, they are under increasing pressure from climate change, pollution, urban development and limited management resources. Among these challenges, land degradation emerges as a crucial but under-researched factor affecting the sustainability of UF.

The project Urban Forest Soil Indicators as a Tool for Climate-Smart Forestry (UrbanFoS) closes this knowledge gap by identifying indicators for soil degradation that are specific to the urban context. Physico-chemical analyses and climate simulation experiments will be used to identify the soil properties that are most sensitive to climate change and anthropogenic stressors. Existing indices for soil degradation will be tested for their applicability to UF and a customised index will be proposed. In addition, UrbanFoS will define remediation measures based on the principles of ecological engineering and nature-based solutions (NBS), ensuring practical ways to improve soil conditions.

By linking soil sensitivity with the provision of ES, UrbanFoS advances monitoring, predictive modelling and decision making for urban forestry. The results will not only support adaptive management strategies to mitigate land degradation, but also improve the ability of UF to deliver multiple ES, conserve biodiversity and contribute to climate resilience. In doing so, UrbanFoS introduces a novel conceptual and methodological framework for climate-smart urban forestry (CSUF) and provides science-based tools to

bridge the gap between urban sustainability goals and the realities of climate and anthropogenic pressures.

Key words: urban forests, soil degradation, climate change adaptation

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IMPACT OF CLIMATE CHANGE ON FOREST SOILS IN LIMESTONE AREAS OF TARA NATIONAL PARK

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ABSTRACT

Understanding the capacity of forest soils to support vegetation is critical, especially in the context of climate change. This study focuses on mapping the soil water balance level (WBL) and nutrient regime (NR) in forest soils developed on limestone in Tara National Park (Western Serbia), where European beech (*Fagus sylvatica*) is a dominant tree species.

Using a digital elevation model (DEM), dominant landforms were identified (hollows, ridges, slopes, spurs, summits, and valleys), and 44 soil profiles were sampled across varying slope gradients (<30° and >30°) and aspects (warm: S, SW, SE, W; cold: N, NE, NW, E; and neutral: slopes <12.5°).

Detailed laboratory analyses were conducted to determine key physical and chemical properties, including texture, structure, color, skeleton content, pH, base saturation, and nutrient content.

WBL and NR values were calculated using standard transfer tables. WBL ranged from 2 to 4 (2 = very dry; 3 = dry; 4 = moderately dry), while NR ranged from rich to medium-rich, based on base saturation.

These data were visualized using GIS ArcMap 10.8, and site types were identified through map overlays.

Under the RCP4.5 and RCP8.5 climate change scenarios (reference period 1971-2000), notable differences in temperature and precipitation patterns are observed, affecting soil properties. Average temperatures increased by 0.4°C and 4.5°C, while precipitation decreased by 10–20% and 5–30%, respectively. Both scenarios predict reduced precipitation during the growing season, negatively impacting WBL and NR.

Due to climate changes, a decline in site index quality can be expected with shifts to more thermophilic species on drier sites. Our study showed that growth optima for species, such as Turkey oak (*Quercus cerris*) and European hop-hornbeam (*Ostrya carpinifolia*), increased under climate change. This may enrich beech forests or even substitute beech as dominating species on the driest sites in the future.

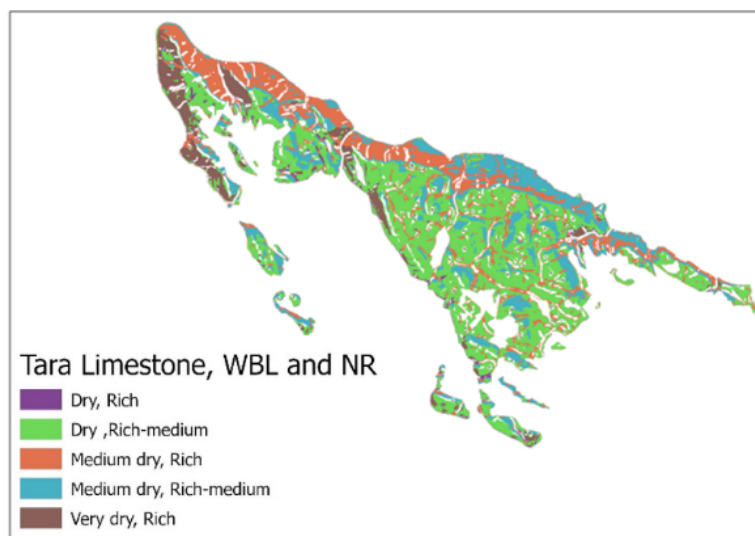


Figure 1. Water balance level & Nutrient regime in study area

Development of digital site mapping and estimating future tree species suitability in Serbia is essential for forest practitioners. With these models, the impact of climate change on the distribution of tree species can be analyzed, which can serve as a basis for future management and planning strategies for major tree species in different site types.

Key words: forest soils, beech, limestone, water balance level, nutrient regime, Tara National Park, climate change

ACKNOWLEDGMENT

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FLOWER STRIPS – A NEW ELEMENT OF AGRICULTURAL LANDSCAPES

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ABSTRACT

Modern agricultural landscapes are highly complex multifunctional systems. They are not only used for food and energy production, but are also expected to provide various ecosystem services within the agroecosystems. Industrial agriculture, which is practised on large areas, has led to increased productivity, but due to its high intensity, it is also responsible for numerous environmental problems. The loss and fragmentation of natural habitats, along with the widespread use of pesticides and synthetic fertilisers have led to a loss of biodiversity. In recent years, there has been a dramatic decline in the abundance and diversity of all groups of wild insect pollinators, including wild bees, hoverflies, butterflies and moths, with many pollinator species being threatened with extinction (COM 2018, 395). In addition, agricultural intensification has led to soil degradation, which can be regarded as a loss of a non-renewable resource, particularly through the depletion of soil organic carbon (FAO and ITPS, 2015).

The introduction of flower strips into agricultural landscapes on small areas (1%), can contribute to the creation of new habitats that support existing wild pollinators and promote increases in their abundance and diversity at both local and landscape scales. The results of the EcoStack project recommend six species for flower mixtures in Serbia: *Centaurea cyanus*, *Coriandrum sativum*, *Cynara scolymus*, *Daucus carota*, *Phacelia tanacetifolia* and *Sinapis alba*.

This practice has also been shown to benefit other beneficial organisms, such as predatory insects, pest parasitoids, birds, and plants – leading to greater species richness and abundance. Such an approach can

enhance biodiversity and overall ecosystem functioning, including crop pollination, suppression of pests and invasive weed populations, improved soil fertility through erosion control, and climate change mitigation via carbon sequestration in soils by conserving both below- and above-ground biomass. In this context, flower strips should be regarded as a key element of agricultural landscapes within sustainable farming systems such as conservative, organic, regenerative, and biodynamic agriculture.

Keywords: agricultural landscape, ecosystem services, flower strips

ACKNOWLEDGMENT

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THE INFLUENCE OF CLIMATE CHANGES ON AGROCLIMATE CONDITIONS IN TOPLICA DISTRICT

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ABSTRACT

The impact of climate change until the year 2100 on basic agroclimatic indices in the area of the Toplica district (Serbia) was investigated. The length of the growing season, the occurrence of the last spring and first autumn frost, the average number of frosty and icy days, as well as the average number of summer and tropical days were analyzed. In order to investigate the impact on the mentioned indices, simulations of air temperature (T) were previously performed, based on the application of a multi-model ensemble of 7 regional climate models from the EURO-CORDEX project. The projections are based on the RCP4.5 and RCP8.5 scenarios and were made for the periods 1971-2000 (reference), 2021-2050 (near future) and 2071-2100 (far future). For the statistical correction of climate model results, daily data on maximum and minimum air temperatures (Tmax, Tmin) for the period 1971-2000 at the Prokuplje and Kuršumlija stations, which were taken from the Republic Hydrometeorological Service of Serbia, were used.

The analysis of the obtained simulations showed that due to climate change, the agroclimatic conditions in the Toplica district will differ significantly by the end of the 21st century compared to the conditions in the reference period. It is expected that there will be:

- a statistically significant increase in the length of the growing season;
- earlier occurrence of the last spring frost and postponement of the autumn frost, thus extending the frost-free period;
- decrease in the average number of icy and frosty days during the year;
- an increase in the average number of summer and tropical days during the year.

Key words: climate change, agroclimatic indices, Toplica district, Serbia

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SOIL CONTAMINATION, URBAN SOILS, SOIL RECUltIVATION AND REMEDIATION

MICROPLASTICS ON AGRICULTURAL AREAS: CURRENT KNOWLEDGE, RESEARCH GAPS AND FUTURE DIRECTIONS

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ABSTRACT

Plastic contamination has become a major environmental concern due to its pervasive effects on ecosystems and potential risks to human health. While research on aquatic systems has been widely developed, the study of plastics in terrestrial environments, particularly soils, has only gained momentum in the past two decades. Both macro- and microplastics (MPs) can alter soil physical, chemical, and biological properties, with cascading effects on soil biota and ecosystem functioning. MPs, due to their small size and high surface area, pose particular risks as vectors of contaminants, pathogens, and antibiotic resistance genes, which can move through the environment and the food web. In addition, global change drivers such as warming or changes in soil properties may influence plastic degradation, including that of so-called biodegradable plastics, potentially accelerating the release of associated contaminants. Understanding these interactions is crucial for assessing long-term risks to soil health and food security. Yet, methodological gaps in identifying plastics within soil matrices still prevent us from accurately quantifying the magnitude of the problem.

Agricultural practices illustrate the double-edged role of plastics. Plastic mulch films have been widely used to increase yields, conserve soil moisture, and suppress weeds. However, their persistence in soils leads to the accumulation of plastic residues and microplastics, raising concerns about soil biodiversity and sustainability. Alternatives, such as biodegradable plastics, while promising, often degrade incompletely, leaving microplastics behind, and their effectiveness varies across different climates and cropping systems. Cost and performance remain major barriers to adoption.

Moreover, war and armed conflicts damage agriculture areas (e.g., Ukraine). These sites are already known to be contaminated by heavy metals, hydrocarbons, and explosive residues after warfare during decades. Still, plastic inputs from shotgun cartridges or explosives/landmines remain largely unaddressed. Also, recreational activities such as

paintball and airsoft contribute to plastic pollution, since pellets often contain conventional or biodegradable plastics that remain in the environment after use. Additionally, these plastics can be contaminated by pollutants from warfare, further increasing their environmental impact.

In conclusion, plastic contamination in agricultural areas presents an emerging and complex challenge. Microplastics not only degrade soil quality but also act as carriers of pollutants and pathogens. While biodegradable alternatives and better management practices show promise, they raise new questions regarding degradation products, contaminant release, and long-term ecological impacts. Addressing these challenges requires comprehensive research, improved detection methods, innovative materials, and regulatory measures that safeguard soil health while supporting sustainable land use.

Key words: microplastics, soil properties, food security, pollutants, agrochemicals

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BIOCHAR AS A STRATEGY FOR PRODUCING CLEANER BIOMASS OF *PAULOWNIA ELONGATA* ON POPs-CONTAMINATED SOILS

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ABSTRACT

The present study aimed to identify whether the application of sewage sludge-derived biochar (SSB) could aid the production of relatively less contaminated (“cleaner”) biomass of *Paulownia elongata* cultivated on POP-contaminated soil. Due to the heterogeneous nature of organic contamination in the soil, it was also possible to assess the phytoremediation potential of *P. elongata* under two contamination levels: “safe” – below the maximum permissible concentration (MPC; 100 µg kg⁻¹); and “extreme” – exceeding 200 × MPC (Table 1). The findings were derived from a field-scale experiment conducted at a 240 m² pilot site established near a former pesticide storage facility in v. Saimasai (GPS: 43°27'19" N, 77°18'53" E, Almaty region, Kazakhstan).

Table 1: Soil contamination levels (mean concentrations)

POP	MPC [µg kg ⁻¹]	“Safe” [µg kg ⁻¹]	“Extreme” [µg kg ⁻¹]
∑ DDTs	100	86.1	18 626
Chlordane	100	1.15	219
Dieldrin	0.5	0.16	163
∑ Endosulfans	100	1.55	1.90
∑ Endrins	1	0.43	1 275
∑ POPs	100	90.5	20 326

In “safe” soil, *P. elongata* did not accumulate 4,4'-DDE, chlordane, dieldrin, or ∑Endrins. The remaining POPs (∑DDTs and ∑Endosulfans) were primarily accumulated in the aboveground biomass (AGB), reaching

concentrations of 423 ± 19.2 and $36.4 \pm 2.58 \mu\text{g kg}^{-1}$, respectively. Under extreme contamination, only chlordane was not detected in plant tissues, despite its soil concentration increasing from 1.15 to $219 \mu\text{g kg}^{-1}$. A shift in the primary accumulation organ from AGB to roots was observed for all tested compounds with increasing soil contamination. Specifically, $\sum\text{DDTs}$ accumulation decreased in AGB from 423 ± 19.2 to $37.7 \pm 1.75 \mu\text{g kg}^{-1}$, while root concentrations increased from 13.6 ± 0.25 to $627 \pm 41.3 \mu\text{g kg}^{-1}$. An interesting pattern was noted for $\sum\text{Endosulfans}$: although soil concentrations were comparable (1.55 and $1.90 \mu\text{g kg}^{-1}$), accumulation in AGB remained similar (36.4 ± 2.58 and $41.1 \pm 0.15 \mu\text{g kg}^{-1}$), whereas accumulation in roots differed substantially (5.15 ± 0.25 and $687 \pm 25.5 \mu\text{g kg}^{-1}$). This variation can be attributed to the predominant form of $\sum\text{Endosulfans}$ in the soil, with endosulfan β dominating in the first case ($1.47 \mu\text{g kg}^{-1}$) and endosulfan sulphate in the second ($1.90 \mu\text{g kg}^{-1}$).

The incorporation of SSB (Agmeco LT, s.r.o., Brno, Czech Republic) into the soil at two application rates (2.5% and 5% w/v) altered the distribution of POPs in plant tissues. In Ctrl (0%), leaves were the main accumulation organ for all compounds, followed by stems and roots. Considering $\sum\text{DDTs}$, $\sum\text{Endosulfans}$, and $\sum\text{POPs}$ accumulation in leaves, both SSB treatments reduced their accumulation to a comparable extent, by 98.0-98.2%, 95.0%, and 92.8-96.2%, respectively, relative to Ctrl. In stems, 5% SSB demonstrated a stronger reduction in $\sum\text{DDTs}$ and $\sum\text{POPs}$ accumulation (by 94.8% and 39.1%, respectively) compared to 2.5% SSB (by 63.8% and 24.5%, respectively). For $\sum\text{Endosulfans}$, no reduction was observed at 5% SSB, whereas 2.5% SSB decreased their accumulation by 66.9% compared to Ctrl. Overall, a 5% SSB amendment proved more effective in ensuring the production of less contaminated *P. elongata* biomass under comparable contamination nature and levels. Although plant height did not significantly increase under SSB treatment, dry weight of stems and leaves was markedly enhanced at 5% SSB, by 219% and 90.7%, respectively, with no significant yield improvement at the lower dose. Additionally, stem diameter increased under 5% SSB treatment by 31.3%.

In conclusion, the application of 5% SSB to POP-contaminated soil enabled the production of "cleaner" *P. elongata* biomass, particularly timber, thereby supporting its valorization into value-added products and contributing to a circular economy.

Key words: biochar, soil contamination, POPs, fast-growing timber

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MICROPLASTICS AND HEAVY METALS IN AGROECOSYSTEMS: COUPLED PATHWAYS AND RISKS TO SOIL HEALTH

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ABSTRACT

Microplastics (MPs) are now commonly found in agricultural soils. They enter through plastic mulches, sewage sludge, composts, and coated inputs. MPs can bind, carry, and change the mobility and bioavailability of metals.

Many MPs increase the availability of Cd, Pb, and As by altering pH, redox conditions, and sorption surfaces. Weathered and smaller particles show stronger effects. In some soils, MPs can temporarily immobilize metals, but the effect is unstable. Combined MP–metal exposure intensifies oxidative stress in plants, suppresses photosynthesis, reduces biomass, and disrupts microbial communities and enzyme activity. The direction and size of effects depend on polymer type, particle size, soil texture, and organic matter.

These coupled stressors raise food-safety risks through metal uptake in edible tissues of plants. They also threaten core soil functions: aggregation, nutrient cycling, and water regulation. Most of the research on the impact of microplastics on the mobility and toxicity of heavy metals has been done in short-term laboratory experiments; to establish their real effect, long-term field trials are needed to track MP and metal dynamics across soil types.

Key words: microplastics, heavy metals, agroecosystems, soil contamination, bioavailability

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FROM WASTE TO FERTILE SOIL: BIOREMEDIATION AND HUMIC ACID SYNTHESIS AS AN INDICATOR OF REVITALIZATION

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ABSTRACT

Soil is a key component of terrestrial ecosystems, and its fertility strongly depends on the quantity and quality of organic matter. Humic acids represent one of the most stable fractions of soil organic matter and serve as an important indicator of soil fertility and long-term ecological sustainability. In recent years, the valorization of waste materials through bioremediation has attracted growing attention as a strategy to address both environmental pollution and soil degradation. Bioremediation processes not only enable the detoxification and mineralization of organic pollutants, but also contribute to the transformation of waste-derived substrates into humic substances.

This study discusses the potential of bioremediation in converting industrial and organic waste streams from the petrochemical industry into value-added products, focusing on the generation of humic acids. The formation and accumulation of humic acids during biodegradation reflect the stabilization of organic matter, improved soil quality, and serve as measurable markers of soil revitalization. Moreover, the ratio of humic to fulvic acids provides insights into soil organic matter composition, with a lower ratio indicating reduced aromaticity and greater similarity to fulvic acids. These parameters also serve as indicators of soil fertility, as higher levels of humification are associated with enhanced nutrient retention, increased cation exchange capacity, improved water-holding properties, and overall biological functionality of soils. To determine the optical density of a sample containing humic and fulvic acids, the E4/E6 ratio (absorbance ratio at 465 and 665 nm) is used (Table 1). This ratio increases as the average molecular weight of the sample decreases, which means that a higher E4/E6 value indicates a greater presence of fulvic acids relative to humic acids.

Table 1: Humic acid content and E4/E6 ratio

Duration of Bioremediation [days]	Humic Acid Content [%]	E ₄₆₅ (E4)	E ₆₆₅ (E6)	E4 / E6
0	1.92	0.370	0.172	2.15
30	2.08	0.378	0.171	2.21
60	2.30	0.389	0.169	2.30
75	2.62	0.403	0.166	2.43
135	2.72	0.437	0.159	2.75
165	2.83	0.595	0.154	3.86

We conclude that the results indicate that prolonged bioremediation leads to an increase in both humic acid content and the E4/E6 ratio. This suggests that extended treatment not only enhances the accumulation of humic substances, improving soil organic matter stabilization, but also shifts the chemical composition toward a lower proportion of fulvic acids relative to humic acids. Therefore, monitoring these parameters can serve as a reliable indicator of the progress and effectiveness of bioremediation, as well as the improvement of soil quality and fertility.

Key words: bioremediation, humic acids, fulvic acids, waste valorization

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INFLUENCE OF SELECTED ORGANIC SOIL AMENDMENTS ON THE SORPTION OF 2,4-DB

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ABSTRACT

2,4-DB (4-(2,4-dichlorophenoxy)butanoic acid) belongs to the group of herbicides from the phenoxy acid class, with soil processes such as sorption, degradation, and mobility determining its impact on the environment. The mobility of 2,4-DB is largely determined by its physico-chemical properties and the characteristics of the soil, with sorption playing a crucial role in controlling its fate. Various types of organic soil amendments (OSA), such as biochar and sewage sludge, are commonly applied for soil remediation. The objective of this study was to investigate sorption of 2,4-DB to Bayreuth soil and to assess the influence of OSA on its retention.

Column experiments using HPLC were performed under varying pH and ionic strength of the fresh water solution dissolving calcium chloride (CaCl₂) and magnesium chloride (MgCl₂) in Milli-Q water. The concentrations of 2,4-DB spiked to the columns were 10, 50, and 100 mg/L.

With the addition of biochar and sewage sludge to the soil column, the distribution coefficient (K_d) of 2,4-DB generally increased. This effect can be attributed to the presence of functional groups, such as phenolic, carbonyl, and hydroxyl groups, in biochar and sludge, which, as organic soil amendments, enable their interaction with 2,4-DB through hydrogen bonding, dipole–dipole interactions, and electrostatic forces, thereby contributing to its retention in the soil.

HPLC column experiments indicate that organic soil amendments enhance 2,4-DB retention, thereby reducing its mobility and concentration.

Key words: soil, organic soil amendments, 4-(2,4-dichlorophenoxy)butanoic acid, sorption

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ORGANOCHLORINE PESTICIDES IN SOIL FROM AGRICULTURAL AREAS IN SERBIA - HUMAN HEALTH RISK ASSESSMENT

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ABSTRACT

Organochlorine pesticides (OCPs) are persistent organic pollutants widely used in agricultural practice during the second half of the 20th century. Although their application has been banned or restricted for decades, OCP residues remain in soils due to their chemical stability and low biodegradability. The presence of OCPs in agricultural soils in Serbia raises concerns about potential transfer to crops and exposure of rural populations, making human health risk assessment a critical component of environmental monitoring.

The concentrations of OCP in agricultural soils collected from 6 locations (S1-Ivanovo, S2-Omoljica, S3-Banatski Brestovac, S4-Pločica, S6-Skorenovac and S7-Bavanište), where the wild waste dumps were noticed, were collected from the region located on the left side of the Danube River, in the east direction from Belgrade, the capital city. The samples are collected from the topsoil layer (0-10 cm). The OCP concentrations were determined by an Agilent 7890B gas chromatograph equipped with dual micro-electron capture detectors (μ ECDs) and two capillary columns. The concentrations of α -HCH, β -HCH, γ -HCH, HCB, DDE, DDD and DDT (Figure 1) are determined in the soil fraction of 250 μ m, the fraction that can easily enter the human gastrointestinal tract and affect human health. Based on the OCP concentration, the risk for people living in these areas was assessed. Both non-carcinogenic (THQ) and carcinogenic (CR) risks were assessed.

Observing the concentrations (Figure 1), it can be seen that the highest concentrations in almost all investigated soils have DDE, then DDT and then DDD. Exceptions are soil S1 and S7, where in the first case DDT has the highest concentration and in S7 has the lowest concentration compared to the DDD and DDE (Figure 1). Comparing the concentrations of other OCPs, the concentrations are similar in all investigated samples. Slightly higher concentrations are determined in S3, S4, S6, and S7 than in S1 and

S2. Exception is S3, where the β -HCH was significantly higher than HCB, α -HCH and γ -HCH.

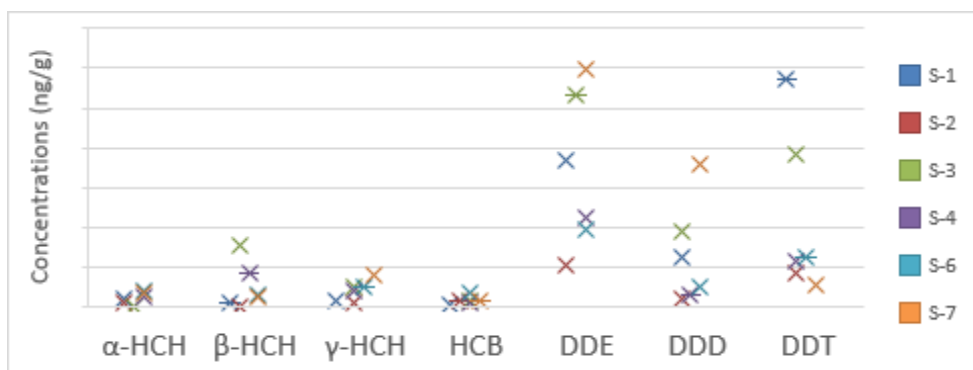


Figure 1. The concentrations of OCPs in topsoil samples

Based on the concentrations of the investigated OCPs, the investigated soils do not pose a risk for human health (via oral, inhalational and dermal exposure). There were no carcinogenic ($CR < 1 \times 10^{-6}$) nor non-carcinogenic ($THQ < 1$) risks for people living in these areas. Anyhow, as these compounds are lipophilic, long-term exposure to these environments should be more frequently monitored.

Key words: soil, wild waste, OCP, toxicological health risk

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POLLUTION ASSESSMENT OF SOILS IN THE PROTECTED AREAS OF PALIĆ AND LUDAŠ LAKES, SERBIA

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ABSTRACT

Palić Lake and Ludaš Lake are two ecologically significant lakes located near Subotica in northern Serbia, each with important conservation roles. Palić Lake is recognized as a Nature Park (NP), while Ludaš Lake is designated both as a Special Nature Reserve (SNR) and a Ramsar Site of International Importance. Due to their protected status and ecological significance, recognizing and assessing potential ecological risks in these regions is of high importance.

Therefore, this research assesses the presence of potentially toxic elements (PTEs - Zn, Cu, Pb, Ni, Cr, Cd, and Mn) in soils from two protected lake areas in NP „Palić“ and the SNR „Ludaš Lake“, recognizing the potential pressures from surrounding anthropogenic activities. Soil samples were collected during 2021 at fix depth (0–30 cm and 30–60 cm). Soil samples were analyzed to assess the level of contamination using geoaccumulation index (I_{geo}), pollution index (PI) and Nemerov pollution index (PIN).

The results indicate that most samples are within the unpolluted to moderately polluted category according to I_{geo} values, with localized increases in Cd (Palić region). Pollution Index values reflect absent to low contamination across most sites, while Nemerov pollution index values ranged from 0.54 to 1.26, which indicates a moderate degree of ecological risk. In general, soils from the Palić area exhibited slightly higher contamination levels than those from the Ludaš area.

Elevated values of soil pollution in the area of Palić (especially Cd) are probably due to anthropogenic sources, as a consequence of intensive agricultural production and proximity of urban settlements. Higher concentrations of Cd may originate from the excessive and inadequate use of mineral fertilizers, particularly phosphate fertilizers, as well as from pesticides and fungicides with older formulations (e.g., cadmium-based).

Further research is needed to effectively monitor the status of PTEs and establishment of buffer strips between targeted locations, areas of intensive agriculture and the lake water body, which can reduce the transfer of

pollutants, limit erosion, and enhance the ecological resilience of the shoreline.

Key words: potentially toxic elements, soil pollution, protected area

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APPLICATION OF QUANTITATIVE INDICES FOR ASSESSMENT OF SOIL POLLUTION: A CASE STUDY IN SERBIA AND BIH

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ABSTRACT

The assessment of soil pollution level and environmental risk from potentially toxic elements (PTEs) is often based on several pollution indexes, among which the pollution index (Pi), enrichment factor (Ef), geo-accumulation index (Igeo), pollution load index (PLI), and potential ecological risk index (PERI) are frequently used. The aim of this work is to critically evaluate the reliability of the achieved assessments, taking into account the variability of PTEs origin and their background contents in soil.

Two extensive sets of data were considered for this evaluation: PTEs contents in 274 top-soil samples of agricultural soils from the catchments of the six main rivers in Serbia: Danube, Sava, Great Morava, West Morava, Drina, and Kolubara and 169 top-soil samples of agricultural soils across three geomorphological units (plains/lowlands, hilly and mountainous terrains) in the northwestern region of Bosnia and Herzegovina (BiH). Nickel (Ni) was selected as the representative PTE in this study, primarily because of its geogenic origin and consequently high background levels in those regions.

Total Ni content was above the legislative threshold value in all soils from all catchments from Serbia. Accordingly, based on Pi, which is based on legislative thresholds, 95% of those soils were categorized as moderately and extremely polluted, without any sample in the category clean. However, when Ni background was introduced in the assessment of pollution through Ef, minor and moderate enrichment were indicated, whereas there was no soil in very or severely enriched categories. Similarly, in the other study, in BiH, total Ni exceeded the maximum allowed concentration for unpolluted soils in 65.4 % of analyzed soils across all geomorphological units. Based on the Igeo, which, as Pi, takes into account

background values, more than 90% of soils were categorized as unpolluted. Opposite to that, Pi categorized more than 50% of soils as low to moderately polluted. The findings clearly evident that Pi may overestimate the pollution level when the background Ni value is high because of geogenic origin. Conversely, indexes like Ei and Igeo qualitatively differ from Pi because they account for background variables. Ei and Igeo significantly lowered the pollution level, as shown by Pi, in both studies.

We concluded that the implementation of indices that account for background PTEs levels results in a more reliable estimate of the pollution level, especially in cases of a high proportion of elements in soil from natural sources. In order to achieve reliable pollution assessment, national legislation must recognize and implement background PTEs levels and establish two categories of thresholds—one for soils with no significant geogenic input of PTEs and the other for soils with a significant geogenic influence on PTEs contents. Without it, an unrealistically defined threshold may not always be accurate in determining the degree of pollution and the corresponding environmental risk; as a result, it may significantly overestimate the level of pollution and produce inaccurate conclusions. This would be especially important in the terms of determining agricultural soil health.

Key words: pollution, potentially toxic elements, environmental risk, pollution indexes

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EFFECT OF SULFUR AMENDMENT ON HEAVY METAL UPTAKE BY RAPESEED FROM MULTICONTAMINATED SEDIMENT

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ABSTRACT

Heavy metals represent a global environmental concern, originating from natural sources and anthropogenic activities. Soils contaminated with heavy metals are unsuitable for food production for humans and animals. However, they can be used for cultivating energy crops for biofuel production with simultaneous process of phytoremediation. Phytoremediation is an environmentally friendly and cost-effective in situ process in which plants accumulate, immobilize, remove, or degrade pollutants from soil, sediment, or water. As heavy metals are often not bioavailable, assisted phytoremediation is applied, where soil amendments enhance metal mobility and plant uptake. Sulfur is a commonly used amendment for mobilizing heavy metals. It naturally occurs in soils in inorganic (sulfides, sulfates) and organic (bound to N and C) forms. Elemental sulfur in soil undergoes microbial oxidation to sulfate ions, which lowers soil pH and increases the solubility and bioavailability of heavy metals.

This study aimed to investigate the effect of sulfur on the uptake of Cr, Cu, Pb, and Cd from multicontaminated sediment by an energy crop – rapeseed (*Brassica napus*). Rapeseed was grown in pots with the addition of 300 mg S/kg and 500 mg S/kg of sediment under semi-controlled conditions. Plant samples were collected six and seven weeks after sowing. Heavy metal content in above-ground plant parts was determined using ICP-MS. Sequential extraction of sediment was performed to assess metal distribution in sediment fractions before and after the experiment. Control plants were grown in contaminated sediment without sulfur addition.

The addition of sulfur did not increase the concentration of heavy metals in the water-soluble fraction of sediment. As sulfates of the investigated heavy metals (except Pb) are water-soluble, it may be that sulfur was not transformed into sulfate ions in sufficient amounts. Elemental sulfur addition did not significantly increase chromium concentration in the aboveground biomass of rapeseed. However, prolonged cultivation (seven weeks) in

sulfur-amended sediment resulted in a 50% increase in Cr concentration in the above-ground rapeseed biomass compared to six-week-old rapeseed, whereas no increase was observed in the control. This suggests continued Cr uptake during extended growth in the presence of sulfur. Sulfur amendment did not significantly affect Cu, Cd, or Pb concentrations in above-ground rapeseed biomass, nor did extended cultivation (seven weeks) with sulfur amendment enhance Cu, Cd, or Pb uptake. Uptake efficiency of heavy metals did not differ significantly between the application of 300 mg S/kg and 500 mg S/kg of sediment. Lower uptake of Cd, Cu, and Pb during prolonged sulfur exposure is likely due to reduced bioavailability of these metals, as confirmed by decreased proportions in bioavailable sediment fractions.

Sulfur amendment effectively enhanced chromium uptake in rapeseed during prolonged cultivation, while having little effect on Cu, Cd, and Pb accumulation. The observed decrease in bioavailable metal fractions suggests that sulfur may even reduce heavy metal mobility, indicating its limited effectiveness as a mobilizing agent in the tested sediment. These findings indicate that sulfur can be a useful soil amendment for targeted phytoremediation of chromium-contaminated sediments.

Key words: phytoremediation, heavy metal, sulfur, rapeseed, energy crop

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HEAVY METAL IMMOBILIZATION POTENTIALS OF SOME AGRICULTURAL WASTES IN CONTAMINATED ARABLE SOIL

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ABSTRACT

Soil pollution, particularly heavy metal contamination, poses a critical environmental challenge with implications for human health and ecosystems. This study investigated the potential of agricultural waste materials: Cassava peel (CP), Conventional charcoal (CC), Maize husk (MH), Maize stover biochar (MSB), Oilpalm frond biochar (OFB), and Rice husk (RH) to immobilize heavy metals in contaminated soils and to identify the most suitable immobilization agent.

A neutral loamy sand arable soil (pH 7.34), sampled in 1 kg portions in triplicate, was spiked with intervention levels of selected heavy metals (Cd - 380, Cr - 240, Ni - 720, and Pb - 210 mg kg⁻¹). Each soil sample was amended separately with an equivalent of 10 t ha⁻¹ of the respective additive before being packed into leaching columns. The columns were watered with 100 ml of distilled water at 7-day intervals for 90 consecutive days. Heavy metal concentrations in both leachate and soil samples collected from each column were analyzed to evaluate the efficiency and capacity of the immobilization agents.

The results showed that heavy metal retention in the soils depends on the additives. Control had significantly higher values compared to most other amendments, with the lowest values observed in CP (155.60 mg kg⁻¹ Cd), MH (4.23 mg kg⁻¹ Cr and 174.37 mg kg⁻¹ Ni) and CC (83.43 mg kg⁻¹ Pb). In the leachates, RH, MH, CP, and CP showed the highest concentrations of Cd, Cr, Ni, and Pb, respectively. MH had significantly low immobilization efficiency for Cd (4.85%) and Pb (7.55%) but highest for Cr (97.92%) and Ni (49.75%) with OFB and CC respectively exhibited significantly higher values for Cd (42.91%) and Ni (61.64%). The additives did not differ distinctly in their immobilization capacities, except for MH, which had the lowest values for Cd (190.51 mg l⁻¹) and Pb (113.40 mg l⁻¹), whereas CC and OFB showed better capacities.

Overall, the immobilization potential of the amendments was ranked as follows: OFB > CC > RH > MH > MSB > CP > Control.

Key words: Additives, Capacity, Efficiency, Heavy metals, Immobilization

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NATURE-BASED SOLUTIONS FOR SUSTAINABLE REMEDIATION OF POLLUTED SOILS AND SEDIMENTS

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ABSTRACT

Soil contamination caused by industrial activity, wastewater application, and petroleum derivatives presents a persistent environmental risk, particularly in intensively cultivated regions. Conventional remediation approaches are often expensive and disruptive, whereas phytoremediation offers a sustainable alternative by combining the natural ability of plants to uptake and stabilize pollutants with the potential for biomass valorization. The effectiveness of this approach can be further enhanced by microbial inoculants, such as plant growth-promoting rhizobacteria (PGPR) and mycorrhizal fungi, which improve nutrient availability, stress tolerance, and pollutant bioavailability.

Within the ReNBES project, pot experiments were designed to investigate the capacity of selected crops to remediate soils with different contamination profiles. Three types of soils were selected: (i) dredged sediment contaminated with heavy metals (Cd, Zn, Pb, Cu), (ii) agricultural soil contaminated with diesel fuel, and (iii) Chernozem soil amended with treated sewage sludge. Three plant species were cultivated: hemp, forage sorghum, and alfalfa, under control conditions and in combination with bacterial and fungal PGPR inoculants.

Soil analyses before and after cultivation included pH, total organic carbon, nutrient content, cation exchange capacity, bioavailable fractions of heavy metals, PAHs, and TPHs, alongside enzymatic and microbiological indicators of soil health. Biomass was harvested and assessed for pollutant accumulation. Results demonstrated clear crop-specific responses: sorghum showed strong tolerance and high biomass production across all treatments, hemp displayed elevated uptake of Zn, Cu, and Pb from heavy-metal soils, while alfalfa was most efficient to diesel contamination. The application of PGPR inoculants consistently improved nutrient status and biomass growth,

particularly in sludge-amended soils, confirming their role in enhancing phytoremediation efficiency. The results confirm that crop selection and microbial inoculation are decisive factors for optimizing phytoremediation outcomes. These pot experiments provide essential baseline data for scaling up to field trials and for developing cost-efficient, environmentally sound strategies for remediation and revitalization of contaminated soils in the Western Balkans and beyond.

Key words: phytoremediation, contaminated soil,

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POTENTIALLY TOXIC ELEMENTS IN AGRICULTURAL SOILS: IN VITRO BIOACCESSIBILITY AND HEALTH RISK

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ABSTRACT

Agricultural soil is frequently exposed to various pollution sources due to frequent use of agrochemicals and the proximity of anthropogenic sources. Fertilizers, pesticides, irrigation practices, industrial activities, and especially illegal waste disposals may all contribute to increased pollution of agricultural soil. Once present in the environment, these pollutants may migrate into water, air, and agricultural products, leading to human exposure and potential health risks. Therefore, monitoring and assessing the behaviour of pollutants in the agricultural soil is essential to mitigate pollution and protect human health.

Within the framework of several complementary experiments, we investigated the occurrence, oral and inhalation bioaccessibility and human health risk of potentially toxic elements (PTEs) in different agricultural areas in Serbia. The study included vineyard soils from Central and South Serbia and soils collected in the vicinity of illegal landfills in Vojvodina Province and Central Serbia. Pseudo-total concentrations of PTEs were determined using Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES). To better understand the real human exposure, *in vitro* oral and inhalational bioaccessibility were performed. The Unified BARGE Method (UBM) was applied to simulate the gastrointestinal tract, while the simulated lung fluid (SLF) procedure was used to assess the PTE bioaccessibility in the lungs. The results consistently indicated that oral exposure is the most relevant pathway for human health risk associated with PTE in soil. In vineyard soils, Sr, Cu, and Co showed the highest bioaccessibility in the gastrointestinal tract, followed by Mn, Ni, and Zn. Cumulative health risk assessment demonstrated that pseudo-total Ni, Cr,

Co, and Mn concentrations contributed most significantly to the health risk of workers in the vineyards. However, when bioaccessible (oral and inhalational) fractions were considered, the assessed risk did not exceed threshold values (THQ<1), suggesting no increased risk for workers in the investigated vineyards. By contrast, in agricultural areas located near uncontrolled waste dumps, higher PTE concentrations in the soil were determined. The oral bioaccessibility of Cu was particularly elevated (40.54% of the total concentration), while other investigated PTEs exhibited slightly lower values. Human health risk assessment revealed an increased concern for local agricultural workers, with results pointing to a moderate carcinogenic risk based on both pseudo-total (2.60×10^{-5}) and bioaccessible (1.58×10^{-6}) PTE concentrations. These findings emphasize the importance of including bioaccessibility data in exposure and risk modeling, as the actual internal dose is often lower than the pseudo-total PTE concentrations in soil. Assessing only pseudo-total concentrations may lead to an overestimation of the actual exposure and health risk, especially for PTEs. Therefore, incorporating bioaccessibility data is essential for accurate risk characterization and for prioritizing remediation actions in polluted agricultural areas.

Key words: soil, gastrointestinal tract, lungs, health risk assessment

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INDIGENOUS MICROORGANISMS FOR BIOTRANSFORMATION OF PFAS AND IMPROVEMENT OF THE SOIL QUALITY

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ABSTRACT

The biodegradation of per- and polyfluoroalkyl substances (PFAS), often referred to as “forever chemicals,” has attracted considerable research attention in recent years. Due to their unique chemical and physical properties, these compounds have found widespread use, but their exceptional resistance to breakdown, stemming from the strength of the C–F bond, makes them particularly challenging to degrade by conventional methods. Current studies indicate that the biodegradation of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), which are frequently employed as model compounds, has been demonstrated with several microbial species, including *Acidimicrobium*, *Pseudomonas*, and *Gordonia*, as well as through the use of mixed microbial consortia.

To enable the effective scaling-up of microbial consortia-based bioremediation processes, strategies such as bioaugmentation and biostimulation can be employed. Bioaugmentation entails the deliberate introduction of tailored microbial consortia into contaminated environments to accelerate pollutant degradation, with its success largely dependent on the careful selection and optimization of consortium composition.

Six consortia of anaerobic microorganisms were isolated from the environment, with samples 3 and 4 characterized by long-term PFAS contamination. In the laboratory, the consortia were adapted to extremely high concentrations of PFOA and subsequently used to inoculate a medium supplemented with PFOA at a concentration of 500 ppm. Under anaerobic conditions, after 14 days of incubation, the greatest reduction up to 34% was recorded in sample 4 (Chart 1). Shorter-chain homologues were detected as products of PFOA biotransformation.

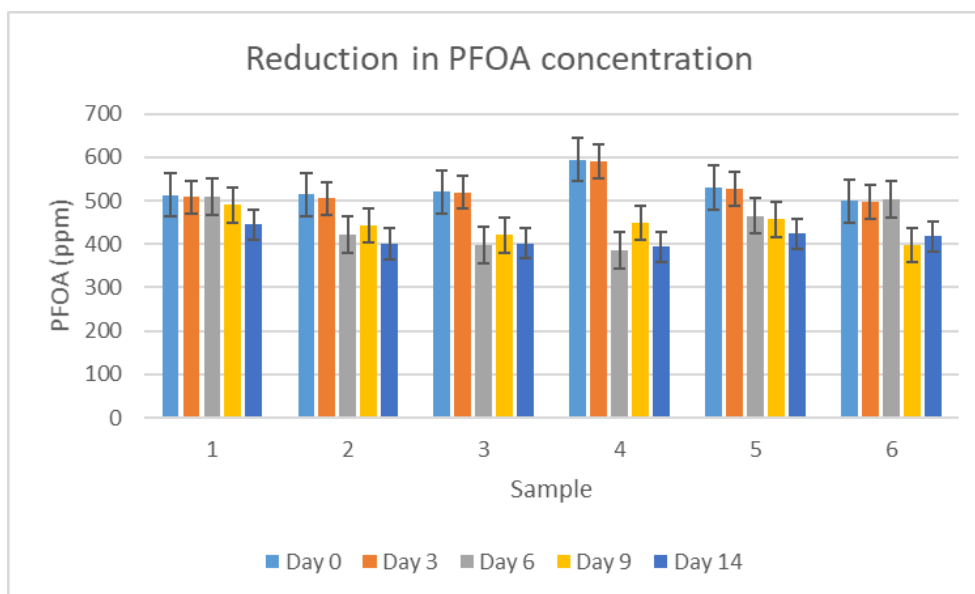


Chart 1. Biodegradation activity of all six consortia.

We conclude that microorganisms isolated from PFAS-contaminated environments possess the potential to reduce the concentrations of these compounds and contribute to soil recovery, and that further research is necessary to optimize this bioremediation process.

Key words: PFAS, microbial consortium, bioremediation

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IMPLEMENTING PLANTATION MISCANTHUS INTO RECLAMATION SYSTEM OF TECHNOGENIC SOILS OF REPUBLIC OF SRPSKA

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ABSTRACT

Surface mining of mineral raw materials has the greatest impact, resulting in soil loss. Temporary soil loss is usually caused by surface mining of mineral raw materials. Mining activities have some of the most noticeable impacts on environment (soil, water, air, organisms).

There are many methods used in the revitalization and reclamation process of technogenic soil. Technogenic soils are formed through overburden and interburden disposal mineral resource extraction. The primary goal of technogenic soil reclamation is surface stabilization and the improvement of soil fertility.

Cultivation of energy crops can represent significant advantages of reclamation of technogenic soil. *Miscanthus* (*Miscanthus giganteus* Greef et Deuter) is a perennial rhizomatous grass with C4 photosynthesis, introduced to Europe. *Miscanthus* is a promising energy crop with several biomass utilisation pathways, including combustion, animal bedding and biogas production. *Miscanthus* cultivation is suitable for soils of low fertility, erosion-prone areas, soils with unfavorable mechanical composition, and even ecologically protected areas.

A particular potential for the development of plantations of miscanthus is found in soils of reduced productivity and low fertility, as well as on technogenic soils (Deposol, Cinerosol, Rekultisol). The areas technogenic soil (mining lands) in Republic of Srpska is estimated from 7,000 to 8,000 ha. The largest mining basins include the open pits at Stanari, Ugljevik and Gacko coal mines, the metallogenetic area of Ljubija (Prijevor), and the Milići bauxite deposit.

Planting miscanthus could simultaneously achieve multiple effects: effective decarbonization, reclamation of degraded soils, production and cycling of organic matter, reduced emissions during combustion compared to fossil fuels, and a sustainable source of renewable energy.

The results of the research on dry mass yield of miscanthus in the Stanari coal basin in the period from the 5th to the 6th year of plantation are 16.5–18 t ha⁻¹. For the purpose of analysis, laboratory tests were carried

out to determine the calorific values of the dry mass of miscanthus after harvest and its comparison with lignite coal from the Raškovac open pit (Stanari deposit).

Table 1. Results of the elementary and calorific value of miscanthus and coal from Raškovac (Stanari coal mine)

No. of sample	Type of sample	Content of moisture	Content of ash	Combustible matter	Volatile matter	C-fix	Total S	Calorific value
1	Whole plant	18.12	5.02	76.86	62.97	13.89	0.09	18,273
2	Stem	18.37	2.38	79.24	66.39	12.86	0.07	18,621
3	Leaf	17.79	6.16	76.05	64.29	11.76	0.10	17,995
4	Coal 1	48.17	11.02	40.80	24.70	16.11	0.14	8,947
5	Coal 2	51.09	5.37	43.54	26.16	17.39	0.10	9,644

Miscanthus has a higher calorific value than lignite. Amount of 20 t of miscanthus is equivalent to 35–40 t of lignite in energy terms. Amount of 20 t of miscanthus is equivalent to 12 t of hard coal. A critical factor for an energy crop is its moisture content at harvest. The drier the crop, the higher the energy yield and bale value.

On degraded and technogenic soils, it is suitable for cultivating energy crops as a form of green renewable energy, as confirmed by this study. In future research, it is necessary to perform an economic assessment (establishment, maintenance, and harvesting costs) of miscanthus, as well as an evaluation of emissions under real conditions, to provide more precise estimates of the overall benefits.

Key words: technogenic soil, energy crops, miscanthus, reclamation

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POTENTIAL OF ENERGY PLANTS COUPLED WITH PGPR FOR PHYTOEXTRACTION OF METALS FROM SOILS

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ABSTRACT

Conventional soil remediation technologies are often costly, energy-intensive, and may negatively affect the soil quality and functions. However, natural-based solutions such as using energy crops and associated microbes may be an environmentally friendly and cost-efficient alternative. The objective of this study was to assess the influence of growing energy crops with the addition of fungal inoculants and bacterial PGPR (Plant Growth-Promoting Rhizobacteria) on heavy metal concentrations and bioavailability in multielement contaminated soil. The pot experiments with soil contaminated with Cr (137 ± 33 mg/kg), Cu (121 ± 21 mg/kg), Cd (3.43 ± 0.8), and Pb (77 ± 15 mg/kg) were performed in 2024. Forage sorghum and hemp were selected for the experiment and grown for 10 weeks in contaminated soil. Before sowing, the soil was treated with two types of PGPR: bacterial (mixture of *Bacillus subtilis*, *Bacillus megaterium* var. *phosphaticum*, *Azotobacter chroococcum*, *Enterobacter*, *Paenibacillus polymyxa*) and fungal (mycorrhizal fungi: *Glomus* VS, *Trichoderma harzianum*). Total concentration of heavy metals were analysed before and at the end of the experiment.

Cr, Cu, and Cd concentrations in the soil of all pots were significantly lower after the harvest compared to the start. The highest decrease in metal concentrations was noticed in pots with sorghum, where Cr concentration was decreased by 47%, Cu by 46%, Cd by 47%, and Pb by 13%. The lowest decrease in concentration was noticed in pots with sorghum + mycorrhizal fungi, and it was statistically significant only for Cu (17%). Compared to sorghum, hemp was less efficient in decreasing metal concentrations in soil (Cr was decreased by 23%, Cu by 33%, Cd by 13%, and Pb concentration remained unchanged). However, application of PGPRs significantly increased the uptake of metals by hemp, inducing a decrease of metals by 38% (Cr and Cu) and 36% for Cd.

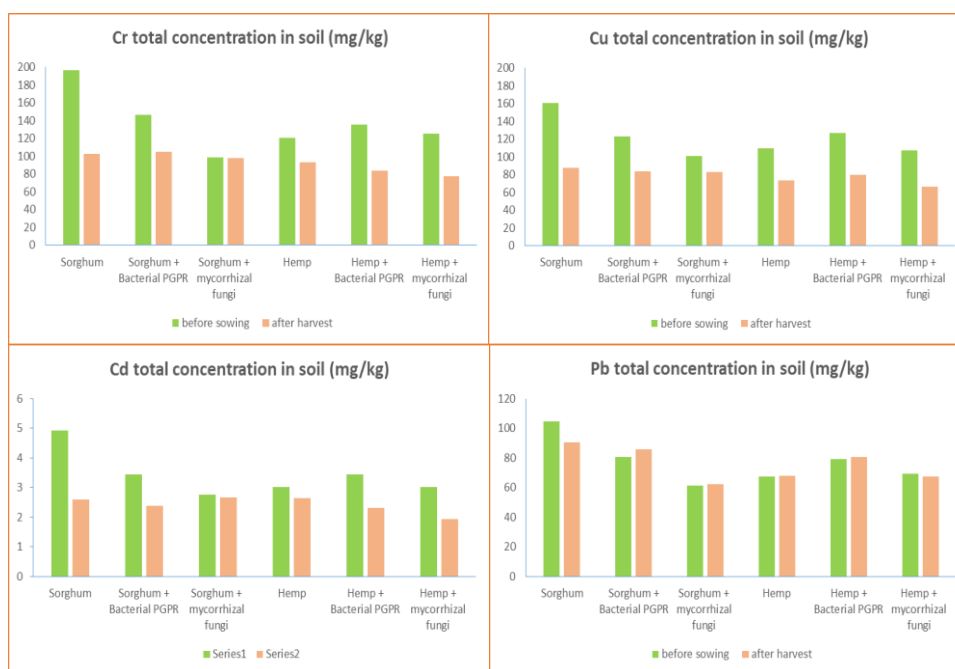


Chart 1. Heavy metal concentrations in soil before and after the experiment

These results demonstrate that energy crops, particularly forage sorghum, can effectively reduce concentrations of heavy metals in contaminated soils. While hemp showed lower overall efficiency, microbial inoculation substantially enhanced its remediation potential. Overall, this approach offers a promising, nature-based alternative for managing multielement contaminated soils.

Key words: soil pollution, heavy metals, phytoextraction

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IMPROVEMENT OF SOIL HEALTH AND BIODIVERSITY THROUGH APPLICATION OF TECHNOSOLS IN ABANDONED MINE-TAILINGS

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ABSTRACT

The Touro mine (NW Spain), exploited for copper extraction between 1974 and 1988, and experienced extreme soil degradation, leaving behind hyperacidic soils with no vegetation. The rapid oxidation of sulfides and contamination of nearby rivers were the main environmental issues.

Different treatments have been carried out to improve soil health, including technosols application, composed of a mixture of ashes from combustion of woody debris biomass, pulp mill from the paper factory, together with sewage sludge, residual aluminium gels from aluminium extrusion industries, mussel shell waste, crushed biomass and filler from crushing amphibolite and schist to obtain road aggregate.

The primary objective of this study was to assess the potential of technosols application to improve degraded soils after mining activities.

To assess the soil health indicators in these areas, two areas were selected (non-restored vs. restored area), where different remediation activities have been carried out over 23 years. Eight samples by area were collected in 2023, and 46 soil health indicators have been analyzed to

assess the impact of remediation activities on soil ecosystem services (provisioning, regulating, supporting and cultural).

In general, the technosol application successfully neutralised soil acidity and restored biological activity. Over 23 years, the treated areas have developed diverse vegetation (pines, eucalyptus, and native species) and local fauna such as rabbits, foxes, and birds of prey. Additionally, these soils demonstrated a high capacity for carbon retention (with >12% organic carbon in surface horizons), contributing to climate change mitigation. Moreover, microbial biomass and diversity are high, with bacterial abundance and total PLFA exceeding reference values. Fungal presence is also robust, although fungal diversity is surprisingly low.

Overall, the technosol-reclaimed soil shows strong potential for ecosystem service delivery - especially in carbon storage, nutrient cycling, and microbial functioning, though challenges remain in nutrient balance and maximising plant productivity.

Key words: soil restoration, mining activity, spolic technosols, soil ecosystem functions

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SOIL AND SOCIETY: EDUCATION, CULTURE, ARCHAEOLOGY AND AWARENESS

ARCHAEOLOGY AND SOIL SCIENCE FOR THE PRESERVATION OF VIMINACIUM LANDSCAPE

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ABSTRACT

Civilisations' development depended on people's relationship with the landscape, and one of the key events in human history was the Neolithic land cultivation for nutrition. The extent to which agriculture was later valued by the Romans is evidenced by many archaeological traces in the landscapes they inhabited.

Viminacium Archaeological Park in present-day Serbia, near the village of Kostolac, preserves the remains of a Roman legionary fortress and a city that developed in the Stig plain near the Danube at the beginning of the Common Era. In addition to the strategic location of the site itself, it was the plain's fertility that influenced the development of a large city with surrounding agricultural estates. However, great organisational skills had to be invested in the water supply and drainage of the marshes for the settlement to become an urban centre. After the downfall of the Roman Empire, established land management died out in this area, and no urban settlement developed again. The significance of Roman achievements is also evidenced by the fact that the area faces water supply problems even today. Thanks to the soil fertility, agriculture has been developed here ever since, with various plants' cultivation in the Middle Ages, the milling industry notably developed in the 19th-20th centuries, and contemporary grain farming with good yields.

Coal exploitation and electricity generation leave permanent marks in the Kostolac landscape, with the loss of large agricultural fields during the last four decades, whose recultivation awaits. Archaeological excavations make parts of the fields disappear as well, but in return bring valuable knowledge on past land management (Figure 1). However, the connection of soil science with the humanities has not been studied enough during the planning of recultivation.

Through recultivation, landscapes can become agricultural again, but can also be used for other activities, gaining new values. Can the results of archaeological research, with archaeobotany, archaeopalynology and geoarchaeology, be used in the recultivation of the degraded Viminacium landscape? The establishment of experimental fields within Viminacium Archaeological Park can be the beginning of the interdisciplinary

collaboration that connects archaeology and soil science, agriculture and cultural heritage protection, responsible and sustainable tourism and environmental preservation. We hope that the initial attempts already conducted by archaeologists will be developed further, both for the interest of science and the local communities, while preserving this invaluable historical landscape.



Figure 1. Viminacium landscape with excavated archaeological remains and visible field marks of buried past structures (photo by Nemanja Mrđić)

Key words: Viminacium, archaeology, soil science, agriculture, recultivation, sustainability.

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SEEING, TOUCHING, SMELLING, TASTING AND HEARING SOIL: THE ROLE OF MULTISENSORY LEARNING IN SOIL EDUCATION

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ABSTRACT

Multisensory learning is an innovative and effective pedagogical approach that enhances soil science education by engaging learners through direct sensory experiences. This method encourages active participation, critical thinking and deeper cognitive engagement by presenting soil as a dynamic, sensory-rich subject.

Recognising the often overlooked complexity and importance of soil, we conducted a multisensorial workshop, aimed to create a more memorable and personal connection between participants and soil. The workshop engaged all five human senses - sight, smell, touch, taste and hearing, while providing an experiential alternative to traditional didactic methods. The activities promoted soil curiosity, education and awareness of the important role of soil in the environment.

Participants took part in creative activities and exercises such as painting with natural soil pigments and soil-based crayons, looking at soil samples under a microscope and tactile, smell and even taste experience of different soil types. Previously unheard 'sounds of soil' highlighted the acoustic dimension of soil biota and further contributed to participant engagement. To provoke thought and create a deeper personal connection, participants were asked to choose a soil type they personally could most identify with — an exercise in anthropomorphism that encouraged individual interpretation and storytelling.

Feedback was sought from participants during and after the workshop to assess its effectiveness. Preliminary analysis of the responses suggests that this approach increased curiosity, emotional understanding and recall of different soils. Experiencing soil with the human senses and not just with scientific information and data helped participants to understand soil comprehensively and not just as passive ground they walk on. Participants expressed a greater appreciation for soil's ecosystem services and developed a newfound curiosity about its hidden properties and qualities.

This case study demonstrates the value of integrating multisensory and interdisciplinary methods into soil education to increase soil literacy and promote public engagement in soil conservation. By transforming soil from

an abstract scientific concept into a tangible experience, such workshops can significantly broaden the audience's understanding and emotional connection to soil. As this area remains underrepresented in both soil science research and education, the results of this initiative show the potential for further interdisciplinary exploration.



Image 1: Working material for soil painting and drawing

Key words: soil curiosity, soil education, soil sensing, multisensorial workshop, multisensory experience, soil perception

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Original scientific paper
Poster presentation

SOIL KNOWLEDGE TRANSFER THROUGH SCIENCE, CULTURE AND ART

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ABSTRACT

The Alpine region is particularly prone to soil degradation due to the effects of climate change and the thoughtless or incorrect use of resources. The SOIL:OurInvisibleAlly project addresses this issue and aims to raise awareness across countries that soil is our invisible ally that needs to be protected and cared for.

The new approach taken is characterized by the use of artistic and cultural events to attract the attention of a broad public. Illustrative, science-based best practice examples are also collected, pilot sites are presented to demonstrate appropriate management tools, and obstacles to sustainable soil management are explored. Sustainable soil management (SSM) is what maintains, restores or improves soil functions, e.g. minimizing and preventing soil erosion, sealing and compaction while maintaining or increasing soil biodiversity and organic matter content and, where possible, improving soil water management. By training local facilitators, advisors, and educators ('multipliers'), the project ensures that soil knowledge spreads in a snowball effect.

A booklet for municipalities, political decision-makers and spatial planners with case studies and tangible SSM solutions is one of the most important outputs of the project and will help to create feasible regulations. It will serve as a guide for decision-makers, highlight success criteria and show how common obstacles can be overcome. Capacity building through workshops is expected to motivate stakeholders to actively engage, while interdisciplinary art and cultural events — such as painting competitions, ceramics making, and the development of educational toys and games for children, youth, and adults — will help raise awareness of the importance of preserving and restoring healthy and resilient soils in Alpine areas.

Key words: Alps, soil resilience, sustainability, interdisciplinarity, arts, culture

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TRANSFERING KNOWLEDGE ON SOILS TO FUTURE DECISION MAKERS: FROM HALF AN HOUR TO THREE DAYS ACTIVITIES

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ABSTRACT

Equipping future decision-makers with accurate and professional knowledge about soil is essential for soil protection and tackling environmental problems. Nevertheless, soil-related topics are still insufficiently represented in school curricula, limiting awareness of the crucial role of soil in ecosystems. To address this gap, as part of the EU Horizon CURIOSOIL project, we have developed a series of optional indoor and outdoor educational activities designed to stimulate soil curiosity and deepen understanding of soil science among primary and secondary school students.

The range of activities offers three flexible formats that differ in content and duration to suit different timetables and curriculum capacities. In each version, the core objectives are maintained: To engage students through interactive, non-graded activities that go beyond the standard curriculum, to encourage active and hands-on learning, and to stimulate their curiosity about soil.

The first and shortest version, lasting around 30–45 minutes, begins with an introductory lesson on soil as a vital natural resource, emphasising its key ecosystem services. This is followed by a quiz with up to ten questions, including fun facts about soil. This format is designed to fit easily into a single lesson and all schools can participate regardless of time and place constraints.

The second, more comprehensive version, which takes up to five hours, is suitable for schools that can spend more time on extra-curricular learning. It extends the introductory lesson and quiz to include simple laboratory analyses of soil samples. Students are introduced to the basic methods of soil research. The workshop concludes with a creative activity where students make their own soil crayons using natural beeswax and finely ground soil powder and create a painting with soil.

The third and most comprehensive outdoor version is usually run during the summer holidays as a three-day summer school on the theme of soil. In addition to classroom and lab activities, students participate in fieldwork and gain hands-on experience with soil science tools and techniques. They excavate a soil profile, describe its horizons using a field data sheet and become „pedologists for a day“. This intensive experience enables the

students to develop a deeper and more personal relationship with the soil and its properties.

Contacted schools showed willingness to implement the activities. Including brief quantitative or qualitative data on participant feedback would strengthen the claims of effectiveness and engagement. Participants reported an increased curiosity about soil, a greater awareness of its ecological importance and a more personal connection to it. These results suggest that hands-on and field-based experiences are more effective than traditional methods in promoting meaningful engagement with soil-related topics.



Image 1: Introductory lesson on soils ecosystem services

Key words: soil knowledge, soil curiosity, extracurricular activities, workshop, summer school, teaching methods

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Original scientific paper
Poster presentation

CITIZEN SCIENCE APPROACH FOR IMPROVEMENT OF SOIL HEALTH THROUGH SCHOOL COMPOSTING

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ABSTRACT

Soil quality is declining globally and requires urgent improvement through practical, widely accessible solutions. Composting has been used for millennia to enhance soil health, yet in urban areas, this sustainable, climate-friendly practice is often less accessible. Within this science project, the aim of the study was to integrate citizen science by involving students directly in the research process as a powerful way to engage schools, using composting as a hands-on method to connect education, sustainability, and community action.

In short term, the project aims to reduce organic waste sent to landfills, lower greenhouse gas emissions, and improve soil health, while simultaneously promoting science, environmental awareness, and community engagement. In the long term, the project seeks to influence policy makers to integrate circular economy practices city-wide and adapt school curricula to strengthen environmental education and science literacy.

The project involves three elementary schools in Novi Sad, and at least 45 student citizen scientists, who will maintain and monitor composting process at their school composters. It was decided that the following research methodology would be implemented to achieve the study objectives. Composting parameters, including temperature, pH, moisture, and EC, will be monitored using sensors, and the data will be recorded under the guidance of project team members and university mentors (two mentors per school). Subsequently, pot experiments will be conducted to assess the effects of compost addition on soil health and plant growth parameters. Physico-chemical and biological properties of compost and soil will be measured, including bacterial and fungal community analysis using 16S rRNA and ITS sequencing. The social aspect of the study will be

assessed regarding the impact of project participation on students' overall health and wellbeing, as well as on their knowledge and attitudes towards science and environmental issues, through questionnaires completed before and after participation.

To summarize, this citizen science approach connects education, sustainability, and policy, demonstrating how small-scale local actions can drive broader societal and environmental change.

Key words: citizen science, compost, education, sustainability, circular economy

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CITIZEN SCIENCE: A PATHWAY TO SUSTAINABLE SEWAGE SLUDGE USE IN AGRICULTURE

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ABSTRACT

The Republic of Serbia is undergoing a transformative expansion of its wastewater treatment infrastructure, which is expected to multiply the amount of sewage sludge generated in the coming years (Figure 1). However, the country currently lacks a comprehensive and sustainable system for sludge management. Agricultural land application presents a promising solution, aligning with circular economy principles. On the other hand, it stays highly regulated due to the risks concerning different contaminants present in the sludge and in soil. Initial possibility assessment of this approach is hindered by outdated and insufficient soil data, limited awareness, but also with additional cost of soil testing that will be mandatory when applying sewage sludge on land, which can be a barrier for smallholder farmers.

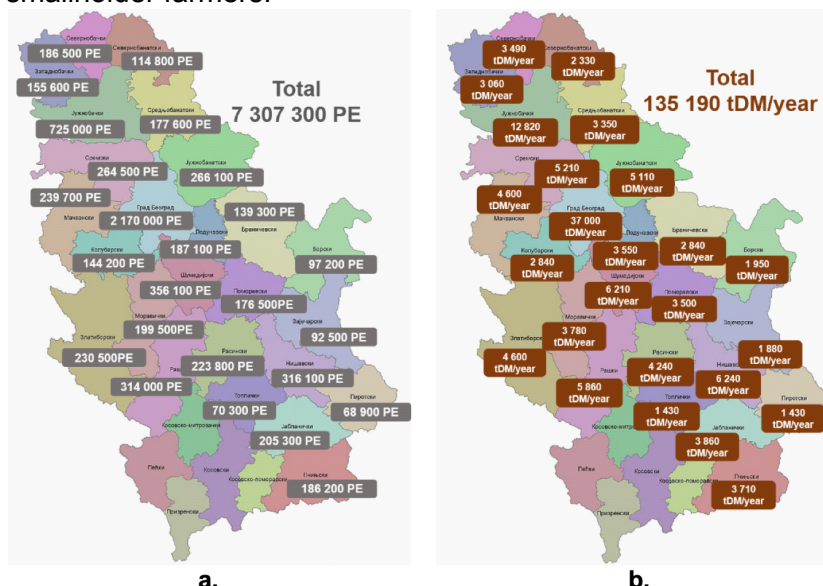


Figure 1. Projected capacity (a); annual production of sludge dry matter (b)

Approach based on citizen science, engaging farmers as active contributors in environmental monitoring and decision-making is a sound approach. Through structured training, participants learn standardized soil sampling methods, enabling them to collect reliable soil data from their own fields. Sampling methods will be aligned with the national Regulation Official Gazette RS 103/2023, which is in accordance with the EU Sewage Sludge Directive (SSD 86/278/EEC) and harmonized with SRPS ISO 18400 series. Parameters analysed will be the soil pH and heavy metal content (obligatory for farmers), but also nutrient and organic matter content in accordance with general ISO/IEC 17025:2017 requirements. These samples are to be analyzed in parallel with expert-collected samples to evaluate the accuracy of citizen-contributed data. This approach empowers farmers to navigate the complex national legislation regarding sewage sludge application (Rulebook on the method and procedure of sludge management from municipal wastewater treatment plants, Official Gazette RS 103/2023) thereby mitigating all potential risks associated with its use in agriculture.

By involving farmers directly in the data collection process, they can reduce soil analysis cost, imposed to them, when applying sewage sludge on their farms. In the same time they can help generate high-quality, location-specific data necessary for assessing the suitability of sludge and derived amendments (compost, biochar, etc.) for agricultural use.

This approach highlights the untapped potential of citizen science in advancing sustainable sludge reuse and soil health monitoring, while managing risks. It offers a scalable model for participatory environmental governance and illustrates how co-produced data can directly inform circular economy strategies and regulatory frameworks.

Key words: citizen science, soil sampling, sewage sludge reuse

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MARGINAL SOILS, RURAL DEVELOPMENT

FROM MARGINAL LANDS TO BIO-BASED PRODUCTS: SUSTAINABLE PATHWAYS FOR BIOMASS PRODUCTION

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ABSTRACT

This research was conducted within the framework of an international “MIDAS” project aimed at unlocking the potential of marginal agricultural lands across Europe for the sustainable cultivation of industrial crops and the development of innovative bio-based products. By identifying and mapping current and future marginal lands eligible for low indirect land-use change (low-ILUC) certification—including assessments of soil erosion, water stress, biodiversity constraints and opportunities, and ecosystem services—the project supports informed decisions on biomass production from underutilized land.

Selected industrial crops adapted to marginal conditions are being optimized through modern biotechnological approaches and tailored agronomic practices, with a focus on improving water-use efficiency and overall resource sustainability. Innovative farming models such as intercropping and agroforestry are tested through farm-level case studies, generating practical solutions for biomass harvesting and biodiversity enhancement. Regional Advisory Groups ensure continuous engagement with farmers, industry stakeholders, and researchers.

Biomass derived from these systems is being transformed into advanced bio-based products—including biochemicals, composites, and elastomers—aligned with the principles of circularity and biorefinery. Multiple biomass-to-product value chain pathways are evaluated using a sustainability-driven, multi-criteria decision-making tool to support the design of regional bio-based value webs that foster biodiversity and climate resilience. Business models will be co-developed to promote circular economy practices at the farm level, with strong participation of local actors.

Through international collaboration, MIDAS facilitates knowledge exchange with partners on crop selection, agronomic innovations, and bio-based product development, contributing to globally relevant, win-win strategies for sustainable land use.

Keywords: biodiversity, bio-based products, marginal lands, sustainable agriculture, value chains

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REVITALIZING AGRICULTURE THROUGH FARMS: ECOLOGICAL AND REPOPULATION STRATEGIES

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ABSTRACT

From ancient times, agriculture has been the cornerstone of society and civilization. By providing enough food for all members of a community, it secures the future and further development of society. An important part of the agricultural system in every country are farms.

Over the last three decades, the number of farms in the Republic of Serbia has declined from over a million in 2002 to less than 500,000 in 2024 (Statistical Office of the Republic of Serbia). Urbanization, industrialization, and the search for “a better life” are the main reasons for these changes in agriculture. Climate change and economic crises have also contributed to this situation.

However, numerous studies have shown that the promotion of farms, farm life, and the revival of agriculture, especially in rural areas, can offer many opportunities in various aspects such as the economy, society, and ecology. Revitalizing farm agriculture in rural regions creates many positive effects: increased livestock production, organic farming, and a large base of raw materials for many types of industry (meat, leather, fiber, healthy organic food).

Many farms could be restored and used for agritourism, as accommodations, museums, or educational centers for children, preserving heritage and old traditions. The restoration of farms could also alleviate city life by decreasing the number of people in already overpopulated urban areas. Farm life provides a healthier lifestyle with less pollution and stress and lowers poverty rates.

Creating a network of farms could be beneficial from an ecological perspective as well. Farm ecosystems act as wind barriers and, together with windbreak belts, decrease erosion processes. Soil fertility is also better preserved since a large amount of manure is regularly produced on farms, which helps maintain humus levels and reduces the need for mineral fertilizers. Many farms to this day are guardians of biodiversity, as they preserve many rare animal breeds and plant varieties especially in remote regions.

The results of preliminary studies have shown that there is great potential for farms in many aspects of agriculture and human activity. Further research should contribute to creating strategies and plans for future actions.

Key words: agriculture revival, rural repopulation, socio-ecological impact, farms

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PROJECT COMPENDIUM

During the Congress, fifteen projects were presented within the Project Expo section - a space designed for learning from one another, exchanging ideas, and finding inspiration for future collaboration.

Projects in this Compendium are listed alphabetically by title, as each carries equal importance. Regardless of their size or scope, all share a common goal: contributing to soil health - a goal that can only be achieved together.

BELIS

Breeding European legumes for increased sustainability

Legumes, both for grain and forage production, play a crucial role in agriculture by providing essential proteins for human and animal consumption and offering environmental benefits mostly related to symbiotic nitrogen fixation. Despite their potential, legume cultivation in Europe has been limited due to a lack of high-yielding and resilient varieties, resulting in a high import rate for legume grains and nitrogen fertilizers into Europe. BELIS aims to bridge the gap by leveraging advanced breeding methodologies and fostering collaboration among research and industry stakeholders.

The project's key objectives are to develop cost-effective breeding tools, improve the economic and regulatory environment for legume breeding, and ensure efficient innovation transfer through a collaborative platform for public private partnership. The project is focusing on seven forage crops (lucerne, red, white and annual clovers, sainfoin, birdsfoot trefoil and vetches) and seven grain crops (pea, faba bean, soybean, white lupin, lentil, chickpea and common bean) representing a major part of the diversity of legume species cultivated in Europe.

The European Union's Horizon Europe program launched the project, "Breeding European Legumes for Increased Sustainability" 101081878, in October 2023 (1.10.2023 – 30.09.2028.), to build a firm base for the legume breeding community in research and industry across Europe.

INRAE (Institut national de recherche pour l'agriculture, l'alimentation et l'environnement) is Coordinator of BELIS project. With a consortium of 34 partners from 18 countries, including research institutes, plant breeders, seed companies, registration offices and advisory services, BELIS is poised to tackle some of the most pressing challenges in legume breeding research and varieties production.

The Institute of Field and Vegetable Crops (IFVCNS), National Institute of the Republic of Serbia, actively contributes to the implementation of the BELIS project, with the aim of enhancing legume breeding programs through the development of advanced tools and approaches. In addition, IFVCNS is developing protocols for abiotic stresses, working on phenotypic and molecular breeding as proofs of concept, improvement of VCU tests and protocols and contributing to the variety recommendation on EU level for various legume crops.

 <https://www.belisproject.eu/>

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ClimaPannonia

Building climate resilience via large-scale uptake of systemic solutions in agricultural ecosystems in the Pannonian region

ClimaPannonia is the coordinated effort of key Pannonian Biogeographical Area (PBA) stakeholders toward strengthening the resilience of the agricultural sector and the region's community against climate change's disastrous effects. This will be achieved by enabling the widest possible uptake of tested and validated climate-neutral solutions for four agriculture subsectors: (i) water-food nexus, (ii) agroforestry, (iii) organic crop production, (iv) cattle production. ClimaPannonia aims to support the PBA agriculture sector in drastically improving its climate resilience. By implementing innovative systemic solutions and fostering collaboration among the six countries within the PBA – Hungary, Serbia, Croatia, Romania, Czechia, and Slovakia – ClimaPannonia will pave the way for a more sustainable and resilient agriculture. By harnessing the knowledge and expertise of leading experts in PBA and leveraging the knowledge of partners from countries such as Germany, Italy and France, ClimaPannonia seeks to ensure that the solutions implemented are innovative not only at the PBA level but also at the European scale.

Solutions from the four agricultural sectors will be tested in four different environments and the same technology will be transferred and replicated across eight environments. Business models and digital solutions will be considered final outcomes.

Project Duration: 1st of March 2025 – 1st of March 2029.

Coordinator and Partners: Univerzitet u Novom Sadu, Poljoprivredni fakultet Novi Sad – coordinator; Udruženje Eko-inovacija na Balkanu; Nemzeti Innovációs Ügynökség Nonprofit Zártkörűen Működő Részvénytársaság; Sveučilište u Zagrebu Agronomski fakultet; Česká zemědělská univerzita v Praze.

Funding Source/Programme: HORIZON-MISS-2023-CLIMA-01

ID Number of Project: 101156281

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C-FARMS **Climate Smart Soil for ZERO-CARBON farms**

The project strengthens climate resilience in the border region by enhancing knowledge of climate impacts on agriculture and promoting adaptation and mitigation strategies. Joint efforts support sustainable soil use, reduce carbon footprint, and improve environmental performance.

The initiative conducts research, pilot actions, and demonstrations of soil organic carbon (SOC) sequestration and recarbonization techniques, including cover cropping, organic mulching, nutrient management, conservation tillage, and crop diversification.

A public-private-people partnership, “Soil Health Living Labs”, restores soil fertility, improves soil health, and increases carbon storage through climate-smart agricultural practices. Knowledge and experiences are shared through outreach, education, and capacity-building activities.

The project engages farmers, cooperatives, policymakers, and experts in Soil Health Living Labs, hosts study tours of SOC-positive projects, runs workshops and Training-of-Trainers (ToT) sessions, and organizes a conference on climate change and soil recarbonization. Together, these actions expand climate-smart agriculture and strengthen resilience across the program area.

Funding Source/Programme: Interreg VI-A Hungary-Serbia, implemented within the 2021–2027 European Union financial framework under the Instrument for Pre-Accession Assistance (IPA)

Project ID: HUSRB/23S/11/034

Project duration: 01 August 2024 – 31 January 2026.

Lead Partner: Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia (RS)

Partners:

P1: Regional Development Agency Bačka Ltd. Novi Sad (RS)

P2: Vackor Environment and Nature Protection Organisation (HU)

Contact:

 <https://hungary-serbia.eu/projects/c-farms>

 <https://www.linkedin.com/company/c-farms-project/>



Interreg



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IPA Hungary - Serbia

C-FARMS

**Donau Soja-Austrian Development Agency
Strategic Partnership Programme**

Empowering Southeast and East European Agri-Food Sector through Sustainable, Traceable, and Non-GM Crop Production, Use, and Consumption

Since 2017, Donau Soja has partnered with the Austrian Development Agency (ADA) to strengthen sustainable, non-GM crop production in Southeast and Eastern Europe. The programme is active in Ukraine, Moldova, Serbia, and Bosnia and Herzegovina, supporting farmers, processors, and value chain stakeholders by promoting sustainable, non-GM soya and crop production, while fostering regional value chains. These efforts contribute to local economic development, poverty reduction, and progress towards the UN Sustainable Development Goals.

Following the successful implementation of Strategic Partnership I (2017–2023), Donau Soja and ADA launched Strategic Partnership II in April 2024. Running until 2029, this new phase expands beyond soya to include multi-crop strategies and digitalisation. It aims to build resilient, traceable, and sustainable agri-food systems, strengthen links between non-EU producers and EU value chains, and safeguard the environment.

Under the output “*Facilitated dissemination of best practices for non-GM, traceable, and sustainable crop production,*” the programme implements interventions that promote and share knowledge across the agri-food sector. Activities include online and on-site knowledge transfer initiatives (such as demo fields and field days, winter courses, seminars, study tours, and workshops); dissemination of results, lessons learned, and success stories; production of knowledge-transfer materials and publications; and information sharing through digital communication. These activities directly empower farmers and other stakeholders at the start of the value chain, equipping them with the knowledge, skills, and tools to improve productivity, increase profitability, and enhance their capacity to adapt to climate change.

More information: <https://www.donausoja.org/projects/ada/>



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SoilDNAFootprints

Environmental DNA – biomarker of soil quality in Vojvodina

Objectives: The project Environmental DNA – biomarker of soil quality in Vojvodina aims to develop and implement an innovative type of soil biomarker to preserve biodiversity and soil fertility in the Autonomous Province of Vojvodina (Serbia). Key objectives are: to develop, standardize, and implement environmental DNA (eDNA) analysis to assess soil biodiversity; to identify the taxonomic profiles of microbial and fauna communities across different soil types in Vojvodina; to correlate qualitative and quantitative community compositions with physical and chemical soil quality parameters and conduct integrative data analysis to formulate sustainable land use strategies and to create a comprehensive database and an biodiversity map for Vojvodina's soils.

Key Activities and Outputs: This Project introduces a groundbreaking methodology to analyze soil biodiversity in Vojvodina for the very first time in the region. By mapping the taxonomic profiles of soil microbiomes as well as invertebrate fauna through environmental DNA (eDNA) analysis, we capture a true and unique picture of the region's soil biodiversity—its ecological "DNA footprint." The project is organized into six work packages (WPs) and 13 associated activities. Critical WPs focus on soil sampling, testing of the soil's physical and chemical properties, analysis of soil communities based on environmental DNA (eDNA) and results integration by bioinformatics and statistical methods. The outcomes form the foundation of a detailed reference database, featuring taxonomic and physiological profiles of key soil organisms essential for monitoring of soil microbial and faunal communities. This database will serve as a vital long-term tool to assess soil fertility and overall health by tracking biodiversity changes.

Expected Impact: The project will open exciting opportunities for the national scientific community to engage in international collaborations focused on advancing soil biodiversity.

Project Duration: 2021-2025

Coordinator and Partners: University of Novi Sad, Faculty of Sciences (coordinator) and Institute of Field and Vegetable Crops, Novi Sad (partner)

Funding Source: Provincial Secretariat for Higher Education and Scientific Research of Autonomous Province of Vojvodina

ID Number of Project: 003042578 2024 09418 003 000 000 001/2

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→ eDNA

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PI Prof. Dr. Mihajla Djan  mihajla.djan@dbe.uns.ac.rs

WasteToWealth

From Waste to Wealth: How Compost Shapes Soil and Health

Objectives: This citizen science initiative aims to implement circular economy practice of composting in elementary schools and examine the effect of obtained compost on the soil health. Project engages school children in designing and maintaining **school composters**, monitoring the composting process, and using the resulting compost to **enhance soil quality in school yards**. Through hands-on participation, students will learn about sustainability, circular economy, soil science, and microbiology while contributing to real scientific research. Beyond the ecological aspect, this project also explores the potential impact of composting and gardening on students' wellbeing, knowledge and environmental awareness.

Key Activities and Outputs: In the **preparatory phase** University biology, ecology and chemistry students and schoolteachers will be trained in basic principles of composting, on-site parameter measurements and sampling. In **composting phase** student scientists will maintain and monitor composting process by soil sensors, while detailed physico-chemical and biological analyses of compost will be conducted in the laboratories of the Faculty of Sciences. **Pot experiment phase** will assess the effect of compost amendment on soil health and plant growth parameters, including soil microbiome analysis, physico-chemical and biological properties, plant sprouting, stem length, etc. **Impact and engagement activities** will include assessment of the students' wellbeing and their knowledge and attitude towards environmental issues and science, visit to City's composting facility and microbiology and chemistry labs at the Faculty of Sciences. The project will openly distribute data on physico-chemical, biological and microbiome properties of compost and soil.

Expected Impact: project aims to test the feasibility of school composting in our city, contribute to waste and GHGs emission reductions, implement circular economy practice, improve soil health and students' wellbeing, knowledge and awareness on science and environmental issues. To that, we aim to influence policy makers to further expand and fund similar initiatives in more schools across Novi Sad and Serbia.

Project Duration: 7 months (June 16th 2025 – January 16th 2026)

Coordinator: University of Novi Sad Faculty of Sciences

Funding Source/Programme: Impetus Accelerator grant

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Funded by
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Improving C-balances on organic farms for the sequestration of atmospheric carbon

Agricultural soils in Slovenia, Serbia, and Poland have been facing a continuous decline in organic matter over the past three decades, resulting in reduced soil fertility and increased greenhouse gas emissions. Organic farming offers great potential for carbon sequestration, but its implementation remains limited due to insufficient technical knowledge and weak cooperation among farmers, advisors, and policymakers.

The project aims to enhance carbon sequestration in organic farming by improving knowledge, strengthening collaboration, and promoting sustainable practices through demonstration trials, training programmes, and policy support. By fostering collaboration and practical implementation, the project contributes to sustainable soil management and climate change mitigation in Central and Eastern Europe.

Main activities:

- Establishment of demonstration trials testing cover crops, agroforestry systems, and organic amendments to enhance soil organic carbon.
- Development of training materials and capacity-building programmes for farmers and advisors.
- Workshops, field visits, and policy dialogues involving farmers' associations, advisory services, and decision-makers.
- Creation of a Best Practices Toolbox containing guidelines, case studies, and examples for wider dissemination across Europe.

Funding Source/Programme: Funded by the European Climate Initiative (EUKI), a programme of the German Federal Ministry for Economic Affairs and Climate Action (BMWK)

Project duration: February 2025 – April 2027.

Implementing organisation: Naturland e.V., Germany

Partners: Agricultural Institute of Slovenia (KIS), Slovenia; Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Serbia; and The National Institute of Horticultural Research, Poland

Contact: Vogt-Kaute Werner  w.vogt-kaute@naturland.de

 <https://www.euki.de/en/euki-projects/improving-c-balances-on-organic-farms-ii/>

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LOESS
Literacy boost through an Operational Educational
Ecosystem of Societal actors on Soil health

Launched in mid-2023, the LOESS project is a three-year international initiative aimed at spreading knowledge, raising awareness, and developing innovative educational resources about **soil health**. Twenty partner organizations in 15 countries are building together the knowledge, tools and networks to protect soil for generations to come.

LOESS connects experts, educators and local communities across Europe in mapping out the current level of soil knowledge at different educational stages. This research phase created a comprehensive understanding of needs and opportunities in soil education, which then opened the way for the creation of **LOESS innovative learning resources** – such as online courses, learning modules and scenarios, podcasts, citizen science tool, augmented reality application. By leveraging modern technology, LOESS aims to make soil topics more accessible, engaging and widely used. These resources link soil education to pressing global and local challenges, such as climate change, biodiversity loss, and sustainable development, giving a comprehensive view on why soil health shall be a priority at this time. LOESS educational content is tailored to students, young professionals, teachers and other educators and society at large. These open-access materials are freely available to all, translated to multiple languages and together will shape an **European Atlas of Soil Education and Training**.

Project Duration: 2023 – 2026.

Partners: WILA Bonn (Germany), Wageningen University (Netherlands), European Schoolnet (EU), Center for the Promotion of Science (coordinating locally in Serbia) and others.

Contact Information: www.loess-project.eu or isujdovic@cpn.rs



LoginEKO Healthy Food for Everyone

Since 2018, LoginEKO has been transforming the food system from the ground up. From their 3,700 ha organic farm, they create, test, and share solutions that make farming more sustainable, transparent, and healthy choices more accessible. Their approach combines a scalable farming model with their self-developed Farming Software, traceability solutions, and plant-based food development. By proving what works in practice and sharing it openly, LoginEKO aims to inspire change across the global food system.

LoginEKO operates its certified organic farm in Serbia as a real-world testing ground for a plant-based, sustainable farming model with diverse 5–6 year crop rotations. On this foundation, they develop their own Farming Software, built and tested on the farm, to help farmers plan, manage, and analyze operations more efficiently. They advance seed-to-fridge traceability through The Origin, their free platform that demystifies food origins and builds consumer trust, while also creating plant-based food solutions that connect sustainable farming directly to healthier diets. All of these activities are supported by their commitment to openly share knowledge and solutions, inspiring wider adoption and driving system-wide change.

LoginEKO is demonstrating that organic farming at scale can rival or exceed EU average conventional yields while protecting the environment. Their model combines ecological principles with data-driven precision to create sustainable solutions that benefit farmers, food companies, consumers, and policymakers alike.

Partners: Global Network of Lighthouse Farms, Naturland, EIT Food
Funding source/programme: Privately funded by Login5 Foundation.
Contact information: <https://www.logineko.com/> or info@logineko.com



MIDAS

Marginal land Industrial Crops and Innovative Biobased Value Chains



Utilization of marginal lands for growing sustainable industrial crops and developing innovative bio-based products project aims to evaluate, further improve, and optimize sustainable raw materials with low ILUC by developing selected industrial crops and cultivation systems on marginal agricultural land throughout Europe. This includes a way that implies climate resilience, but also acceptability for biodiversity with the support of viable bio-based value chains. Mapping existing and future marginal lands classified as low ILUC, with predictions of further soil erosion and water scarcity, as well as changes in biodiversity, ecosystem services and guidelines for increasing co-benefits, provides a better understanding of available marginal land for "low ILUC" biomass production. Industrial crops, which thrive on such lands, are further optimized with advanced biotechnological tools and adapted to agronomic practices for improved resource efficiency. The agricultural community, the bio-based industry and the academic community are involved in this process through the Regional Advisory Services. The produced biomass enables the development of innovative bio-based products such as biochemicals, composites, elastomers, following the concept of biorefinery and circular use. Future directions from biomass to products are mapped, which will lead to value chain/network concepts and, with sustainability assessment, produce a multi-criteria tool for the design of sustainable bio-based value networks, but also condition the improvement of regional biodiversity. Finally, through case studies, the project develops adequate business plans for agricultural farms to encourage circularity by involving the agricultural community, industrial actors and the academic community. In addition, through international cooperation, MIDAS enables the exchange of best practices and contributes to the development of win-win scenarios.

MIDAS is co-financed by the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101082070, started on 1 November 2022 that will continue through 31 October 2026.

It is coordinated by the Centre for Renewable Energy Sources and Saving Foundation (CRES) from Greece and brings together 24 partners from 13 countries, including research organizations, industries and SMEs.

More information about the MIDAS project can be found at:

<https://www.midas-bioeconomy.eu/>

<https://www.linkedin.com/company/midas-project>

ReNBES

Natural based efficient solution for remediation and revitalization of contaminated locations using energy crops

Soil contamination by metals and organics is still one of the major environmental problems in Serbia, even more, Europe. Consequently, Serbia has recognized the issue related to soil contamination and adopted a set of regulations at the national level. Soil remediation is, therefore, an urgent requirement across the whole of Europe. Conventional soil remediation technologies are very often costly, energy-intensive and may negatively affect the soil quality and functions. However, natural-based solutions (NBS) using energy crops, associated microbes and soil amendments may serve as an environmentally friendly and cost-efficient alternative. For the first time, in the ReNBES project innovative and effective NBS which combines phytoremediation with energy crops productions and their conversion to biochars and return to the soil achieving contaminants stabilization effects, carbon sequestration and climate change mitigation will be developed and validated. In order to achieve above mention goals, ReNBES project will conduct comprehensive research including (1) development of phytoremediation strategy with and without the addition of produced biochar through the application from pot to field scale, (2) assessment of phytobiomass valorization and (3) development of decision roadmap in order to facilitate the future implementation of ReNBES strategy for site-specific soil decontamination. The guideline will contain the multi-criteria evaluation of the environmental, legal and economic viability of the proposed ReNBES technology. Based on research results, ReNBES project will boost the scientific excellence of the two research groups, UNSFS and IFVCNS, and produce results that will have a huge impact on creating highly efficient sustainable phytoremediation practices while contributing to the improvement and protection of the environment, climate change mitigation and carbon sequestration by applying the principles of the circular economy.

Project Duration: 1.12.2023 – 30.11.2026.

Coordinator and Partners: University of Novi Sad, Faculty of Sciences and Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia.

Funding Source/Programme: This research was supported by the Science Fund of the Republic of Serbia.

ID Number of Project: # 6769

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Transition of sewage sludge to compost

Regional Landfill Subotica, in cooperation with the Institute of Field and Vegetable Crops, and in accordance with relevant legal and strategic documents, is implementing a project focused on the reuse of biodegradable waste (green waste and sludge from wastewater treatment plants) to produce a new product - compost.

In this way, the quantity of generated sludge, which is expected to increase in the coming years, will not be disposed of in landfills but will instead be transformed into a valuable resource.

The project involves the establishment of an experimental field, compost production, application of compost on the field, soil quality analysis after compost application, and the preparation of a study with recommendations and options for the use of the obtained compost — both for the needs of the Regional Landfill and for potential commercialization.

The project results will contribute to the revision of existing regulations governing the use of sludge from wastewater treatment plants in agriculture. It will also provide practical guidance for other local and regional landfills on the possibilities of utilizing biodegradable waste, valorizing existing resources, and reducing environmental impacts.

Project Duration: 25.03.2024 - 20.12.2025.

Responsible Party: Regional landfill Subotica

Partner: Institute of Field and Vegetable Crops

This initiative, with technical and financial support from the European Union (EU) and in partnership with the Ministry of Environmental Protection, is implemented by the United Nations Development Program (UNDP) EU for Green Agenda in Serbia, in cooperation with the Embassy of Sweden and the European Investment Bank (EIB), with additional financial resources provided by the governments of Sweden, Switzerland and Serbia.

ID Number of Project: 00139323/00129089/2023/7

Website <https://zelenatranzicija.undp.org.rs/sr/upravljanje-otpadom-na-zelenu-energiju/>



Republic of
Serbia

This project is funded by
the European Union



EU for Green Agenda in Serbia



TwinSubDyn

Twinning excellence on organic soil amendments effect on nutrient and contaminant dynamics in the subsurface

TwinSubDyn aims to establish a research knowledge hub at UNSPMF, Serbia, on the impacts of organic soil amendments (OSA) on the fate of contaminant-, and nutrient dynamics in the soil subsurface and implications for groundwater quality. The project will significantly boost research and innovation capacities of UNSPMF, through a twinning action with internationally-leading research institutions in this research field from Europe, i.e. UNIVIE, FZJ, MLU and IRNASCSIC. The strategy for stepping up and stimulating scientific excellence and innovation capacity for our TwinSubDyn defined research topic is based on: (1) Networking for Excellence - through transfer of knowledge, best practice and expertise during secondments, between UNSPMF and the aforementioned research institutions; (2) Establishment of long-lasting strategic partnerships with leading European research organisations; (3) Raising the EU and global research profile of UNSPMF and its staff - through delivering lectures by experts, short-term on-site training, organization of workshop/summer school and strengthening the research management and administration unit at UNSPMF; (4) Development of Science and Innovation Strategy and key action planning in the TwinSubDyn field for UNSPMF; (5) Spreading scientific knowledge through the available multiple dissemination channels, and finally (6) Increasing overall competence via the strategic collaborative consortium TwinSubDyn research project and its intrinsic knowledge exchange and gains.

Project Duration: 1.08.2022 – 30.11.2025.

Coordinator and Partners: University of Novi Sad Faculty of Sciences, University of Vienna, Forschungszentrum Jülich Germany, Martin-Luther-Universität Halle-Wittenberg and Spanish National Research Council, Instituto de la grasa.

Funding Source/Programme: Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

ID Number of Project: Grant agreement No. 101059546

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Funded by
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UrbanFoS

Urban Forest Soil Indicators as a Tool for Climate-Smart Forestry

Objectives: The main objective of the project Urban Forest Soil Indicators as a Tool for Climate-Smart Forestry (UrbanFoS) is to define soil degradation indicators in urban forests (UF) within the framework of Climate-Smart Forestry (CSF).

Key Activities and Outputs: Physico-chemical analyses and climate simulation experiments will be used to identify the soil properties most sensitive to climate change and anthropogenic stressors. Existing indices for soil degradation will be tested for their applicability to UF, and a customised index will be proposed. In addition, UrbanFoS will define remediation measures based on the principles of ecological engineering and nature-based solutions (NBS), ensuring practical methods to improve soil conditions. By linking soil sensitivity with the provision of ecosystem services (ES), UrbanFoS advances monitoring, predictive modelling, and decision-making for urban forestry. The results will support adaptive management strategies to mitigate land degradation, improve UF ability to deliver multiple ES. In doing so, UrbanFoS introduces a novel conceptual and methodological framework for CSUF and provides science-based tools to bridge the gap between urban sustainability goals and the realities of climate and anthropogenic pressures.

Expected Impact: Defining indicators of soil degradation in UF within the concept of CSF will contribute to the adaptation to and mitigation of climate change and anthropogenic pressure in urban areas. In this way, UF will fulfil its most important functions.

Expected results: Improvement of existing systems for planned management of UF, as well as enhancement of soil conditions in urban areas through the application of anti-erosion remedial and preventive measures.

Project Duration: 2023 – 2026.

Coordinator and Partners: University of Belgrade, Institute of Chemistry, Technology and Metallurgy, National Institute of the Republic of Serbia and University of Belgrade Faculty of Forestry

Funding Source/Programme: Science Fund of the Republic of Serbia/Prizma, ID Number of Project: 7043

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<https://www.linkedin.com/posts/project-urbanfos-94aa002b2>

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Science Fund
of the Republic of Serbia

RhizoDETOX

Utilizing rhizobia to reduce the risk of heavy metal accumulation in alfalfa: Nickel (Ni) case study

Accumulation of potentially toxic elements in the soils has become a worldwide issue. Nickel (Ni) is one of the most common contaminants, discharged into the environment by both natural and human activities. Nickel is an essential element in small quantities, but toxic at high concentrations, causing negative effects in plants. Alfalfa (*Medicago sativa* L.), due to its symbiosis with nitrogen-fixing bacteria, rhizobia, contributes to the incorporation of nitrogen in soil and is considered as promising plant for the cultivation in marginal soils. Rhizobia could act on metals in soil reducing their toxicity. The RhizoDETOX project aims to develop rhizobial inoculant, which would improve the growth of alfalfa and reduce the risk of heavy metal accumulation in the edible part of the plants.

In the project, nickel tolerant rhizobia are selected, genetically characterized, tested for the ability of Ni biosorption, and to stimulate alfalfa growth in the presence of Ni. The ability of rhizobia to alleviate stress in soils with elevated Ni concentrations is evaluated through alfalfa growth and Ni uptake, accumulation and translocation in the system soil-root-shoot of the plant. It has been found that, unlike N, the content of heavy metals is generally higher in the root than in the above-ground part of the plant (potential for phytostabilization). Some strains reduce Ni in the shoot, improve nitrogen nutrition, and increase yield, but further research in the project will enable more precise data to be obtained.

The RhizoDETOX will enable sustainable alfalfa cultivation in low Ni contaminated soils, offering an effective strategy for increasing productive area in environmental-friendly and cost-effective way.

Project Duration: January 2024 – December 2026.

Coordinator and Partners: Institute of Soil Science, Belgrade, Serbia, Lead Institution; Institute for Forage Crops Kruševac, Serbia, Partner Institution

Funding Source/Programme: Science Fund of the Republic of Serbia, Program PRIZMA, Project Number 7015

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<https://www.instagram.com/rhizodetox/profilecard/?igsh=MnpnaXFjcTFhaRm>

<https://www.facebook.com/share/1LNggRuLnH/>



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The Walnut Fund

<https://thewalnutfund.com/>



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The Soil Re-Union Science for Healthy Soils

4th International and 16th National Congress
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22-23. October 2025. Fruške Terme, Vrdnik, Srbija



Serbian
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Soil Science



Serbian Society of Soil Science, SDPZ 2025.